



City & Guilds Level 3 Advanced Technical Extended Diploma in Engineering (720) (1145-32)

May 2023 Version 2.2

(For delivery from September 2023)

Qualification Handbook

Qualification at a glance

Industry area	Engineering
City & Guilds qualification number	1145-32
Age group	16-19 (Key Stage 5), 19+
Entry requirements	Centres must ensure that any pre-requisites stated in the <i>What is this qualification about?</i> Section are met.
Assessment	<p>To gain this qualification, candidates must successfully achieve the following assessments:</p> <ul style="list-style-type: none"> • Two externally set, internally marked, externally moderated assignments • Two externally set, externally marked exams, sat under examination conditions • Optional unit, externally set, internally marked, externally verified assessments as required
Additional requirements to gain this qualification	Employer involvement in the delivery and/or assessment of this qualification is essential for all candidates and will be externally quality assured.
Grading	<p>This qualification is graded.</p> <p>For more information on grading, please see Section 7: Grading.</p>
Approvals	These qualifications require full centre and qualification approval
Support materials	<p>Sample assessments</p> <p>Guidance for delivery</p> <p>Guidance on use of marking grids</p>
Registration and certification	Registration and certification of this qualification is through the Walled Garden, and is subject to end dates.
External quality assurance	This qualification is externally quality assured by City & Guilds, and its internally marked synoptic assignments are subject to external moderation. Additional internally marked units / optional assessments are subject to external verification. There is no direct claim status available for this qualification.

Title and level	Size (GLH)	TOT	City & Guilds qualification number	Ofqual accreditation number
City & Guilds Level 3 Advanced Technical Extended Diploma in Engineering (720)	720	1200	1145-32	601/4506/7

Version and date	Change detail	Section
1.1 May 2016	Small typographical errors	Throughout
	TQT added for qualifications	2 Introduction
	Assessment component titles amended	
	Employer involvement guidance updated throughout	4. Employer involvement
	Summary of assessment methods and conditions	5. Assessment
	Moderation and standardisation of assessment updated throughout	6. Moderation and standardisation of assessment
	Awarding individual assessments Awarding grades and reporting results	7. Grading
1.2 July 2016	Enquiries about results	8. Administration
	Re-sits and shelf-life of assessment results	
	Malpractice	
	Access arrangements and special consideration	
1.3 November 2016	Depth updated	Unit 303 Topic 2.2
1.3 November 2016	Correction made to assessment details	5 Assessment
1.4 June 2017	Addition of the examination paper based module number	1. Introduction – Assessment requirements and employer involvement
		5. Assessment
		5. Assessment – exam Specification
		7. Grading – Awarding grades and reporting results
	Removal of AO 6-8 from Synoptic Assignments and the readjusted approximate weightings (only if applicable)	5. Assessment – Assessment Objectives
	Revised Exam Specification, Exam duration and AO weightings	5. Assessment – Exam Specification
	Addition of Provisional Grade Boundaries for Synoptic Assignment	7. Grading
Branding Changes	City & Guilds Logo	
1.5 July 2017	Revised 530/532 Exam AO weightings	Exam specification
2.0 August 2018	Update to grading details	Section 7

Version and date	Change detail	Section
2.1 May 2019	Wording changed regarding retakes	5. Assessment – Summary of assessment methods and conditions 8. Administration – Re-sits and shelf-life of assessment results
2.2 May 2023	Clarified moderation and external verification processes	5 Assessment 6 Moderation and standardisation of assessment
	Updated website links and references	3 Delivering Technicals qualifications - Support materials 8 Administration

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1 Introduction

What is this qualification about?

The following purpose is for the **City & Guilds Level 3 Advanced Technical Extended Diploma in Engineering (720)**

Area	Description
OVERVIEW	
Who is this qualification for?	This qualification is for you if you are looking to start in the broad Advanced Manufacturing and Engineering sector in more specialised roles. It covers a wide range of topics allowing you to experience the sectors skills requirements. There are no entry requirements for this qualification.
What does this qualification cover?	<p>You will study theoretical aspects of the subject and apply them to practical tasks. Compulsory topics include:</p> <ul style="list-style-type: none">• engineering materials• electronics, control and instrumentation• mechanical structures and dynamics• manufacturing methods in engineering• engineering design• engineering mathematics and statistics• engineering workshop practice• innovation and new technologies• manufacturing engineering• robotics and automated manufacture. <p>You will also be able to choose two from a number of optional topics, which focuses on technical skills required within the engineering industry. These include:</p> <ul style="list-style-type: none">• project management• automotive engineering• power & energy in engineering• aerospace engineering• rail engineering <p>You will study both the practical use and underpinning knowledge of the subject, which may involve local employers providing real examples as part of the training. It is expected that you will visit or have visits from employers who can provide demonstrations and talks on the industry, which may also be a relevant work placement with an employer.</p>

WHAT COULD THIS QUALIFICATION LEAD TO?

Will the qualification lead to employment, and if so, in which job role and at what level?	<p>The City & Guilds Level 3 Advanced Technical Extended Diploma in Engineering (720) could lead to employment opportunities for you as:</p> <ul style="list-style-type: none">• aerospace manufacturing technician• electronics manufacture technician• product support engineer
Why choose this qualification over similar qualifications?	<p>City & Guilds offers three sizes of Level 3 qualification in Engineering: Certificate, Diploma and Extended Diploma. You would take the Certificate if you want an introductory qualification to develop some of the basic skills and knowledge required by employers in the Engineering industry.</p> <p>The Certificate is likely to be taken alongside other programmes such as GCSEs or AS Levels over a one-year course of study.</p> <p>You would take the Diploma if you want to develop a broader set of skills and knowledge and learn about a specific sector such as Marine Engineering. The Diploma is likely to be taken alongside other programmes such as GCSEs or AS Levels over a one-year course of study.</p> <p>You would take the Extended Diploma if you want to specialise in advanced manufacturing and engineering job roles, including learning about the different sectors, robotics and developing your project management skills. The Extended Diploma is likely to be taken as part of a full-time two year programme of study, or alongside other qualifications such as AS or A Levels over a longer period of time.</p>
Will the qualification lead to further learning?	<p>When you have achieved this qualification you have a choice of seeking employment or going on to further learning. Examples include:</p> <ul style="list-style-type: none">• Higher Apprenticeship in Advanced Manufacturing Engineering.• Foundation Degree FdSc in Aerospace Engineering Manufacturing.• Foundation Degree FdEng Renewable Energy Technologies.

WHO SUPPORTS THIS QUALIFICATION?

Employer/Higher Education Institutions	The following employers support this qualification: EDF Energy, AMEC, Bosch, Bramble House, MBDA.
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Qualification structure

For the **City & Guilds Level 3 Advanced Technical Extended Diploma in Engineering (720)** the teaching programme must cover the content detailed in the structure below:

Unit number	Unit title	GLH
Mandatory		
301	Engineering Materials	60
302	Electronics, Control and Instrumentation	60
303	Mechanical Structures and Dynamics	60
304	Manufacturing Methods in Engineering	60
305	Engineering Design	60
306	Engineering Mathematics and Statistics	60
307	Engineering Workshop Practice	90
308	Innovation and New Technologies	30
310	Manufacturing Engineering	60
311	Robotics and Automated Manufacture	60
Optional – Learners must be taught at least 120 GLH from units 309, 312 - 317		
309	Project Management	60
312	Civil Engineering	60
313	Aerospace Engineering	60
314	Power and Energy in Engineering	60
315	Automotive Engineering	60
316	Rail Engineering	60
317	Marine Engineering	60

Total qualification time (TQT)

Total Qualification Time (TQT) is the total amount of time, in hours, expected to be spent by a Learner to achieve a qualification. It includes both guided learning hours (which are listed separately) and hours spent in preparation, study and assessment.

Title and level	Size GLH	TQT
City & Guilds Level 3 Advanced Technical Extended Diploma in Engineering	720	1200

Assessment requirements and employer involvement

To achieve the **City & Guilds Level 3 Advanced Technical Extended Diploma in Engineering (720)** candidates must successfully complete **all** the mandatory assessment components **as well as** the optional assessment components for their chosen optional units.

Component number	Title
Mandatory	
031	Level 3 Engineering – Synoptic assignment (1)
034	Level 3 Engineering - Synoptic assignment (2)*
530	Level 3 Engineering - Theory exam (1)*
532	Level 3 Engineering - Theory exam (2)*
Optional	
309	Level 3 Project Management - Assignment
312	Level 3 Civil Engineering - Assignment
313	Level 3 Aerospace Engineering - Assignment
314	Level 3 Power and Energy in Engineering - Assignment
315	Level 3 Automotive Engineering - Assignment
316	Level 3 Rail Engineering - Assignment
317	Level 3 Marine Engineering - Assignment

In addition, candidates **must** achieve the mandatory employer involvement requirement for this qualification **before** they can be awarded a qualification grade. For more information, please see guidance in *Section 4: Employer involvement*.

Employer involvement

Component number	Title
Mandatory	
832	Employer involvement

**Number of mandatory assessments per assessment type*

2 Centre requirements

Approval

New centres will need to gain centre approval. Existing centres who wish to offer this qualification must go through City & Guilds' **full** Qualification Approval Process. There is no fast track approval for this qualification. Please refer to the City & Guilds website for further information on the approval process: www.cityandguilds.com

Resource requirements

Centre staff should familiarise themselves with the structure, content and assessment requirements of the qualification before designing a course programme.

Centre staffing

Staff delivering this qualification must be able to demonstrate that they meet the following requirements:

- be technically competent in the areas in which they are delivering
- be able to deliver across the breadth and depth of the content of the qualification being taught
- have recent relevant teaching and assessment experience in the specific area they will be teaching, or be working towards this
- demonstrate continuing CPD.

Physical resources

Centres must be able to demonstrate that they have access to the equipment and technical resources required to deliver this qualification and its assessment.

Internal Quality Assurance

Internal quality assurance is key to ensuring accuracy and consistency of tutors and markers. Internal Quality Assurers (IQAs) monitor the work of all tutors involved with a qualification to ensure they are applying standards consistently throughout assessment activities. IQAs must have, and maintain, an appropriate level of technical competence and be qualified to make both marking and quality assurance decisions through a teaching qualification or recent, relevant experience.

Learner entry requirements

Centres must ensure that all learners have the opportunity to gain the qualification through appropriate study and training, and that any prerequisites stated in the *What is this qualification about?* section are met when registering on this qualification.

Age restrictions

This qualification is approved for learners aged 16 – 19, 19+.

3 Delivering technical qualifications

Initial assessment and induction

An initial assessment of each learner should be made before the start of their programme to identify:

- if the learner has any specific learning or training needs
- support and guidance they may need when working towards their qualification
- the appropriate type and level of qualification.

We recommend that centres provide an introduction so that learners fully understand the requirements of the qualification, their responsibilities as a learner, and the responsibilities of the centre. This information can be recorded on a learning contract.

Employer involvement

Employer involvement is essential to maximise the value of each learner's experience. Centres are required to involve employers in the delivery of technical qualifications at Key Stage 5 and/or their assessment, for every learner. This must be in place or planned before delivery programmes begin in order to gain qualification approval. See *Section 4: Employer involvement* for more detail.

Support materials

The following resources are available for this qualification:

Description	How to access
Sample assessments	Available on the qualification pages on the City & Guilds Website: www.cityandguilds.com
Technical Qualifications: Guide to Teaching, Learning and Assessment	Available on the City and Guilds website: 14-19-teaching-learning-assessment-guide-pdf.ashx (cityandguilds.com)
Quality Assurance Guide for Centres: Technical Qualifications and the Extended Project Qualification (EPQ)	Available on the City and Guilds website: technicals-quality-assurance-guide-for-centres-pdf.ashx (cityandguilds.com)

4 Employer involvement

Employer involvement is a formal component of Key Stage 5 Technical qualifications. It does not contribute to the overall qualification grading, but is a mandatory requirement that all learners must meet. As such it is subject to external quality assurance by City & Guilds.

Department for Education (DfE) requirements state:

Employer involvement in the delivery and/or assessment of technical qualifications provides a clear 'line of sight' to work, enriches learning, raises the credibility of the qualification in the eyes of employers, parents and students and furthers collaboration between the learning and skills sector and industry.

[Technical qualifications] must:

- *require all students to undertake meaningful activity involving employers during their study; and*
- *be governed by quality assurance procedures run by the awarding organisation to confirm that education providers have secured employer involvement for every student.*

Extract from: ***Vocational qualifications for 16 to 19 year olds, 2017 and 2018 performance tables: technical guidance for awarding organisations, paragraphs 89-90***

City & Guilds will provide support, guidance and quality assurance of employer involvement.

Qualification approval

To be approved to offer City & Guilds technicals, centres must provide an Employer Involvement planner and tracker showing how every learner will be able to experience meaningful employer involvement, and from where sufficient and suitable employer representatives are expected to be sourced.

Centres must include in their planer a sufficient range of activities throughout the learning programme that provide a range of employer interactions for learners. Centres must also plan contingencies for learners who may be absent for employer involvement activities, so that they are not disadvantaged.

As part of the approval process, City & Guilds will review this planner and tracker. Centres which cannot show sufficient commitment from employers and/or a credible planner and tracker will be given an action for improvement with a realistic timescale for completion. **Approval will not be given** if employer involvement cannot be assured either at the start of the qualification, or through an appropriate plan of action to address this requirement before the learner is certificated.

Monitoring and reporting learner engagement

Employer involvement is a formal component of this qualification and is subject to quality assurance monitoring. Centres must record evidence that demonstrates that each learner has been involved in meaningful employer based activities against the mandatory content before claiming the employer involvement component for learners.

Centres must record the range and type of employer involvement each learner has experienced and submit confirmation that all learners have met the requirements to City & Guilds. If a centre cannot provide evidence that learners have met the requirements to achieve the component, then the learner will not be able to achieve the overall Technical Qualification.

Types of involvement

Centres should note that to be eligible, employer involvement activities **must** relate to one or more elements of the mandatory content of this qualification.

As the aim of employer involvement is to enrich learning and to give learners a taste of the expectations of employers in the industry area they are studying, centres are encouraged to work creatively with local employers.

Employers can identify the areas of skills and knowledge in their particular industry that they would wish to see emphasised for learners who may apply to work with them in the future. Centres and employers can then establish the type of input, and which employer representative might be able to best support these aims.

To be of most benefit this must add to, rather than replace the centre's programme of learning.

Some examples of meaningful employer involvement are listed below. Employer involvement not related to the mandatory element of the qualification, although valuable in other ways, does not count towards this element of the qualification.

The DfE has provided the following examples of what does and does not count as meaningful employer involvement, as follows^{1,2}:

The following activities meet the requirement for meaningful employer involvement:

- *students undertake structured work-experience or work-placements that develop skills and knowledge relevant to the qualification³;*
- *students undertake project(s), exercises(s) and/or assessments/examination(s) set with input from industry practitioner(s);*
- *students take one or more units delivered or co-delivered by an industry practitioner(s). This could take the form of master classes or guest lectures;*
- *industry practitioners operate as 'expert witnesses' that contribute to the assessment of a student's work or practice, operating within a specified assessment framework. This may be a specific project(s), exercise(s) or examination(s), or all assessments for a qualification.*

In all cases participating industry practitioners and employers must be relevant to the industry sector or occupation/occupational group to which the qualification relates.

The following activities, whilst valuable, do not meet the requirement for meaningful employer involvement:

- *employers' or industry practitioners' input to the initial design and content of a qualification;*
- *employers hosting visits, providing premises, facilities or equipment;*
- *employers or industry practitioners providing talks or contributing to delivery on employability, general careers advice, CV writing, interview training etc;*
- *student attendance at career fairs, events or other networking opportunities;*

¹ As extracted from: Vocational qualifications for 16 to 19 year olds 2017 and 2018 performance tables: technical guidance for awarding organisations

² This list has been informed by a call for examples of good practice in employer involvement in the delivery and assessment of technical qualifications - **Employer involvement in the delivery and assessment of vocational qualifications**

³ DfE work experience guidance

- *simulated or provider-based working environments eg hairdressing salons, florists, restaurants, travel agents, small manufacturing units, car servicing facilities;*
- *employers providing students with job references.*

Types of evidence

For each employer involvement activity, centres are required to provide evidence of which learners undertook it, e.g. a candidate attendance register. The types of additional evidence required to support a claim for this component will vary depending on the nature of the involvement. E.g. for a guest lecture it is expected that a synopsis of the lecture and register would be taken which each learner and the guest speaker will have signed; expert witnesses will be identified and will have signed the relevant assessment paperwork for each learner they have been involved in assessing; evidence of contribution from employers to the development of locally set or adapted assignments.

Quality assurance process

As the employer involvement component is a requirement for achieving the KS5 Technical qualifications, it is subject to external quality assurance by City & Guilds at the approval stage and when centres wish to claim certification for learners.

Evidence will be validated by City & Guilds before learners can achieve the employer involvement component. Where employer involvement is not judged to be sufficient, certificates cannot be claimed for learners.

Sufficiency of involvement for each learner

It is expected that the centre will plan a range of activities that provide sufficient opportunities for each learner to interact directly with a range of individuals employed in the related industry. Centres must also provide contingencies for learners who may be absent for part of their teaching, so they are not disadvantaged. Any absence that results in a learner missing arranged activities must be documented. Where learners are unable to undertake all employer involvement activities due to temporary illness, temporary injury or other indisposition, centres should contact City & Guilds for further guidance.

Live involvement

Learners will gain most benefit from direct interaction with employers and/or their staff; however the use of technology (eg the use of live webinars) is encouraged to maximise the range of interactions. Where learners are able to interact in real time with employers, including through the use of technology, this will be classed as 'live involvement'.

It is considered good practice to record learning activities, where possible, to allow learners to revisit their experience and to provide a contingency for absent learners. This is not classed as live involvement however, and any involvement of this type for a learner must be identified as contingency.

Timing

A learner who has not met the minimum requirements cannot be awarded the component, and will therefore not achieve the qualification. It is therefore important that centres give consideration to scheduling employer involvement activities, and that enough time is allotted throughout delivery and assessment of the qualification to ensure that requirements are fully met.

5 Assessment

Summary of assessment methods and conditions

Component numbers	Assessment method	Description and conditions
031 034	Synoptic assignment	<p>The synoptic assignments are externally set, internally marked and externally moderated. The assignments require candidates to identify and use effectively in an integrated way an appropriate selection of skills, techniques, concepts, theories, and knowledge from across the content area. Candidates will be judged against the assessment objectives.</p> <p>Assignments will be released to centres as per dates indicated in the Assessment and Examination timetable published on our website.</p> <p>Centres will be required to maintain the security of all live assessment materials. Assignments will be password protected and released to centres through a secure method.</p> <p>There will be one opportunity within each academic year to sit the assignment. Candidates who fail the assignment will have one re-sit opportunity. The re-sit opportunity will be in the next academic year, and will be the assignment set for that academic year once released to centres. If the re-sit is failed, the candidate will fail the qualification.</p> <p>Please note that for externally set assignments City & Guilds provides guidance and support to centres on the marking and moderation process.</p>
530 532	Externally marked exam	<p>The exams are externally set and externally marked.</p> <p>The exams are designed to assess the candidate's depth and breadth of understanding across content in the qualification at the end of the period of learning, using a range of question types and will be sat under invigilated examination conditions. See JCQ requirements for details: http://www.jcq.org.uk/exams-office/ice---instructions-for-conducting-examinations</p> <p>The exam specifications show the coverage of the exam across the qualification content.</p> <p>Candidates who fail the exam at the first sitting will have a maximum of two opportunities to retake. If the candidate fails the exam three times then they will fail the qualification. (Note: the third and final retake opportunity applies to Level 3 only.)</p>

		For exam dates, please refer to the Assessment and Examination timetable.
Optional units 309, 312 313, 314 315, 316 317	Unit Assignment	The unit assignment is externally set, internally marked and externally verified . The assignment requires candidates to identify and use effectively skills, knowledge and understanding from across the unit content area. Candidates will be judged against the unit grading criteria Arrangements for release, security and re-sitting assignments are the same as detailed for the synoptic assignment.

What is synoptic assessment?

Technical qualifications are based around the development of a toolkit of knowledge, understanding and skills that an individual needs in order to have the capability to work in a particular industry or occupational area. Individuals in all technical areas are expected to be able to apply their knowledge, understanding and skills in decision making to solve problems and achieve given outcomes independently and confidently.

City & Guilds technical qualifications require candidates to draw together their learning from across the qualification to solve problems or achieve specific outcomes by explicitly assessing this through the synoptic assignment component.

In this externally set, internally marked and externally moderated assessment the focus is on bringing together, selecting and applying learning from across the qualification rather than demonstrating achievement against units or subsets of the qualification content. The candidate will be given an appropriately levelled, substantial, occupationally relevant problem to solve or outcome to achieve. For example this might be in the form of a briefing from a client, leaving the candidate with the scope to select and carry out the processes required to achieve the client's wishes, as they would in the workplace.

Candidates will be marked against assessment objectives (AOs) such as their breadth and accuracy of knowledge, understanding of concepts, and the quality of their technical skills as well as their ability to use what they have learned in an integrated way to achieve a considered and high quality outcome.

How the assignment is synoptic for this qualification

A typical assignment brief could be to develop an automated testing system for a piece of equipment. This would require the candidate to develop a design specification for the system, taking account of a range of factors. They will develop a working model, including the mechanical components and support structures. They will also need to programme and configure the system so that it is functional. Candidates will need to develop and implement a process for testing the functionality of the system. They will submit a report on the feasibility of commercially producing the designed system.

External exam for stretch, challenge and integration

The external assessment will draw from across the mandatory content of the qualification, using a range of shorter questions to confirm breadth of knowledge and understanding. Extended response questions are included to go into more depth, giving candidates the opportunity to demonstrate

higher level understanding and integration through discussion, analysis and evaluation, and ensuring the assessment can differentiate between 'just able' and higher achieving candidates.

Optional unit assessments and integration into the synoptic qualification content

While the mandatory units for this qualification provide the main skills and knowledge required to work in the engineering industry, the optional units provided give centres flexibility when devising programmes to meet local employment needs, where the purpose of the qualification demands this.

The assessments for the optional units will require that the candidate has experienced the full breadth of mandatory learning of the qualification in order to better demonstrate the rounded performance expected at higher grades.

Optional unit assessments are externally set, internally marked and externally verified.

Assessment objectives

The assessments for this qualification are set against a set of assessment objectives (AOs) which are used across all City & Guilds Technicals to promote consistency among qualifications of a similar purpose. They are designed to allow judgement of the candidate to be made across a number of different categories of performance.

Each assessment for the qualification has been allocated a set number of marks against these AOs based on weightings recommended by stakeholders of the qualification. This mark allocation remains the same for all versions of the assessments, ensuring consistency across assessment versions and over time.

The following table explains all AOs in detail, including weightings for the synoptic assignments. In some cases, due to the nature of a qualification's content, it is not appropriate to award marks for some AOs. Where this is the case these have been marked as N/A. Weightings for exams (AOs 1, 2 and 4 only) can be found with the exam specification.

Assessment objective	City & Guilds Level 3 Advanced Technical Extended Diploma in Engineering (720) Typical expected evidence of knowledge, understanding and skills	Approximate weighting (Assignment)
AO1 Recalls knowledge from across the breadth of the qualification.	Mechanical and electrical design calculations, electrical and mechanical component parts, technological terms, mechanical theory, electrical theory, PLC programming coding and operations, control system parts, camera parts, manufacturing operations, CAD system operations, product planning terms, product planning theory, costing theory, test methodology, report writing principles, health and safety.	20%
AO2 Demonstrates understanding of concepts, theories and processes from across the breadth of the qualification.	Mechanical interface of equipment design and aircraft structure, relationship between mechanical components, control equipment and electrical components used in the design, selection of components, capabilities and functionality of camera operations, parameters for testing,	20%

	properties of materials and components, manufacturing planning/costing processes, manufacturing processes, programming processes, structural and design performance characteristics.	
AO₃ Demonstrates technical skills from across the breadth of the qualification.	Degree of accuracy, features of CAD software used effectively, features of PLC programming used effectively, manual dexterity, inspection, quality of finish, electrical and mechanical integrity, measuring, testing, health and safety.	20%
AO₄ Applies knowledge, understanding and skills from across the breadth of the qualification in an integrated and holistic way to achieve specified purposes.	Applying knowledge and understanding across all tasks, justifying recommendations/approaches taken, understanding of electrical and mechanical components in CAD, representation of mechanical features using CAD, interpreting electrical and mechanical drawings to produce physical design models, application and understanding of control systems, application of understanding of product planning/costing, application of understanding of measurement to testing of mechanical and electrical components, application and understanding of PLC programming techniques, application of understanding of material properties and manufacturing processes for the development from a design model.	20%
AO₅ Demonstrates perseverance in achieving high standards and attention to detail while showing an understanding of wider impact of their actions.	Meeting specific requirements of the task, attention to detail when completing drawings, programmes and assemblies (accuracy, neatness, annotation, orientation of components, structural integrity, coding integrity, finishing).	20%

Exam specification

AO weightings per Exam

AO	Exam 530 weighting (approx. %)	Exam 532 weighting (approx. %)
AO1 Recalls knowledge from across the breadth of the qualification.	23	20
AO2 Demonstrates understanding of concepts, theories and processes from across the breadth of the qualification.	52	60
AO4 Applies knowledge, understanding and skills from across the breadth of the qualification in an integrated and holistic way to achieve specified purposes.	25	20

The way the exams cover the content of the qualification is laid out in the tables below:

Assessment type: Examiner marked, written exam*

Assessment conditions: Invigilated examination conditions

Grading: X/P/M/D

530	Duration: 3 hours		
Unit	Unit Title	Number of marks	%
Unit 301	Engineering materials	23	23
Unit 304	Manufacturing methods in engineering	14	14
Unit 305	Engineering design	14	14
Unit 306	Engineering mathematics and statistics	24	24
N/A	Integration across the units	25	25
	Total	100	100

Assessment type: Examiner marked, written exam*

Assessment conditions: Invigilated examination conditions

Grading: X/P/M/D

532	Duration: 2 hours		
Unit	Unit Title	Number of marks	%
Unit 307	Engineering workshop practice	16	27
Unit 308	Innovation and new technologies	32	53
N/A	Integration across the units	12	20
Total		60	100

*These exams are sat under invigilated examination conditions, as defined by the JCQ:
<http://www.jcq.org.uk/exams-office/ice---instructions-for-conducting-examinations>

Entry for exams can be made through the City & Guilds Walled Garden.

6 Moderation and standardisation of assessment

City & Guilds' externally set synoptic assignments for technical qualifications are designed to draw from across the qualifications' content, and to contribute a significant proportion towards the learner's final qualification grade. They are subject to a rigorous external quality assurance process known as external moderation.

Moderation is the process where external quality assurers are standardised to a national standard in order to review centre marking of internally marked assessments. These external quality assurers are referred to as 'moderators'. Moderators will review a representative sample of 'candidate work' across the mark range from every centre. Their marks act as a benchmark to inform City & Guilds whether centre marking is in line with City & Guilds' standard.

Where moderation shows that the centre is applying the marking criteria within a reasonable range of mark tolerance, centre marks for the whole cohort will be accepted. Where moderation shows that the centre is either consistently too lenient or consistently too harsh in comparison to the national standard, an appropriate adjustment (up or down) will be made to the marks of the whole cohort, retaining the centre's rank ordering. Due to the nature of the assessment and the marking grid across Assessment Objectives (AOs), it is not expected that the tutors mark and the moderators mark will match exactly.

Where centre application of the marking criteria is inconsistent, an appropriate adjustment for the whole cohort may not be possible on the basis of the sample of candidate work. In these instances a complete remark of the candidate work may be necessary.

Additional unit and optional unit assessments are also subject to external quality assurance through a verification process. This involves external quality assurers scrutinising IQA records; sampling candidates' work across a range of units and also sampling across the mark/grade range. Centres are then provided with feedback and actions to ensure that results are valid and reliable.

For more detailed information, on the quality assurance process for synoptic assignments and additional unit and optional unit assessments please refer to 'Quality Assurance Guide for Centres: Technical Qualifications and the EPQ available to download on the City & Guilds website.

It is vital that centres familiarise themselves with this process, and how it impacts on their delivery plan within the academic year.

Supervision and authentication of internally assessed work

The Head of Centre is responsible for ensuring that internally assessed work is conducted in accordance with City & Guilds' requirements.

City & Guilds requires both tutors and candidates to sign declarations of authenticity. If the tutor is unable to sign the authentication statement for a particular candidate, then the candidate's work cannot be accepted for assessment.

Internal standardisation

For internally marked work⁴ the centre is required to conduct internal standardisation to ensure that all work at the centre has been marked and/or graded to the same standard. It is the Internal Quality Assurer's (IOA's) responsibility to ensure that standardisation has taken place, and that the training includes the use of reference and archive materials such as work from previous years as appropriate.

Internal appeal

Centres must have an internal process in place for candidates to appeal the marking of internally marked components, ie the synoptic assignment and any optional unit assignments. This must take place before the submission of marks or grades for external quality assurance. The internal process must include candidates being informed of the marks (or grades) the centre has given for internally assessed components, as they will need these to make the decision about whether or not to appeal.

Post-moderation procedures

Once the external quality assurance processes have been completed, feedback is provided to the centre on the standard of the internal assessment, highlighting areas of good practice, and potential areas for improvement. This will inform future centre assessment, and standardisation activities, as well as external quality assurance and risk management activity.

City & Guilds will then carry out awarding, the process by which grade boundaries are set with reference to the candidate evidence available on the platform.

Centres retaining evidence

Centres must retain assessment records for each candidate for a minimum of three years. To help prevent plagiarism or unfair advantage in future versions, candidate work may not be returned to candidates. Samples may however be retained by the centre as examples for future standardisation of marking.

⁴ For any internally assessed optional unit assignments, the same process must be followed where assessors must standardise their interpretation of the assessment and grading criteria.

7 Grading

Awarding individual assessments

Individual assessments will be graded, by City & Guilds, as pass/merit/distinction where relevant. The grade boundaries for pass and distinction for each assessment will be set through a process of professional judgement by technical experts. Merit will usually be set at the midpoint between pass and distinction. The grade descriptors for pass and distinction, and other relevant information (eg archived samples of candidate work and statistical evidence) will be used to determine the mark at which candidate performance in the assessment best aligns with the grade descriptor in the context of the qualification's purpose. Boundaries will be set for each version of each assessment to take into account relative difficulty.

Please note that as the merit grade will usually be set at the arithmetical midpoint between pass and distinction, there are no descriptors for the merit grade for the qualification overall.

Grade descriptors

To achieve a pass, a candidate will be able to

- Demonstrate the knowledge and understanding required to work in the occupational area, its principles, practices and legislation.
- Describe some of the main factors impacting on the occupation to show good understanding of how work tasks are shaped by the broader social, environmental and business environment it operates within.
- Use the technical industry specific terminology used in the industry accurately.
- Demonstrate the application of relevant theory and understanding to solve non-routine problems.
- Interpret a brief for complex work related tasks, identifying the key aspects, and showing a secure understanding of the application of concepts to specific work related tasks.
- Carry out planning which shows an ability to identify and analyse the relevant information in the brief and use knowledge and understanding from across the qualification (including complex technical information) to interpret what a fit for purpose outcome would be and develop a plausible plan to achieve it.
- Achieve an outcome which successfully meets the key requirements of the brief.
- Identify and reflect on the most obvious measures of success for the task and evaluate how successful they have been in meeting the intentions of the plan.
- Work safely throughout, independently carrying out tasks and procedures, and having some confidence in attempting the more complex tasks.

To achieve a distinction, a candidate will be able to

- Demonstrate the excellent knowledge and understanding required to work to a high level in the occupational area, its principles, practices and legislation.
- Analyse the impact of different factors on the occupation to show deep understanding of how work tasks are shaped by the broader social, environmental, and business environment it operates within.
- Demonstrate the application of relevant theory and understanding to provide efficient and effective solutions to complex and non-routine problems.
- Analyse the brief in detail, showing confident understanding of concepts and themes from across the qualification content, bringing these together to develop a clear and stretching plan, that would credibly achieve an outcome that is highly fit for purpose.

- Achieve an outcome which shows an attention to detail in its planning, development and completion, so that it completely meets or exceeds the expectations of the brief to a high standard.
- Carry out an evaluation in a systematic way, focussing on relevant quality points, identifying areas of development/ improvement as well as assessing the fitness for purpose of the outcome.

Awarding grades and reporting results

The overall qualification grade will be calculated based on aggregation of the candidate's achievement in each of the assessments for the mandatory units, taking into account the assessments' weighting. The qualification will be reported on a seven grade scale: Pass Pass, Pass Merit, Merit Merit, Merit Distinction, Distinction Distinction, Distinction Distinction*, Distinction* Distinction*.

All assessments **must** be achieved at a minimum of pass for the qualification to be awarded. Candidates who fail to reach the minimum standard for grade pass for an assessment(s) will not have a qualification grade awarded and will not receive a qualification certificate.

The approximate pass grade boundary for the synoptic assignments in this qualification are

Synoptic Assignment	Pass mark %
031	40
034	40

Please note that each synoptic assignment is subject to an awarding process before final grade boundaries are confirmed.

The contribution of assessments towards the overall qualification grade is as follows:

Assessment method	Grade scale	% contribution
Synoptic assignment (031)	X/P/M/D	30
Synoptic assignment (034)	X/P/M/D	30
Exam (530)	X/P/M/D	30
Exam (532)	X/P/M/D	10

Both synoptic assignments and exams are awarded (see 'Awarding individual assessments', at the start of Section 7, above), and candidates' grades converted to points. The minimum points available for each assessment grade is listed in the table below. The range of points between the pass, merit and distinction boundaries will be accessible to candidates. For example; a candidate that achieves a middle to high pass in an assessment will receive between 8 and 10 points, a candidate that achieves a low to middle merit in an assessment will receive between 12 and 14 points. The points above the minimum for the grade for each assessment are calculated based on the candidate's score in that assessment.

	Pass	Merit	Distinction
Assignment (031)	6	12	18
Assignment (034)	6	12	18
Exam (530)	6	12	18
Exam (532)	6	12	18

The weighted average of candidate's points for each assessment is calculated, and the overall grade of the qualification will then be determined using the following criteria.

Qualification Grade	Minimum points
Distinction*, Distinction*	20.5
Distinction, Distinction*	18.7
Distinction, Distinction	17
Merit, Distinction	14
Merit, Merit	11
Pass, Merit	8.5
Pass, Pass	6

Candidates achieving Distinction*, Distinction * will be the highest achieving of the Distinction candidates.

8 Administration

Approved centres must have effective quality assurance systems to ensure valid and reliable delivery and assessment of qualifications. Quality assurance includes initial centre registration by City & Guilds and the centre's own internal procedures for monitoring quality assurance procedures.

Consistent quality assurance requires City & Guilds and its associated centres to work together closely; our Quality Assurance Model encompasses both internal quality assurance (activities and processes undertaken within centres) and external quality assurance (activities and processes undertaken by City & Guilds).

For this qualification, standards and rigorous quality assurance are maintained by the use of:

- internal quality assurance
- City & Guilds external moderation (synoptic assessments)
- City & Guilds external verification (additional unit / optional assessments).

In order to carry out the quality assurance role, Internal Quality Assurers (IQAs) must have and maintain an appropriate level of technical competence and have recent relevant assessment experience. For more information on the requirements, refer to *Section 2: Centre requirements* in this handbook.

To meet the quality assurance criteria for this qualification, the centre must ensure that the following procedures are followed:

- suitable training of staff involved in the assessment of the qualification to ensure they understand the process of marking and standardisation
- completion by the person responsible for internal standardisation of the Centre Declaration Sheet to confirm that internal standardisation has taken place
- the completion by candidates and supervisors/tutors of the record form for each candidate's work.

External quality assurance

City & Guilds will undertake external moderation and verification activities to ensure that the quality assurance criteria for this qualification are being met. Centres must ensure that they co-operate with City & Guilds staff and representatives when undertaking these activities.

City & Guilds requires the Head of Centre to

- facilitate any inspection of the centre which is undertaken on behalf of City & Guilds
- make secure arrangements to receive, check and keep assessment material secure at all times,
- maintain the security of City & Guilds confidential material from receipt to the time when it is no longer confidential and
- keep completed assignment work and examination scripts secure from the time they are collected from the candidates to their dispatch to City & Guilds.

Enquiries about results

The services available for enquiries about results include a review of marking for exam results and review of moderation for synoptic assignments. Requests must be submitted within the specified

period after the publication of results for individual assessments. Please see the **City & Guilds website** for more information.

Re-sits and shelf-life of assessment results

Re-sits and shelf-life of assessment results Candidates who have failed an exam or wish to re-take it in an attempt to improve their grade, can do so **twice**. The best result will count towards the final qualification. See guidance on individual assessment types in Section 5.

Factors affecting individual learners

If work is lost, City & Guilds should be notified immediately of the date of the loss, how it occurred, and who was responsible for the loss. Centres should use the JCQ form, JCQ/LCW, to inform City & Guilds Customer Services of the circumstances.

Learners who move from one centre to another during the course may require individual attention. Possible courses of action depend on the stage at which the move takes place. Centres should contact City & Guilds at the earliest possible stage for advice about appropriate arrangements in individual cases.

Malpractice

Please refer to the City & Guilds guidance notes *Managing cases of suspected malpractice in examinations and assessments*. This document sets out the procedures to be followed in identifying and reporting malpractice by candidates and/or centre staff and the actions which City & Guilds may subsequently take. The document includes examples of candidate and centre malpractice and explains the responsibilities of centre staff to report actual or suspected malpractice. Centres can access this document on the City & Guilds website.

Examples of candidate malpractice are detailed below (please note that this is not an exhaustive list):

- falsification of assessment evidence or results documentation
- plagiarism of any nature
- collusion with others
- copying from another candidate (including the use of ICT to aid copying), or allowing work to be copied
- deliberate destruction of another's work
- false declaration of authenticity in relation to assessments
- impersonation.

These actions constitute malpractice, for which a penalty (eg disqualification from the assessment) will be applied.

Where suspected malpractice is identified by a centre after the candidate has signed the declaration of authentication, the Head of Centre must submit full details of the case to City & Guilds at the earliest opportunity. Please refer to the form in the document *Managing cases of suspected malpractice in examinations and assessments*.

Access arrangements

Access arrangements are adjustments that allow candidates with disabilities, special educational needs and temporary injuries to access the assessment and demonstrate their skills and knowledge without changing the demands of the assessment. These arrangements must be made before assessment takes place.

It is the responsibility of the centre to ensure at the start of a programme of learning that candidates will be able to access the requirements of the qualification.

Please refer to the *JCQ access arrangements and reasonable adjustments and Access arrangements - when and how applications need to be made to City & Guilds* for more information. Both are available on the City & Guilds website: <http://www.cityandguilds.com/delivering-our-qualifications/centre-development/centre-document-library/policies-and-procedures/access-arrangements-reasonable-adjustments>

Special consideration

We can give special consideration to candidates who have had a temporary illness, injury or indisposition at the time of the examination. Where we do this, it is given after the examination.

Applications for either access arrangements or special consideration should be submitted to City & Guilds by the Examinations Officer at the centre. For more information please consult the current version of the JCQ document, *A guide to the special consideration process*. This document is available on the City & Guilds website: <http://www.cityandguilds.com/delivering-our-qualifications/centre-development/centre-document-library/policies-and-procedures/access-arrangements-reasonable-adjustments>

UAN:	K/506/5475
Level:	3
GLH:	60

What is this unit about?

In this unit you will come to understand a range of materials used in engineering. By learning about their physical and other properties you will begin to see how to identify the most appropriate material satisfy particular specifications. You will consider the effects of heat treatment and its effect on a material's structure and so to how this can change materials properties.

You must be able to differentiate between a range of materials used in engineering. You will consider new material developments along with their impact on product manufacture.

To achieve this unit you will need to develop a broad understanding of the types and properties of materials available to engineers. This is best done by research and reading about the many materials and their applications. It is important not to get confused by trying to remember too much detail - modern materials are so many and so complex that even experts can only remember the materials used in their particular specialist area.

In the course of studying this unit you will be able to answer such questions as:

- Why is that material used in that situation?
- How are new materials affecting production processes?
- How can I measure the various properties of a material?
- What are electrical components made of?
- How are LEDs made in different colours?

Learning outcomes

In this unit, learners will be able to

1. Know the properties and characteristics of engineering materials
2. Understand metal heat treatment techniques and their effects on material structures
3. Use testing methods to determine material properties
4. Understand the basic principles of composite materials
5. Understand the basic principles of electronic materials

Scope of content

This section gives details of the scope of content to be covered in the teaching of the unit to ensure that all the learning outcomes can be achieved.

Learning outcome:

1. Know the properties and characteristics of engineering materials

Topics

- 1.1 Properties and characteristics of engineering materials
- 1.2 Materials and their use in Engineering

Topic 1.1

Learners must know the meaning of the following material properties:

Mechanical properties

- strength (tensile and compressive)
- hardness
- toughness (and brittleness)
- malleability
- ductility
- elasticity
- plasticity.

Physical properties

- conductivity (thermal and electrical)
- density and specific gravity
- specific heat capacity.

They should also know what is meant by the following terms:

- corrosion resistance
- creep
- fracture
- hardenability
- magnetism
- fluidity
- fusibility
- weldability
- porosity.

Topic 1.2

Learners must know the following types of materials, their relative properties and their typical applications in engineering:

Ferrous metals

- low, medium and high carbon steels
- stainless steels
- cast irons.

Non-ferrous metals

- aluminium and its alloys

- copper, brass and bronze
- nickel
- titanium.

Non-metallic materials

- plastics (thermosetting, thermoplastic and elastomers)
- composites
- ceramics.

Smart materials

- shape memory (metal alloys and polymers)
- thermochromic and photochromic pigments
- piezoelectric.

Learning outcome:

2. Understand metal heat treatment techniques and their effects on material structures

Topics

- 2.1 Heat Treatment Methods
- 2.2 Effect on materials structure

Topic 2.1

Learners must know and be able to carry out the following types of heat treatment methods for metals, and understand why they are used:

Ferrous metals:

- quenching
- tempering
- normalizing
- case hardening.

Non-ferrous metals:

- solution and precipitation hardening
- annealing.

Learners must also know the process of induction hardening and understand why this may be used.

Topic 2.2

Learners must understand how heat treatment affects the properties of the material being processed, considering the effect of:

- in ferrous metals, the iron/carbon equilibrium diagram
- lattice structures
- grain growth
- in non-ferrous metals, precipitation of particles to impede the movement of dislocations.

Learning outcome:

3. Use testing methods to determine material properties

Topics

- 3.1 Mechanical testing methods
- 3.2 Carry out tests on materials
- 3.3 Analyse results of tests
- 3.4 Select materials to meet specification requirements

Topic 3.1

Learners must know how the following types of mechanical testing are carried out and which properties they are used to measure:

- tensile
- hardness (Brinell, Rockwell, Vickers)
- toughness/impact resistance (Izod, Charpy)
- fatigue (Wohler)
- bend.

Learners must also know what is meant by a proof load test.

Topic 3.2

Learners must be able to carry out the following tests:

- tensile strength
- hardness
- bending
- density
- electrical conductivity.

They must be able to test the following types of materials:

- ferrous metal
- non-ferrous metal
- thermoplastic
- thermoset plastic.

Topic 3.3

Learners must be able to analyse the data produced by testing to determine the properties of the material being tested. This must include using the test piece dimensions and test values to calculate the appropriate material properties, where relevant.

Learners must also be able to identify the yield strength and ultimate tensile strength from graphs of tensile test results and calculate Young's modulus.

Topic 3.4

Learners must understand how the selection of a material for an application may need to be based on a compromise between several material properties. They must be able to evaluate which materials are most appropriate to meet the needs of a design specification, through consideration of the:

- mechanical properties of the material
- physical properties of the material
- cost
- aesthetics
- manufacturing constraints related to the material choice
- corrosion resistance of the material

- sustainability issues.

Learning outcome:

4. Understand the basic principles of composite materials

Topics

- 4.1 Principles and components of composite materials
- 4.2 Pre-impregnated (pre-preg) materials
- 4.3 Dry fibre moulding
- 4.4 Use of adhesive and bonding materials

Topic 4.1

Learners must know that composites comprise of two or more materials which are separately identifiable within the structure of the material. They must understand the difference between composite materials and metal alloys or chemical mixtures.

Learners must know that there are different types of reinforcement and core structures used in composites and common applications for each of these types:

- matrix:
 - polymer matrix composite (PMC)
 - metal matrix composite (MMC)
 - ceramic matrix composite (CMC)
- honeycomb
- foam.

Learners must know that the following types of fibre are used to provide reinforcement within composite materials that use a matrix:

- glass
- carbon
- aramids
- thermoplastic
- metal
- ceramic
- natural.

Learners must understand how the arrangement of the reinforcing matrix (weave style) will influence the relative properties of the composite material:

- aligned continuous
- random discontinuous
- uni-directional.

Learners must also know the meaning of the following terms with regard to the composite matrix:

- bonded
- stitched
- braids
- roving.

Learners must know that composites may also include additional materials and understand the purpose of these:

- resin
- additives
- fillers
- pigments
- fire retardants.

Learners must know how the relative properties of composite materials compare to non-composite materials used in similar applications:

- strength
- toughness
- stiffness (rigidity)
- thermal stability
- strength to weight ratio
- chemical resistance.

They must also understand the typical characteristics of composite materials compared to non-composite materials used in similar applications:

- weight
- cost
- lifespan
- sustainability
- degradation
- repair
- assembly
- bespoke properties.

Learners must understand the following terms used during the manufacture of products made from composite materials:

- polymerization
- reaction
- curing.

Learners must also understand the health and safety considerations during the manufacture of composite materials:

- ventilation and temperature control of work areas
- protection of respiratory system
- fire protection
- implications of long and short term exposure to fibres, solvents and matrix materials
- safe disposal of waste
- COSHH.

Topic 4.2

Learners must know what is meant by pre-impregnated (pre-preg) materials and understand how they affect the manufacturing characteristics:

- price
- set-up cost
- productivity rate
- quality control.

Learners must know how pre-preg materials are prepared to manufacture products:

- use of templates
- cutting
- release films
- safe disposal of waste.

Learners must understand how products are manufactured from pre-preg materials through the application of heat and pressure, using:

- a vacuum bag and oven (out of autoclave)
- an autoclave.

Topic 4.3

Learners must know what is meant by dry fibre moulding and understand how this affects the manufacturing characteristics of products:

- price
- set-up cost
- productivity rate
- quality control
- wastage.

Learners must understand how the following techniques are used during the manufacture of products using dry fibre moulding:

- resin infusion
- resin transfer
- filament winding
- pultrusion.

Topic 4.4

Learners must understand how adhesive and bonding materials are used during the manufacture of products made from composite materials:

- surface preparation, using mechanical, abrasion or solvent means
- how the adhesive and bonding material can be applied
- how temperature, pressure and environmental conditions affect the curing of the product.

Learners must know the typical defects in composite products:

- voids
- disbonds and delamination
- porosity.

They must also know the tests that can be carried out to detect faults:

- tap testing
- thermography
- x-ray
- shearography
- ultrasonic.

Learning outcome:

5. Understand the basic principles of electronic materials

Topics

- 5.1 Conductive materials
- 5.2 Resistive and dielectric materials
- 5.3 Semi-conductor materials

Topic 5.1

Learners should understand in general terms how the following materials conduct electricity:

- metals
- electrolytes
- superconductors
- semiconductors
- plasmas
- nonmetallic conductors such as graphite and conductive polymers.

Topic 5.2

Learners must know that most ceramics are insulators. They must also know the types of materials used for insulation in the following applications:

- cable insulation
- PCB substrates
- conformal coatings on PCBs.

Learners must understand what is meant by dielectric and must know the relative positions in an ordered table of dielectric constants of the following materials:

- air
- mica
- polymers
- titanium, strontium and barium compounds.

Topic 5.3

Learners should understand the mechanism by which semiconductors conduct electricity at a sub-atomic level. They should understand how they are 'grown' and what is meant by doping, 'npn' and 'pnp' junctions.

Learners should know the relative electrical properties, physical properties and cost of common semiconductor materials:

- silicon
- gallium arsenide
- germanium
- indium
- antimony.

Learners should know the typical applications of semiconductors including:

- lasers
- LEDs (including being able to explain why they are different colours)
- optoelectronics
- solar panels.

Guidance for delivery

It is important that the learners have a full understanding of the underpinning knowledge of each of the topics. Very important is the practical application of this knowledge and understanding in the working environment. Learners must be able to apply their knowledge and understanding when working on a range of engineering activities, different types of equipment and working environments. Although content will be delivered in a classroom environment, it is important that learners can relate this knowledge and understanding to actual workshop situations and practical tasks.

Tutors delivering this unit have opportunities to use a wide range of techniques. Lectures, discussions, seminar presentations, site visits, videos/DVDs, research using the internet or library resources and use of tutors with relevant and appropriate industrial experience are all suitable. Visiting expert speakers could add to the relevance of the subject for learners. The learning outcomes are sequential. Group activities are permissible, but tutors will need to ensure that individual learners have equal experiential and assessment opportunities.

Although engineering materials can be delivered purely theoretically, the learner would benefit from a range of practical experiences to support learning. Access to a range of materials and structured experiments would ensure any learning was reinforced.

Applying the knowledge being delivered to everyday situations will benefit learners:

- Why do power lines sag in the summer?
- How do reading glasses return to their original shape?
- Why don't we use gold for electrical cables?
- What happens when I try and melt a plug top?
- Why are there gaps between railway lines?
- How are planes being manufactured to be more fuel efficient?

It is important that learners are able to use their knowledge of materials and apply it to real life situations.

Employer engagement

Employer engagement is essential in order to maximise the value of learners' experience. A partnership approach should be adopted where possible with employers with whom the consortium has links, and with employers used for work experience placements.

The use of scenario led contextualised tasks are essential in the delivery and assessment of this unit. Much of the work can be set in the context of case studies of local employers. Visits to companies/shows/exhibitions will enhance this particular part of the unit.

It would be helpful for teachers to develop a method of maintaining contact with a range of employers in the sectors may be able to help with keeping the examples of legislation, policies and codes of practice used in the taught content, up to date.

UAN:	M/506/5476
Level:	3
GLH:	60

What is this unit about?

Much of the electronics you see today is hidden and taken for granted. This unit is an opportunity to look into modern electronic principles and to see how control systems are used. In order to do this you need to understand some basic electronic theory, but the majority of the unit is about electronics in practice, controlling robots and other industrial machines and measuring important parameters through instrumentation. You will have the opportunity to work with control equipment and to set up your own systems to

Some of the questions you might want to answer by studying this unit are:

What electronic signals make machines and robots work?

What electrical components allow movements and sensing to take place?

How are movements and speeds and product quantities actually measured and how can they be displayed?

Learning outcomes

In this unit, learners will be able to

1. Apply the principles of electricity, magnetism and electrical circuits
2. Apply the principles of digital electronics
3. Understand microcontrollers and their application
4. Apply open and closed loop control in servo systems
5. Use sensors and transducers in control and robotic systems
6. Understand the basic principles of industrial instrumentation

Scope of content

This section gives details of the scope of content to be covered in the teaching of the unit to ensure that all the learning outcomes can be achieved.

Learning outcome:

1. Apply the principles of electricity, magnetism and electrical circuits

Topics

- 1.1 Fundamentals of matter and current flow
- 1.2 Electrical components
- 1.3 DC and AC circuits and power sources
- 1.4 Electromagnetism
- 1.5 Circuit design and build

Topic 1.1

Learners must know the relationship between matter and its composition, energy, and understand the meaning of the term 'current flow':

Learners must understand the following terms when referring to matter:

- atom
- nucleus
- electron
- proton
- neutron
- valence
- valence shell
- ion
- element
- compound
- molecule
- mixture.

Learners must know the relationship between:

- kinetic energy
- potential energy
- photons
- electron orbits
- energy levels
- shells and sub-shells.

Learners must understand the following terms relating to current flow and voltage in different materials:

- electron flow
- potential difference and voltage
- direct current
- alternating current
- conductive materials
- resistive materials
- semi-conductor materials.

Topic 1.2

Learners must understand the operation of the following types of linear circuit components:

- resistors
- capacitors
- inductors
- semiconductors.

Learners must understand how the contribution to circuit function of these components relates to the materials they are made of and their physical construction. They should know the following for each component:

- physical characteristics
- operating characteristics
- symbols
- ratings
- uses of typical types of the component
- identification using colour codes etc.

Topic 1.3

Learners must know typical examples of how electrical and electronic components are used in the real world.

Learners must understand the following terms when relating to direct current:

- conductors and insulators
- resistance
- Ohm's law
- Kirchhoff's Laws
- DC power supplies
- DC circuits
- DC amplifiers
- DC circuit measurements.

Learners must understand the following terms when referring to alternating current

- semiconductors
- single phase ac circuit theory
- capacitance
 - permittivity
 - dielectric constant
- inductance
- impedance
- transformers
- RL, RC, LC circuits
- three-phase ac theory
- amplifiers
- AC power supplies
- AC and DC circuits
- AC circuit measurements.

Topic 1.4

Learners must know what is meant by the terms magnetism and electro-magnetism.

They must know the following about electromagnetism:

- units

- the properties of magnetic fields
- electromagnetic induction
- electromagnetic fluxes and flux linkages
- Faraday's law
- Fleming's left and right hand rules.

Topic 1.5

Learners must be able to use computer aided design software to design, build and test a range of DC and AC circuits.

Learning outcome:

2. Apply the principles of digital electronics

Topics

- 2.1 Number systems
- 2.2 Logic gates and circuits
- 2.3 Logic signal waveforms
- 2.4 Design and build

Topic 2.1

Learners must understand the following number systems:

- binary
- hexadecimal
- octal
- binary coded decimal (BCD).

Learners must know and be able to apply the following concepts:

- binary arithmetic
- Boolean algebra
- truth tables
- Gray code
- Karnaugh Maps.

Topic 2.2

Learners must understand the differences between analogue and digital logic.

They must know the following basic logic gates and understand how these are used in circuits:

- NOT
- AND
- OR
- NAND
- NOR
- EX-OR

They must understand how these logic gates can be used to create combinational logic circuits:

- construct, recognise and use truth tables for NOT, AND, OR, NAND, NOR and EX-OR gates and simple combinations of them
- understand the operation of, and use combinations of, NOT, AND, OR, NAND, NOR and EX-OR gates to form other logic functions
- generate the Boolean expression from a truth table or logic diagram.

Topic 2.3

When referring to basic waveforms, learners must know the following logic waveforms:

- analogue logic signals
- digital logic signals

Learners must know what is meant by logic timing. They must know how the following switches operate:

- relay
- diode
- transistor

Topic 2.4

Learners must be able to design, build and test a logic control circuit for a real-world application.

Learning outcome:

3. Understand microcontrollers and their application

Topics

- 3.1 Technology, circuits and controllers
- 3.2 Control systems
- 3.3 Practical applications

Topic 3.1

Learners must know the meaning of the following terms:

- Microelectronics technology
- Micro-miniature circuits
- microprocessor
- clock
- memory (ROM and RAM)
- input/output ports
- bus structure.

Topic 3.2

Learners must understand the differences between hard wired and software based control systems.

Learners must understand and be able to draw typical control systems layouts using open loop and closed loop control, showing:

- input
- error detection
- processor
- driver
- output device
- feedback.

Learners must know the following input subsystems and their functions:

- analogue to digital converters (ADC)
- optical switches
 - slotted
 - reflective

- shaft encoders (including a comparison)
 - slotted disk
 - binary coded
 - Gray coded

Learners must know the following output subsystems and their functions:

- digital to analogue converters (DAC)
- display types
- stepper motors.

Topic 3.3

Learners must be able to use the following when working with control systems:

- Software
- Hardware
- Interfaces.

Learners must know examples of applications of microcontrollers.

Learning outcome:

4. Apply open and closed loop control in servo systems

Topics

- 4.1 Measurement systems
- 4.2 Input transducers
- 4.3 Signal conditioning
- 4.4 Damping
- 4.5 Meaning of terms and expressions
- 4.6 Formulae for deriving controller output
- 4.7 Definitions of integral and derivative control
- 4.8 Building and analysing circuits

Topic 4.1

Learners must know the meaning of the following requirements of measurements systems:

- reliability
- repeatability
- range (reproducibility)
- sensitivity
- stability
- response time
- rise time
- settling time
- steady state
- desired value
- loading effects/errors.

Learners must understand the use of true value inputs, when working with a measurement system or a measured value of variable output.

Topic 4.2

Learners must be able to use the following input transducers:

- voltage to voltage
- voltage to current
- frequency to voltage
- resistance to voltage.

Topic 4.3

Learners must understand how signal conditioning is carried out using the following circuit arrangements:

- transducer action
- analogue input interfaces
- digital input interfaces.

Learners must know calibration procedures for signal conditioning circuits.

Topic 4.4

Learners must understand the following terms related to damping:

- under-damped
- over-damped
- critical damping.

Topic 4.5

Learners should know and understand the following terms and expressions when working with control systems:

- system block diagrams
- reliability
- repeatability
- range (reproducibility)
- sensitivity
- stability
- response time
- rise time
- settling time
- steady state
- desired value
- loading effects / errors
- two step control
- continuous control
- proportional band
- dead band, off-set
- hysteresis
- proportional gain (K_p), derivative gain (K_d)
- Integral gain (K_i).

Topic 4.6

Learners must be able to use and apply the following formulae:

- controller output = $K_p(\text{error} + K_i \times \text{integral of error} + K_d \times \text{derivative of error})$
- output = $k_p(e + k_i \int e + k_d \frac{de}{dt})$.

Topic 4.7

Learners must know that:

- "integral control is a controller output that is proportional to the integral to the error with respect to time"
- "derivative control is a controller output that is proportional to the rate of change of the error with respect to time".

Topic 4.8

Learners must be able to build and analyse control circuits. They must be able to:

- configure inputs
- measure and analyse outputs
- apply system tuning using tables / charts
- analyse the operation of the circuit

Learners must understand the difference between stepped and ramped input signals

Learners must know how to use sinusoidal measuring equipment such as a PC-based data logger and understand the storage scope of this type of equipment

Learning outcome:

5. Use sensors and transducers in control and robotic systems

Topics

- 5.1 Types of sensor and their application
- 5.2 Types of actuator and their connections
- 5.3 Connecting proximity switches
- 5.4 Sensor power supplies
- 5.5 Building a control system

Topic 5.1

Learners must know which types of sensors to use for:

- measuring machine parameters for robot control loops
- determining the position of objects in 3-D space
- adjusting the robot control for the environment
- detecting and preventing failures, detecting and avoiding collisions,
- monitoring the interaction with the environment
- monitoring the environmental changes / temperature
- inspecting the final product.

Learners must be able to classify sensors as one or more of the following types:

- digital
- analogue
- safety
- internal and external.

Learners must know the different types of proximity sensors:

- inductive
- capacitive

- optical.

They must understand the meaning of the following terms related to proximity sensors:

- sensing range
- material tuning
- required output (sink source)
- switching capability
- banking capability.

Learners must know the following different types of differential pressure devices:

- turbine
- strain gauge
- piezo electric
- ultrasonic.

They must understand the meaning of the following terms related to differential pressure devices:

- resistive bridge trimming
- trimming of volts / seconds
- trimming of power level

Learners must know the different types of tacho-generators:

- resolvers
- encoders.

They must understand the meaning of the following terms related to tacho-generators:

- setting volts / rpm
- setting of volts / mm
- setting of data sequence.

Learners must know the meaning of the following terms relating to temperature measurement devices:

- thermocouples:
 - zero
 - range
 - span
 - junction compensation
 - type.
- Resistance thermometers (pt100 devices):
 - zero
 - range
 - span.

Learners must be able to use technical information contained in manufacturers data sheets to select an appropriate temperature measurement device for an application.

Topic 5.2

Learners must know the function of the following transducer types, their limitations and the common connection types used with them:

- Digital sensors:
 - limit switch
 - proximity switch

- photo electric switch
- Hall effect switch
- float switch
- ultrasonic switch

- Analogue sensors:
 - temperature sensor
 - flow switch
 - load cell
 - laser
 - pressure transducer
 - vision system

- safety sensors:
 - gate plug
 - light curtain
 - safety mat

- internal and external sensors:
 - internal:
 - potentiometer
 - LVDTs
 - synchros
 - resolvers
 - optical encoders
 - load cells
 - photoelectric.
 - External
 - proximity
 - limit switch
 - optical systems
 - Hall effect switch
 - ultrasonic switch.

Learners must be able to suggest the most suitable sensor/transducer for a particular application and be able to explain their decision.

Learners must know how to calibrate the following devices:

- proportional valves
 - trimming of input signals
 - span
 - zero.
- servo motors
 - setting of absolute datum optical sensor / drive to stall
 - deriving maximum holding torque.

Topic 5.3

Learners must know the following proximity switch connection types:

- 2 wire d.c. & a.c. – normally open (NO) contact, normally closed (NC) contact, grounding connections, residual load current

- 3 wire d.c. – transistor switched outputs (NPN & PNP types), normally open, normally closed
- 4 wire d.c. – transistor switched outputs (NPN & PNP types), normally open/closed
- external to a controller.

Learners must know the following measures are used for circuits that operate in areas of high radio frequency interference, and electromagnetic interference (RFI/EMI)

- screening
- short cable lengths
- segregation of data and power conductors
- power supply filtering
- limit error signals at source.

Learners must understand the following considerations that can apply when connecting controllers, relays and display elements:

- current consumption
- load resistance
- sensor current
- transient protection.

Topic 5.4

Learners must know the types and sources of supply. They must understand the following consideration when referring to sensor power supplies:

- switch-on spikes
- supply voltage ripple
- stabilisation.

Topic 5.5

Learners must be able to manufacture systems with sensors and actuators:

- set up sensors
- set up actuators
- select an appropriate sensor for a given application
- wire a selection of transducers with different connection types into a control system
- wire proximity switches to obtain AND and OR functions
- wire proximity switches in sink and source mode
- measure the performance characteristics of the system
- analyse the performance of a control system.

Learning outcome:

6. Understand the basic principles of industrial instrumentation

Topics

- 6.1 Instrumentation principles
- 6.2 Circuit measurement and test

Topic 6.1

Learners must understand how the following can be used in instrumentation:

- Analogue Techniques

- Digital Techniques
- Drives and Controls
- Photonics and Instrumentation

Topic 6.2

Learners must understand how basic electrical and electronic circuit testing is used in industrial instrumentation and be able to use basic electrical measuring equipment.

Guidance for delivery

It is important that the learners have a full understanding of the underpinning knowledge of each of the topics. Very important is the practical application of this knowledge and understanding in the working environment. Learners must be able to apply their knowledge and understanding when working on a range of engineering activities, different types of equipment and working environments. Although content will be delivered in a classroom environment, it is important that learners can relate this knowledge and understanding to actual workshop situations and practical tasks.

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Employer engagement

Employer engagement is essential in order to maximise the value of learners' experience. A partnership approach should be adopted where possible with employers with whom the consortium has links, and with employers used for work experience placements.

The use of scenario led contextualised tasks are essential in the delivery and assessment of this unit. Much of the work can be set in the context of case studies of local employers. Visits to companies/shows/exhibitions will enhance this particular part of the unit.

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UAN:	T/506/5477
Level:	3
GLH:	60

What is this unit about?

Have you ever wondered how a refrigerator actually works, or that fancy new-fangled heating device in the house? Or do you perhaps wonder how a supporting beam, in a building that you know, can take all of that weight without bending or breaking? This unit is designed to help you to understand a range of physical properties that everyday objects, structures and machines exhibit. These studies are where physics and engineering meet, and it's essential that you have a good grasp of them before you move on to further studies. You will look at some of the physics behind the internal combustion engine and you might be prompted to look at some of the technology and data behind the next generation - the hybrid. You might be surprised how inefficient the plain petrol and diesel engines are!

Some questions you might want to answer in this unit are:

- How much weight can structural beams take before they fail
- What is the best shape for a structural beam?
- How can I work out what a snooker ball will do when it hits another ball?
- How efficient is my car engine, really?

Learning outcomes

In this unit, learners will be able to

1. Apply bending moments, shear forces and deflections in simple structures
2. Design simple beams and columns
3. Use mechanical science principles to solve practical problems in dynamics
4. Understand thermodynamics in engines and heat pumps

Scope of content

This section gives details of the scope of content to be covered in the teaching of the unit to ensure that all the learning outcomes can be achieved.

Learning outcome:

1. Apply bending moments, shear forces and deflections in simple structures

Topics

- 1.1 Reactions, shear force and bending moments
- 1.2 Shear force diagrams
- 1.3 Bending moment diagrams
- 1.4 Beam deflections under loading

Topic 1.1

Learners must be able to calculate reactions, shear force and bending moment values for various positions on:

- simply supported beams, with and without overhangs
- cantilever beams.

Topic 1.2

Learners must be able to draw shear force diagrams for simply supported beams where the load is applied at a point, uniformly distributed or a combination of these two loads.

Topic 1.3

Learners must be able to produce bending moment diagrams for beams where the load is applied at a point, uniformly distributed or a combination of these two loads.

Topic 1.4

Learners must be able to calculate deflections at mid-span for simply supported beams

Learning outcome:

2. Design simple beams and columns

Topics

- 2.1 First and second moment of area
- 2.2 Use the theory of bending to determine sizing and stresses of rectangular beam sections
- 2.3 Axially loaded columns
- 2.4 Eccentrically loaded columns
- 2.5 Forces in a structural frame

Topic 2.1

Learners must be able to calculate the first and second moment of area for the following sections:

- Rectangular
- Circular
- Trapezoidal
- Compound shapes.

Topic 2.2

Learners must be able to use the theory of bending to determine the size and stress levels in rectangular beam sections.

Theory of bending:

$$\frac{M}{I} = \frac{f}{y}$$

Topic 2.3

Learners must be able to calculate the safe load for a given section size, and the section size required for a given load, for axially loaded columns of the following beam sections:

- Rectangular
- Circular
- T
- I
- C (structural channel).

When calculating safe load, the materials considered should be limited to:

- structural steel
- other common steels
- timber
- concrete.

They must understand the effective length and be able to use permissible stress design tables.

Topic 2.4

Learners must be able to calculate stress values in eccentrically loaded columns of circular section.

Topic 2.5

Learners must be able to use Bow's notation to calculate the magnitude and direction (compressive or tensile) of loads applied to a structural frame.

Learning outcome:

3. Use mechanical science principles to solve practical problems in dynamics

Topics

- 3.1 Energy and energy conversion
- 3.2 Linear motion
- 3.3 Angular motion
- 3.4 Oscillating motion
- 3.5 Machines
- 3.6 Friction

Topic 3.1

Learners must know the law of conservation of energy and the relationship between work done in raising a body to potential energy.

They must be able to solve practical problems for energy conversion or stored energy, using either graphical methods or by calculation:

- potential energy P.E. = mgh
- linear and angular kinetic energy, in terms of $\frac{1}{2}mv^2$ and $\frac{1}{2}I\omega^2$
- stored energy S.E. = $\frac{1}{2}fx$

Topic 3.2

Learners must be able to solve practical problems involving bodies in linear motion:

- Newton's laws of motion
- Accelerating and decelerating masses using $F = ma$
- Inertia
- Motion under gravity (defining $g = 9.81\text{ms}^{-2}$)
- Velocity and acceleration using:

$$v = \frac{ds}{dt}$$

$$a = \frac{dv}{dt}$$

$$v = u + at,$$

$$s = ut + \frac{1}{2}at^2$$

$$s = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

- Use of vector diagrams to determine achieved tracks and relative velocities
- Colliding bodies - coefficient of restitution
- Bodies in trajectories (ballistics), using differential calculus

They must also know the definition of a Newton as the force required to accelerate a mass of 1kg at the rate of 1ms^{-2} .

Topic 3.3:

Learners must be able to solve practical problems involving bodies in angular motion:

- Circular motion
 - angular speed $\omega = \frac{v}{r} = 2\pi f$
 - centripetal acceleration $a = \frac{v^2}{r} = \omega^2 r$
 - centripetal force $F = \frac{mv^2}{r} = m\omega^2 r$
- Moment of inertia and radius of gyration of discs and rimmed flywheels

Topic 3.4

Learners must be understand the following with relation to oscillating motion:

- periodic motion
- simple harmonic motion
- harmonics
- how resonance occurs and its possible effects on periodic motion systems

Topic 3.5:

Learners must be able to carry out calculations for the use of simple machines:

- lifting machines
 - load

- effort
- mechanical advantage
- velocity ratio
- work
- energy
- power
- efficiency

Topic 3.6:

Learners must understand the difference between dynamic and static friction. They must be able to carry out calculations involving the coefficient of friction for a body in contact with a flat or sloped surface.

Learning outcome:

4. Understand thermodynamics in engines and heat pumps

Topics

- 4.1 First Law of Thermodynamics
- 4.2 Ideal gas law
- 4.3 The p - V diagram
- 4.4 Engine cycles
- 4.5 The Second Law of Thermodynamics and engines
- 4.6 Reversed heat engines

Topic 4.1

Learners must understand the First Law of Thermodynamics and be able to apply this to solving practical problems.

Topic 4.2

Learners must be able to apply the ideal gas law to solving problems under adiabatic conditions, involving either constant temperature, pressure or volume.

Topic 4.3

Learners must know that a pressure volume diagram (or p - V diagram) shows corresponding changes in volume and pressure in a system. They must be able to calculate the work done under constant pressure $W = p\Delta V$ and use the area of the loop to estimate the work done by the system.

Topic 4.4

Learners must understand the Otto and Diesel cycles in an engine and how these relate to the First Law of Thermodynamics:

- input power
- indicated power
- friction power

- engine efficiency (including typical values)
 - overall
 - thermal
 - mechanical.

Topic 4.5

Learners must understand how the second law of thermodynamics applies to engines. They must understand:

- the concept of a source and a sink and the need for an engine to work between them.
- the maximum theoretical efficiency
- reasons for the lower efficiencies of practical engines

Topic 4.6

Learners should have a basic understanding of how refrigerators and heat pumps work with reference to the Second Law of Thermodynamics. They must be able to calculate their respective Coefficients of Performance (CoP_{ref} and CoP_{hp}), given W , Q_{in} and Q_{out}

Guidance for delivery

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UAN:	A/506/5478
Level:	3
GLH:	60

What is this unit about?

The management of manufacturing process is a crucial part of the manufacturing engineer's skill, for it is this that can, and does, make the difference between a particular product making a profit for the company, and the company making a loss. But it's more than just the material and the process that is important - the fact that the costs of storing and insuring stock are held down and the quality assurance is properly done, can make just as much difference. This unit gives an insight into how products are made on an industrial scale, and shows you some of the methods used to keep the process profitable.

Some of the questions you might want to answer during this unit are:

- How are products made to a high standard in mass-production?
- How does a company avoid running out of material stocks and bringing production to a halt?
- What manufacturing methods are used to take advantage of modern materials?
- What quality assurance methods are commonly used in modern manufacturing?

Learning outcomes

In this unit, learners will be able to

1. Understand manufacturing processes and techniques
2. Understand production and automation systems
3. Understand advanced manufacturing techniques
4. Understand process planning requirements
5. Understand quality control issues

Scope of content

This section gives details of the scope of content to be covered in the teaching of the unit to ensure that all the learning outcomes can be achieved.

Learning outcome:

1. Understand manufacturing processes and techniques

Topics

- 1.1 Mechanical processes and techniques
- 1.2 Electrical processes and techniques
- 1.3 Electronics processes and techniques

Topic 1.1

Learners must know each of the following processes and techniques and understand:

- how they are used. Where applicable, the use of the process should include CNC equipment.
- how they change the material being processed. The materials covered should be metals unless a process or technique is specifically for another type of material.
- health and safety considerations when using the process, including any actions normally taken to reduce the risk of injury.
- methods of assessing the quality of the process.
- examples of common products that the process or technique is used to manufacture, relating the process to the characteristics that the product needs to possess. For instance: axles and shafts are usually roll forged because the process results in a grain structure that imparts toughness and wear resistance to the material.

Each process or technique should be treated quite generally, but the method must be clear, as must the way in which each process is used in industry.

Machining processes:-

- Conventional methods
 - turning
 - milling
 - hole production including:
 - drilling
 - punching
 - reaming
 - thread cutting using taps
- Electrical machining methods
 - electro-discharge machining (EDM)
 - electro-chemical machining (ECM)
- Abrasive machining methods - grinding techniques:
 - honing
 - lapping
- Forging:
 - upset forging
 - drop forging (open die, closed die)

Fabrication processes:-

- Cutting:

- plasma
- flame (eg: oxy-acetylene)
- laser
- Joining:
 - mechanical fastening (screw, bolt, rivet)
 - adhesives
 - brazing
 - welding:
 - gas welding (oxy-acetylene)
 - electric arc welding
 - Metal Inert Gas / Metal Active Gas (MIG / MAG)
 - Tungsten Inert Gas (TIG)
 - friction welding
 - resistance welding (spot and seam)
 - welding plastics using heat

Topic 1.2

Learners must know the common types of electrical cable (mains, coaxial, ribbon cable, twin lead) and how they are terminated.

They should know how transformers are wound and how large transformers, motors and generators are constructed.

Topic 1.3

Learners must know the processes used to assemble electrical products and understand the reasons for their use:

- Manufacture of integrated circuits
- Printed circuit boards:
 - component mounting:
 - through-hole
 - surface mount
 - automatic pick and place
 - soldering
 - manual
 - wave
 - reflow
 - cleaning
 - conformal coating (potting)
- mass production assembly of appliances and equipment

Learning outcome:

2. Understand production and automation systems

Topics

- 2.1 Scale of manufacture
- 2.2 Inspection methods
- 2.3 Measurement methods
- 2.4 Assembly and build methods
- 2.5 Component finishing and assembly protection methods.
- 2.6 Automation methods

Topic 2.1

Learners must understand how the scale of manufacture influences the processes and techniques and level of automation used to make a product:

- bespoke (one-off)
- batch
- mass
- flow-line (continuous).

Learners must understand how and why aids to production such as jigs, fixtures, templates and moulds are used at different scales of production.

Topic 2.2

Learners must understand the difference between quality assurance and quality control and the reasons why process checks and inspection techniques are necessary.

Topic 2.3

Learners must know the characteristics and features that can be measured using gauging and measuring equipment, and how this equipment is used in industry:

- in-process gauging (go/no-go gauges, templates)
- manual methods
 - Vernier callipers
 - Micrometer.
- automated methods
 - Coordinate Measurement Machine (CMM)
 - laser techniques.

Learners must understand the reasons for sampling rather than 100% inspection.

Topic 2.4

Learners must know how products are assembled and built in quantity:

- cradles
- automatic component sorting
- fixtures
- conveyor belts
- automated assembly.

Topic 2.5

Learners must know how components are finished and protected from subsequent damage:

- finishing methods:
 - plating (galvanizing)
 - painting
 - anodising and electroplating
 - plastic coating
- Assembly protection:
 - coatings
 - shrink-wrap
 - packaging.

Topic 2.6

Learners must understand how and why automation is applied to manufacturing, assembly processes and materials handling:

- manufacturing using Computer Numerical Control (CNC) equipment
 - program entry and proving
 - tool changing
 - material feed
 - coolant
- materials handling around a manufacturing facility
- transfer machines and automatic loading / unloading of machines
- robotic systems:
 - welding
 - assembly
 - paint spraying.

Learning outcome:

3. Understand advanced manufacturing techniques

Topics

- 3.1 Additive processes
- 3.2 Casting
- 3.3 Moulding & extrusion
- 3.4 Chemical
- 3.5 Cutting
- 3.6 High frequency techniques
- 3.7 Joining
- 3.8 Powder based

The purpose of this learning outcome is to give a broad outline of some of the many modern manufacturing techniques that are in use and still undergoing development.

Learners must know each of the following processes and understand:

- how they are used.
- how they change the material being processed. The materials covered should be metals and, where a process is specifically for another type of material, non-metals.
- health and safety considerations when using the process, including any actions normally taken to reduce the risk of injury.

- How the process compares to conventional manufacturing techniques, in terms of the properties and characteristic of the produced item.

Topic 3.1

Learners must know how additive manufacturing processes are used for rapid prototyping and understand the reasons for their use:

- 3D printing techniques
- stereolithography.

Topic 3.2

Learners must know how precision casting techniques are used:

- investment
- gravity
- low pressure
- vacuum casting of polymers.

Topic 3.3

Learners must know how moulding and extrusion are used to shape and form materials:

- Moulding of plastics:
 - injection
 - transfer
 - blow
 - thermoforming
 - vacuum
- Extrusion of plastics and metals.

Topic 3.4

Learners must know how the subtractive manufacturing processes of chemical milling and etching are used.

Topic 3.5

Learners must know how the materials are cut using an abrasive water jet cutter.

Topic 3.6

Learners must know how technologies using high frequency ultrasonic waves are being used to remove and cut materials.

Topic 3.7

Learners must know how electron beam welding and ultrasonic welding are being used to join materials.

Topic 3.8

Learners must know how powder compaction and sintering techniques are being used to make products.

Learning outcome:

4. Understand process planning requirements

Topics

- 4.1 Production Planning
- 4.2 Management of materials

Topic 4.1

Learners must understand the information that is required in a production plan and how this helps to facilitate the successful manufacture of a commercial product:

- process and tooling
- time required
- materials required
- dimensions
- health and safety
- quality assurance and quality control.

For a given product, learners must be able to identify the processes required to manufacture it. For a given scale of manufacture they must be able to justify the selection of appropriate processes and the automation required.

Topic 4.2

Learners must know the types of stock used in a manufacturing company:

- raw materials
- work in progress
- finished products

Learners must understand how stock and components are purchased, managed and stored during production and the relative advantages and disadvantages of each of the following approaches:

- fully stocking with buffer stock
- Kanban
- 'just in time' (JIT) manufacture

Learning outcome:

5. Understand quality control issues

Topics

- 5.1 Quality Concepts
- 5.2 Quality Improvement Strategies
- 5.3 Quality Tools and Techniques

Topic 5.1

Learners must understand how quality concepts affect the performance of a company:

- 'cost of Quality'
- quality standards
- culture of quality.

Topic 5.2

Learners must know the strategies commonly used by large companies to manage or improve quality, their principles, and the relative advantages and disadvantages of these strategies:

- Statistical Process Control
- Total Quality Management (TQM)
- Six Sigma
- Lean
- Supplier Quality Management.

Topic 5.3

Learners must know the tools and techniques used to manage or improve quality, their principles and under what circumstances they would be suitable

- Quality Circles
- Cause and effect
- Process Capability
- Quality Function Deployment (QFD)
- Value stream mapping
- Poka Yoke .

Guidance for delivery

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Employer engagement

Employer engagement is essential in order to maximise the value of learners' experience. A partnership approach should be adopted where possible with employers with whom the consortium has links, and with employers used for work experience placements.

The use of scenario led contextualised tasks are essential in the delivery and assessment of this unit. Much of the work can be set in the context of case studies of local employers. Visits to companies/shows/exhibitions will enhance this particular part of the unit.

It would be helpful for teachers to develop a method of maintaining contact with a range of employers in the sectors may be able to help with keeping the examples of legislation, policies and codes of practice used in the taught content, up to date.

UAN:	F/506/5479
Level:	3
GLH:	60

What is this unit about?

Design is an essential part of the engineering manufacturing process. In this unit you will have the opportunity to develop skills in 2D and 3D computer aided design (CAD), producing drawings that you will use later to manufacture items for your practical assignments. Before a designer gets to that stage, there is a process of product development, market survey and testing and, in most cases, looking at previous versions of a product to see how it can be improved and made more appealing to the customer.

For the design of engineering components such as car engine parts, aircraft undercarriages or train brake units, performance and reliability are key. In this unit you will be able to look at that process and see how a customer's product specification is developed and turned into a final design for manufacture. You will learn the meaning of the phrases 'fit, form and function', and 'fit for purpose' and learn to use them when deciding if a particular design is finished.

Particular questions you will be able to answer are:

- What exactly is a design specification and how is it arrived at?
- What is the next stage - how does a designer start to produce the images we associate with the finished product?
- Can a designer use other tools such as clay modelling or 3D printing?
- Can I have a go at CAD? (Yes you can!)

Learning outcomes

In this unit, learners will be able to

1. Understand the process of developing a product design specification from a design brief
2. Develop a product design specification from a customer brief
3. Understand how engineering design solutions meet product design specifications
4. Understand the effects of historic engineering design achievements
5. Produce 2D CAD drawings
6. Produce 3D CAD drawings

Scope of content

This section gives details of the scope of content to be covered in the teaching of the unit to ensure that all the learning outcomes can be achieved.

Learning outcome:

1. Understand the process of developing a product design specification from a design brief

Topics

- 1.1 Terminology and definitions in the design process
- 1.2 Key elements of product design specifications
- 1.3 Key factors that are considered in development of a product design specification

Topic 1.1

Learners should know that the design process covers everything that goes into the development and making of a product, starting with a defined need and finishing with the supply of an article that is fit for purpose to satisfy that need. They should understand that some factors must be considered throughout the process:

- customer design brief
- product design specification (pds)
- fit
- form
- function.

Topic 1.2

Learners should know that a specification is a list of needs that a product must satisfy and may contain several different types of need:

- aesthetic requirements
- cost
- environmental issues
- size
- safety considerations
- function
- materials
- limitations affecting the choice of manufacturing methods
- maintenance requirements.

Topic 1.3

Learners should understand that the needs in a specification may originate from several different research activities:

- customer design brief
- market research, including product analysis
- legislation and standards
- 'design for manufacture'
- technological advances.

Learning outcome:

2. Develop a product design specification from a customer brief

Topics

2.1 Analysing a design brief

2.2 Design criteria

Topic 2.1

Learners must understand how a product design specification is developed from a customer design brief. They must be able to analyse a customer design brief to determine:

- target audience for the product
- the function of the product (what it will be used for)
- product performance requirements
- materials
- quantity required
- manufacturing methods (assembly)
- costs
- competitor products.

Topic 2.2

Learners must understand the difference between design constraints and design wants, and between subjective and objective criteria. They should also understand that there may be conflicting requirements, for example properties required versus the cost of different materials, or processes to use versus cost of production.

They must be able to develop a design specification that uses objective criteria wherever feasible, covering the main requirements for the product:

- aesthetic requirements, including shape and surface finish
- cost
- environmental issues, such as sustainability
- size, including dimensions and ergonomic requirements
- safety considerations, including legal requirements
- function, including performance, maximum acceptable failure rate within warranty and product life cycle requirements
- materials, including manufactured and bought in components, where applicable
- limitations affecting the choice of manufacturing methods
- maintenance requirements
- production volume
- future related products.

Learning outcome:

3. Understand how engineering design solutions meet product design specification

Topics

- 3.1 Idea generation
- 3.2 Evaluating design ideas
- 3.3 Methods of representing designs
- 3.4 Methods of testing designs

Topic 3.1

Learners should understand that:

- design is an iterative process and that initial ideas may be developed or improved several times to create a design proposal
- ideas can be inspired by the analysis of existing products or the analysis of functional requirements
- initial designs are often represented by sketching
- ideas should be evaluated against the design brief and specification.

Topic 3.2

Learners should be able to use a range of processes to evaluate design ideas:

- comparison matrices
- ranking
- decision trees.

Topic 3.3

Learners should know that design ideas can be represented graphically and using physical models:

- sketches
- orthographic drawings (detail drawings)
- general arrangement drawing
- assembly drawing
- systems diagrams
- circuit diagrams
- flow charts
- prototypes, including block modelling and rapid prototypes.

Topic 3.4

Learners should understand the difference between subjective and objective evaluation. Learners should understand the advantages and limitations of different ways of testing ideas, including:

- virtual modelling of components and assemblies (3d cad)
- virtual modelling of electronic circuits, including performance testing and pcb design
- block modelling
- rapid prototypes, including stereolithography and 3d printing
- functional prototypes.

Learning outcome:

4. Understand the effects of historic engineering design achievements

Topic

4.1 Significant engineering achievements of the 19th to 21st centuries

Topic 4.1

Learners must understand how the following achievements from the 19th, 20th and 21st centuries have contributed to social and economic development:

- steam engine and railways
- development of steelmaking
- electrical power and the light bulb
- the internal combustion engine
- replaceable parts and mass production
- television and radio
- automated machines and robotics
- computer and internet
- nanotechnology

Learning outcome:

5. Produce 2D CAD drawings

Topics

5.1 Computer Aided Design

5.2 Produce 2D CAD drawings

Topic 5.1

Learners must know the advantages of using CAD software compared to manual drawing methods:

- speed of drawing creation, checking and editing,
- ease of creating modified revisions,
- accuracy of finished drawing,
- ability to save drawing electronically
- ability to share drawings by email
- compatibility with CAM systems

Learners must be aware of the range of computer drawing software packages available and the hardware required to run them. They do not need an in-depth working knowledge of each system, but they do need to know that there is a range of options available, and that these vary significantly in complexity and cost. These could include, but not be limited to:

- 2D Design
- Corel Draw
- Autodesk Inventor
- Solidworks
- Creo
- Spaceframe
- SketchUp
- CAD freeware.

Topic 5.2

Learners must be able to produce drawings using 2D CAD software. Whilst there is no prescribed software, learners are expected to use, manipulate and produce drawings using a range of tools:

- drawing (page) set up
- line types, styles and colour
- insert shapes (circle, arc, polygon, rectangle, ellipse)
- insert and edit text (position, font style, font height, rotation)
- grid spacing and snap to grid
- editing tools (zoom in/zoom out, pan, erase, copy, mirror, offset, move)
- dimensioning (linear, angular, diameters, radii, leader, tolerances)
- annotation
- hatching simple enclosed areas

Learning outcome:

6. Produce 3D CAD drawings

Topics

6.1 Produce 3D CAD drawings

6.2 Produce hard copies of CAD drawings

Topic 6.1

Learners must be able to produce accurate 3D models using 3D CAD software.

Whilst there is no prescribed software, learners are expected to use, manipulate and produce solid models using a range of tools:

- draw lines, polylines and 2D shapes
- extrude
- revolve
- 3D primitive shapes (box, cuboid, sphere, cylinder, cone, torus)
- Creation of irregular/asymmetric shapes
- rendering using a range of materials
- assembly of products from components (align, mate).

Topic 6.2

Learners must also be able to convert models to orthographic (working) drawings conforming to British Standard 8888, including any relevant dimensions.

Learners must be able to print/plot the output from a 3D CAD package:

- device selection
- setting paper size (A4, A3, etc.), orientation and source
- configuration of printer/plotter settings.

Learners must also be able to output files to a 3D printer.

Guidance for delivery

It is important that the learners have a full understanding of the underpinning knowledge of each of the topics. Very important is the practical application of this knowledge and understanding in the working environment. Learners must be able to apply their knowledge and understanding when working on a range of engineering activities, different types of equipment and working environments. Although content will be delivered in a classroom environment, it is important that learners can relate this knowledge and understanding to actual workshop situations and practical tasks.

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UAN:	T/506/5480
Level:	3
GLH:	60

What is this unit about?

Mathematics is key to understanding most engineering principles, and it is a vital tool in engineering in areas such as design, research and development, performance monitoring and cost analysis. The way this unit is written, you will learn each of the four main subjects with engineering applications in mind - hence the title '*Engineering Mathematics and Statistics*'. This will give you a definite purpose to your learning, which you will find much more interesting. The result will be that you will be equipped with the correct mathematical and technical communication skills to begin an undergraduate course at university or college without having to catch up during the first year.

Learning outcomes

In this unit, learners will be able to

1. Apply principles of algebra
2. Apply principles of trigonometry
3. Apply principles of calculus
4. Apply principles of complex numbers
5. Apply statistical methods

Scope of content

This section gives details of content to be covered in the teaching of the unit to ensure that all learning outcomes can be achieved.

Learning outcome:

1. Apply principles of algebra

Topics

- 1.1 Algebraic functions
- 1.2 Indices
- 1.3 Exponentials and logarithms
- 1.4 Equations, functions and formulae
- 1.5 Practical engineering problems

Topic 1.1

Learners must be able to solve engineering problems involving algebraic functions:

- definition, description and presentation
- equalities and inequalities of functions

Topic 1.2

Learners must be able to solve engineering problems involving indices:

- laws of indices
- numerical indices
- orders of magnitude.

Topic 1.3

Learners must be able to solve engineering problems involving exponentials and logarithms:

- definition and purpose
- $y=ax$ and its graph
- laws of logarithms
- e^x and its graph
- $\ln x$ and its graph
- $\ln x$ as an inverse function of e^x
- use of logarithms in calculations.

Topic 1.4

Learners must be able to solve engineering problems involving equations, functions and formulae:

- equations:
 - linear
 - quadratic - roots and coefficients
 - polynomial - roots
 - simultaneous
- manipulation of algebraic equations and formulae including but not limited to:
 - expansion of brackets
 - collection of like terms
 - simple division
 - Remainder Theorem
 - Factor Theorem
- graphical interpretation of algebraic functions including but not limited to:

- linear - equation of a straight line, parallel and perpendicular lines
- quadratic
- cubic
- intersection points as solutions
- co-ordinate geometry of a circle.

Topic 1.5

Learners must be able to select and use appropriate algebraic methods to solve relevant practical engineering problems.

Learning outcome:

2. Apply principles of trigonometry

Topics

- 2.1 Trigonometric functions
- 2.2 Trigonometric identities and formulae
- 2.3 Graphs of trigonometric functions
- 2.4 Use of trigonometry to solve engineering problems

Topic 2.1

Learners must know and be able to use the relationships between the sine, cosine, tangent, secant, cosecant and cotangent of an angle.

Topic 2.2

Learners must be able to solve engineering problems involving trigonometric identities and formulae:

- compound and double angle formulae for sine and cosine
- area of a triangle using $\frac{1}{2}ab\sin C$
- degree and radian measure
- arc length and area of a sector using $l = r\theta$ and $A = \frac{1}{2}r^2\theta$

Topic 2.3

Learners must be able to solve engineering problems involving graphs of trigonometric functions:

- plotting and recognition of trigonometric functions
- frequency, phase, amplitude and period of a sine/cosine function.

Topic 2.4

Learners must be able to select and use appropriate principles of trigonometry to solve relevant practical engineering problems.

Learning outcome:

3. Apply principles of calculus

Topics

- 3.1 Principles of differentiation
- 3.2 Principles of integration
- 3.3 Application of calculus to simple engineering problems

Topic 3.1

Learners must be able to solve engineering problems involving differentiation:

- rate of change of a function
- derivative of $f(x)$ using the notation $f'(x)$ or $\frac{dy}{dx}$
- gradient and derivative of simple functions:
 - algebraic
 - exponential
 - logarithmic
- simple rules of differentiation:
 - product and quotient rules
 - chain rule
- first and second order derivatives
- applications of differentiation to:
 - gradients
 - maxima and minima
 - stationary points.

Topic 3.2

Learners must be able to solve engineering problems involving integration:

- integration as the reverse of differentiation
- indefinite and definite integrals
- rules for integration by parts, substitution and partial fractions.

Topic 3.3

Learners must be able to select and use appropriate principles of trigonometry to solve relevant practical engineering problems:

- maximum and minimum values of a function
- application of integration to
 - areas
 - volumes of revolution
 - centres of mass
 - mean and root mean square (rms) values of a function.

Learning outcome:

4. Apply principles of complex numbers

Topics

- 4.1 Complex numbers
- 4.2 Mathematical operations using complex numbers
- 4.3 Graphical representation of complex numbers
- 4.4 Cartesian and polar forms
- 4.5 Application of complex numbers to simple engineering problems

Topic 4.1

Learners must understand complex numbers:

- definition of a complex number
- real and imaginary parts
- powers of j .

Topic 4.2

Learners must be able to carry out mathematical operations using complex numbers:

- addition and subtraction of complex numbers in algebraic form
- multiplication of complex numbers in algebraic form
- conjugation of complex numbers
- division of complex numbers in algebraic form.

Topic 4.3

Learners must be able to graphically represent complex numbers:

- Argand diagram
- Phasor diagram and j operator ($j = \sqrt{-1}$)
- addition and subtraction of phasors in complex form.

Topic 4.4

Learners must be able to solve engineering problems involving Cartesian and polar coordinates:

- definitions and properties of Cartesian and polar coordinates
- conversion between Cartesian and polar
- the polar form of a complex number
- multiplication and division of numbers in polar form
- practical uses

Topic 4.5

Learners must be able to select and use appropriate principles of complex numbers to solve relevant practical engineering problems in electricity and electronics. They must also be able to use and convert between Cartesian and polar coordinates in the context of determining machine tool paths.

Learning outcome:

5. Apply principles of statistics

Topics

- 5.1 Numerical measures
- 5.2 Probability
- 5.3 Normal distribution
- 5.4 Concepts of binomial distribution
- 5.5 Estimation
- 5.6 Graphs and diagrams
- 5.7 Failure rates and safety factors

Topic 5.1

Learners must be able to solve engineering problems involving numerical measures:

- standard deviation and variance
- linear scaling
- choosing linear measures:
 - mean
 - median
 - mode
 - range
 - interquartile range.

Topic 5.2

Learners must be able to solve engineering problems involving probabilities:

- events
 - random
 - mutually exclusive
 - independent
 - dependent
- addition law
- mutually exclusive events
- multiplication law
- conditional probability.

Topic 5.3

Learners must be able to solve engineering problems involving normal distribution:

- properties
- calculating probabilities
- mean, variance and standard deviation.

Topic 5.4

Learners must be able to solve engineering problems involving binomial distribution:

- discrete random variables
- conditions for application of a binomial distribution
- use of formula to calculate distribution (including notation)
- using tables
- mean, variance and standard deviation.

Topic 5.5

Learners must be able to solve engineering problems involving estimation:

- define 'parameters' and 'samples'
- the mean of a large sample
- variance.

Topic 5.6

Learners must be able to solve problems in an engineering quality control context involving graphs and diagrams:

- bar chart
- line graph
- bell curve
- the 'seven tools of quality':
 - fishbone (cause and effect diagram)
 - check sheet
 - control chart
 - histogram
 - Pareto chart
 - scatter plot
 - flow chart (run chart).

Topic 5.7

Learners must be able to solve engineering problems involving failure rates and safety factors:

- simple estimation of failure rates and safe operational life for engineering components and systems

- calculation of safety factors for engineering components and systems.

Guidance for delivery

It is important that the learners have a full understanding of the underpinning knowledge of each of the topics. Very important is the practical application of this knowledge and understanding in the working environment. Learners must be able to apply their knowledge and understanding when working on a range of engineering activities, different types of equipment and working environments. Although content will be delivered in a classroom environment, it is important that learners can relate this knowledge and understanding to actual workshop situations and practical tasks.

Tutors delivering this unit have opportunities to use a wide range of techniques. Lectures, discussions, seminar presentations, site visits, videos/DVDs, research using the internet or library resources and use of tutors with relevant and appropriate industrial experience are all suitable. Visiting expert speakers could add to the relevance of the subject for learners. The learning outcomes are sequential. Group activities are permissible, but tutors will need to ensure that individual learners have equal experiential and assessment opportunities

The topics contained within this unit are identified as being key preparation for a first year undergraduate course in engineering. The emphasis should be on learning mathematical techniques in order to solve engineering problems, not just for the sake of the mathematics itself. At the end of the unit learners should be confident not only in the process of each technique, but also in choosing the most appropriate technique to use in solving a particular problem.

Other mathematics topics are embedded in relevant units, however this unit should also be taught with the other units in mind. This unit should be used to support those subject-focused units as appropriate and examples of the content of those units should be used wherever possible.

The requirement for formal reports in the topics covering practical application is crucial to the development of relevant communication skills. Integrated work resulting in a small number of larger reports could be used as an alternative.

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UAN:	A/506/5481
Level:	3
GLH:	90

What is this unit about?

This unit will introduce you to many of the manufacturing techniques and materials in use today. It will give you the opportunity to build one or more items you have designed in previous units, particularly if you have elected to study that particular subject. There will be opportunities to get hands-on experience of building mechanical and electronic devices from scratch while you learn about the technologies and materials surrounding them. The unit provides some of the opportunities that everyone in engineering should have - the chance to learn and make mistakes safely.

Some of the questions you might want to answer while you are studying this unit are:

- How can I work safely in an engineering workshop?
- What legislation is there to help keep me safe?
- What tools and machines are used for particular jobs?
- How do I use hand and machine tools safely so that I produce good quality work?
- How do I tell if I have done a job correctly?
- How do I test what I have made?

Learning outcomes

In this unit, learners will be able to

1. Understand health and safety requirements in an engineering workshop
2. Know engineering cutting tools and machines
3. Mark out and cut engineering components.
4. Use electrical and electronic engineering tools
5. Assemble engineering components

Scope of content

This section gives details of content to be covered in the teaching of the unit to ensure that all learning outcomes can be achieved.

Learning outcome:

1. Understand health and safety requirements in an engineering workshop

Topics

Legislation applicable to the engineering industry

- 1.1 Purpose of current legislation within the engineering industry
- 1.2 Responsibilities of employers and employees
- 1.3 Methods of identifying hazards in the workplace
- 1.4 Safe behaviour in the workplace

Topic 1.1

Learners must know that there are several items of legislation applicable to the engineering industry:

- Health & Safety at Work etc. Act 1974
- Personal Protective Equipment at Work Regulations
- Control of Substances Hazardous to Health Regulations
- Reporting of Injuries, Diseases and Dangerous Occurrences Regulations
- The Control of Noise at Work Regulations
- Manual Handling Operations Regulations
- "Fire Safety Order" 2005.

They must understand how this legislation affects their own activities in the workplace. They must also know that the legislation *should* be satisfied by their company's safe systems of work and other procedures and they therefore do not need to know every detail of the law.

Learners must understand the purpose of legislation within the engineering industry:

- why there is a need for the legislation
- that there is legislation to cover every aspect of the workplace
- how the legislation keeps them safe in the workplace
- who is responsible for compliance with the regulations
- health and safety culture, training and information.

Topic 1.2

Learners must know the responsibilities that regulations place on employers and employees:

- Employers' responsibilities:
 - minimising risks in the handling, storage and transport of articles and substances
 - instruction, training and supervision to maintain high standards of health and safety at work
 - maintaining the workplace and its environment to be safe and minimising risk to health
 - to provide where appropriate a statement of general policy
 - with respect to health and safety and to provide if appropriate, arrangements for safety representatives and safety committees

- conduct his or her undertakings in such a way so as to ensure that members of the public (i.e. those not in his or her employment) are not affected or exposed to risks to their health or safety.
- Employees' responsibilities:
 - work safely so as not to cause injury to self and others in the vicinity
 - not to attempt any work task unless trained and authorised to do so
 - co-operate with the employer to enable the duties placed on the employer to be performed
 - have regard of any duty or requirement imposed upon the employer or any other person under any of the statutory provisions
 - not interfere with or misuse anything provided in the interests of health, safety or welfare in the pursuance of any of the relevant statutory provisions.

Topic 1.3

Learners must understand the importance of hazard identification and risk assessment in the workplace:

- methods of identifying hazards in the workplace.
- how risk assessments are used to minimise any risks that may be present.
- that risks can only be reduced 'so far as is reasonably practicable'.
- the meaning of 'so far as is reasonably practicable', and that it often means that they will have to wear PPE in addition to barriers, screens and other risk-minimising measures.
- Personal Protective Equipment (PPE) covers, but is not limited to, respirators, masks, safety footwear, high visibility clothing, gloves, protective headwear, hearing protection, barrier cream, protective clothing and sun protection.
- safe working practices
- fire prevention and control.

Topic 1.4

Learners must understand the importance of keeping themselves and others safe whilst working in an engineering workshop.

They must know the practical safety requirements for typical engineering environments:

- General workplace behaviour (moving around safely, asking for guidance, safe clothing)
- Safety signage and labeling
- Knowledge of emergency equipment and evacuation procedures
- Safe use of hand tools
- Safe use of machines (drills, guillotine, bending machine, lathe, mill etc.)
- Safe handling of materials
- Use of PPE (including when and when not to wear gloves, hearing, eye and skin protection).

Learning outcome:

2. Know engineering cutting tools and machines

Topics

- 2.1 Cutting principles
- 2.2 Cutting by shear tools and machinery
- 2.3 Chip cutting tools and machinery
- 2.4 Thermal cutting equipment

Topic 2.1

Learners must know how material are cut using three types of approach:

- cutting by shear
- chip cutting
- thermal cutting.

Topic 2.2

Learners must know the following shear cutting processes, their typical capabilities and be able to use them:

- manual tools
 - hand shears
 - bench shears
 - hand lever punches
- machinery
 - guillotines
 - punches.

Topic 2.3

Learners must know the following chip cutting processes, their typical capabilities and be able to use them:

- manual
 - hacksaws
 - chisels
 - threading with a tap and die (internal and external)
 - filing
- machinery
 - drilling machines
 - lathes
 - milling machines.

Topic 2.4

Learners must know the following thermal cutting processes, their typical capabilities and be able to use them:

- oxy-fuel cutting
- plasma cutting
- laser cutting.

Learning outcome:

3. Mark out and cut engineering components.

Topics

- 3.1 Marking out tools
- 3.2 Measuring tools
- 3.3 Marking out a range of profiles
- 3.4 Marking out a range of material forms
- 3.5 Cutting and shaping materials

Topic 3.1

Learners must know a range of marking out tools, when they are used and be able to use them:

- scribes
- engineering rule
- punch
- engineers try-squares
- dividers
- scribing blocks
- engineering protractors
- slip gauges
- marking out mediums.

Topic 3.2

Learners must know the common measuring tools, when they are used and be able to use them:

- Vernier gauges
- micrometers
- Go/No-Go gauges
- plug gauge.

Topic 3.3

Learners must be able to mark out a range of profiles accurately and within tolerance using appropriate tools:

- datum/centre lines
- square/rectangular profiles
- circles / radial profiles
- linear hole positions
- angles/angular profiles
- radial hole positions.

Topic 3.4

Learners must be able to mark out a range of material forms:

- square/rectangular (bar stock, sheet material, machined components)
 - circular/cylindrical (bar stock, tubes, turned components, flat disks)
 - sections (angles, channel, tee section, joists, extrusions)
 - irregular shapes (such as castings, forgings, odd shaped components).

Topic 3.5

Learners must be able to select appropriate tools and techniques to cut and shape materials. They must be able to produce complex shapes including curved profiles and angles other than 90°.

Learning outcome:

4. Use electrical and electronic engineering tools

Topics

- 4.1 Types of cable
- 4.2 Cable preparation and termination
- 4.3 Cable loom manufacture
- 4.4 Fixing components to circuit boards

Topic 4.1

Learners must know a range of common types of electrical cable and their typical uses

- mains flex
- armoured three-phase power supply cable
- co-axial (satellite/uhf)
- telephone cable.

Topic 4.2

Learners must know and be able to use the tools for cable preparation and termination:

- strippers (standard and precision)
- crimpers
- soldering iron.

When using these tools, they must be able to:

- ensure the correct lengths of exposed conductor
- avoid of nicks in conductor strands
- use different termination types (crimp, solder, ring tags, male/female plug inserts etc.)
- adjust the crimp tools
- carry out pre-use tool checks (test crimps, go-no-go gauges)
- inspect the joint (crimp and solder - visual and pull-off checks).

Topic 4.3

Learners must be able to make up and use a loom board:

- laying out wires and marking up
- making up the loom using devices such as:
 - lacing cord
 - cable ties
 - cable clips and clamps.

Topic 4.5

Learners must be able to use a suitable soldering iron, safety solder and flux, if necessary, to solder a variety of standard electronic components onto circuit board. They must be able to inspect each joint and identify standard soldering faults and their causes.

They should also know the basic processes involved in the following:

- automatic component placement
- automatic soldering of circuit boards
- automatic testing of circuit boards.

Learning outcome:

5. Assemble engineering products

Topics

- 5.1 Assemble engineering products
- 5.2 Test an assembled engineered product

Topic 5.1

Learners must be able to use the following methods and techniques to assemble mechanical components, selecting appropriate tools and equipment as needed:

- aligning
- bending
- fixing
- mechanical jointing
- pre-tensioning
- sealing
- sequential tightening
- threaded jointing and locking devices.

Topic 5.2

Learners must be able to select and safely use appropriate measuring and test equipment to compare an assembled product with its design specification.

Guidance for delivery

It is important that the learners have a full understanding of the underpinning knowledge of each of the topics. Very important is the practical application of this knowledge and understanding in the working environment. Learners must be able to apply their knowledge and understanding when working on a range of engineering activities, different types of equipment and working environments. Although content will be delivered in a classroom environment, it is important that learners can relate this knowledge and understanding to actual workshop situations and practical tasks.

Tutors delivering this unit have opportunities to use a wide range of techniques. Lectures, discussions, seminar presentations, site visits, videos/DVDs, research using the internet or library resources and use of tutors with relevant and appropriate industrial experience are all suitable. Visiting expert speakers could add to the relevance of the subject for learners. The learning outcomes are sequential. Group activities are permissible, but tutors will need to ensure that individual learners have equal experiential and assessment opportunities.

To achieve this unit learners will need to develop a broad understanding of the types of tools and equipment available in an engineering workshop. Selection of the appropriate equipment and technique to suit a particular situation is an important aspect of this unit. Working safely at all times and an understanding of the affect their actions can have on the safety of others is essential.

The unit is also concerned with the design process associated with an engineering product. From initial identification of need, through research, prototypes and review prior to entering production are all covered. On completion of the design phase consideration for the operating environment and manufacturing constraints are investigated.

Employer engagement

Employer engagement is essential in order to maximise the value of learners' experience. A partnership approach should be adopted where possible with employers with whom the consortium has links, and with employers used for work experience placements.

The use of scenario led contextualised tasks are essential in the delivery and assessment of this unit. Much of the work can be set in the context of case studies of local employers. Visits to companies/shows/exhibitions will enhance this particular part of the unit.

It would be helpful for teachers to develop a method of maintaining contact with a range of employers in the sectors may be able to help with keeping the examples of legislation, policies and codes of practice used in the taught content, up to date.

UAN:	F/506/5482
Level:	3
GLH:	30

What is this unit about?

The way that industry and the economy moves forward and grows is by research, development and innovation. During this unit you will have the opportunity to explore the way that new technologies, materials and products are developed and the pressures and constraints that can hinder or help that process. You will also look at low-carbon and digital technologies and how they can drive innovation and development.

Some of the questions you might want to answer during this unit are:

- How do new products and technologies actually get developed?
- Why do we need new products and technologies anyway?
- What are low-carbon technologies and why do we need them?
- What is cloud computing and how does industry make use of it?

Learning outcomes

In this unit, learners will be able to

1. Understand how innovation and new technologies impact on society and industry
2. Understand the need for research and development
3. Understand low-carbon technologies and their impact
4. Understand augmented and virtual reality
5. Understand the impact of digital technologies, cloud computing and the Internet

Scope of content

This section gives details of the scope of content to be covered in the teaching of the unit to ensure that all the learning outcomes can be achieved.

Learning outcome:

1. Understand how innovation and new technologies impact on society and industry

Topics

- 1.1 Benefits of innovation and new technologies
- 1.2 Enablers in the process of innovation
- 1.3 Environmental and social impacts

Topic 1.1

Learners must understand what is meant by innovation. They must also understand the reasons for innovation and new technologies and the benefits of innovation:

- the needs of the market, the economy and society
- market pull and technology push
- how innovation and new technologies contribute towards national and local economic growth
- how innovation and new technologies can contribute towards improved product performance.

Topic 1.2

Learners must understand that the process of innovation can be driven by certain enablers:

- new developments in materials and processes
- market and product research and assessment
- modernisation and competitive advantage
- entrepreneurs.

Topic 1.3

Learners must understand that the innovation can have a substantial impact on the environment and society:

- global demand increases and shifts
- use of fossil fuels and other natural resources
- development of energy and resource efficient technologies
- increased implementation of renewable energy
- efficient and reliable domestic appliances
- improvements in public and workplace safety
- healthier working environments.

Learning outcome:

2. Understand the need for research and development

Topics

2.1 The aim of research and development

2.2 Research and development process

Topic 2.1

Learners must understand the aims of research and development when developing an innovative product:

- making new processes, technologies and materials fit for purpose
- reducing product failure rates
- improving performance over existing products
- product testing in a user environment
- refining production processes.

Topic 2.2

Learners must be know the activities involved in the research and development of an innovative product and understand how these support innovation:

- development of new materials, manufacturing methods and technologies
- virtual modelling
- rapid prototyping (3D printing)
- prototype production
- in-house testing
- market testing
- production line setup
- quality assurance.

Learning outcome:

3. Understand low-carbon technologies and their impact

Topics

- 3.1 Low carbon technologies
- 3.2 Application of low carbon technologies
- 3.3 Stakeholder and public engagement

Topic 3.1

Learners must understand what is meant by low carbon technologies:

- climate change policy and drivers
- carbon capture
- renewable energies
- waste to energy.

Topic 3.2

Learners must understand the implications of low carbon technologies:

- landfill
- incineration
- gasification
- pyrolysis
- anaerobic digesters
- hydrogen applications.

Topic 3.3

Learners must understand the impact of stakeholders, including the public, on the implementation of innovative low carbon technologies:

- planning applications-engaging stakeholders
- site identification process and planning
- practical issues
- sustainable technologies
- advantages and disadvantages of technologies
- feedback clarity.

Learning outcome:

4. Understand augmented and virtual reality

Topics

- 4.1 Augmented and virtual reality
- 4.2 Applications of augmented and virtual reality

Topic 4.1

Learners must understand what is meant by augmented and virtual reality:

- introduction, history, and global view
- how augmented and virtual reality helps product innovation
- existing social and domestic applications for virtual reality
- infrastructure requirements:
 - networks
 - communications
 - protocols.

Topic 4.2

Learners must understand how the further development of augmented and virtual reality could lead to innovative products, and the potential implications of these innovations:

- product design
- sensing and automation
- augmented and virtual reality in industry
- domestic uses.

Learning outcome:

5. Understand the impact of digital technologies, cloud computing and the Internet

Topics

- 5.1 Digital technologies and their applications
- 5.2 Web services and cloud computing

Topic 5.1

Learners should understand the principles of digital technologies, the current applications of digital technologies and their impact on society.

Topic 5.2

Learners should understand how the internet has changed society. They should also understand that cloud computing is an innovation, its architecture, and its potential impact on society.

- cloud computing architecture:
 - infrastructure
 - platforms
 - software
 - benefits
- cloud platforms for storage and processing
- grid computing, cloud computing and the internet
- tools for cloud computing

- type of cloud computing (public, community, hybrid, private).

Guidance for delivery

It is important that the learners have a full understanding of the underpinning knowledge of each of the topics. Very important is the practical application of this knowledge and understanding in the working environment. Learners must be able to apply their knowledge and understanding when working on a range of engineering activities, different types of equipment and working environments. Although content will be delivered in a classroom environment, it is important that learners can relate this knowledge and understanding to actual workshop situations and practical tasks.

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UAN:	J/506/5483
Level:	3
GLH:	60

What is this unit about?

Project Management is a skill used to plan, co-ordinate and control the complex and diverse activities of modern industrial and commercial projects. All projects share one common characteristic - the projection of ideas and activities into deliverables.

Project management can involve the following activities: planning - deciding what is to be done; organising - making arrangements; staffing - selecting the right people for the job; directing - giving instructions; monitoring - checking on progress; controlling - taking action to remedy hold ups; innovation - coming up with new solutions; representing - liaising with users.

The purpose of project management is to foresee or predict as many dangers and problems as possible; and to plan, organise and control activities so that the project is completed as successfully as possible in spite of all the risks. The ever-present element of risk and uncertainty means that events and tasks leading to completion can never be foretold with absolute accuracy. For some complex or advanced projects, even the possibility of successful completion might be of serious doubt.

Learning outcomes

In this unit, learners will be able to

1. Understand why organisations use project management
2. Understand how to set up projects
3. Use management tools to maintain, control and monitor projects
4. Review projects at all stages

Scope of content

This section gives details of the scope of content to be covered in the teaching of the unit to ensure that all the learning outcomes can be achieved.

Learning outcome:

1. Understand why organisations use project management

Topics

- 1.1 Principles of project management
- 1.2 Benefits of project management to organisations and individuals

Topic 1.1

Learners must understand the principles of project management:

- business justification
- learning from experience
- defined roles and responsibilities
- manage by stages
- manage by exception
- focus on products
- objectives
- constraints
- lifecycle.

Topic 1.2

Learners must understand the benefits of project management to both individuals and organisation:

- possible benefits will include
- increased efficiency
- improved customer satisfaction
- organisations may be more effective in delivering services
- improvements in quality and output
- development opportunities within the project team
- increase in an organisation's competitive edge
- opportunities to expand services
- more flexibility
- improved risk assessment.

Learning outcome:

2. Understand how to set up projects

Topics

- 2.1 Considerations when reviewing project proposals
- 2.2 Setting clear goals for projects
- 2.3 Project resource requirements
- 2.4 How roles and responsibilities are allocated within project teams
- 2.5 Project communication needs
- 2.6 Possible risks to successful completion of projects

Topic 2.1

Learners must understand what needs to be considered when reviewing project proposals:

- Financial viability of the project
- Time
- Legal
- Resource
- Budget
- Constraints
- Dependencies
- confidentiality (eg restrictions in relation to the Data Protection Act, who has access to data and project documentation?).

Topic 2.2

Learners must be able to set clear goals for projects:

- identify stakeholders
- identify needs
- use SMART principles
- record goals in project plans.

Topic 2.3

Learners must understand different types of resources needed to complete projects and be able to identify resources for specific projects:

- project requirements against goals
- time constraints
- budget
- human resources
- training needs
- communication needs
- IT requirements.

Topic 2.4

Learners must understand the different roles and responsibilities that exist within projects and be able to allocate roles and responsibilities to team members:

- use of experts from different areas of the organisation
- use of key stakeholders
- identify training needs
- meeting schedules

- timing of reports.

Topic 2.5

Learners must understand the importance of communication in project management and the different types of communication that can be used:

- formal/informal communication
- identifying who requires communication (eg stakeholders, management, team members)

Topic 2.6

Learners must understand risks associated with project management:

- safety issues
- optimistic time and cost estimates
- unexpected budget costs
- unclear roles and responsibilities
- stakeholder needs not sought
- changing requirements after the start of the project
- new requirements
- poor communication
- lack of commitment.

Learners must understand how to mitigate for risks:

- health and safety training
- regular project review meetings
- appropriate communication
- training and monitoring.

Learning outcome:

3. Use management tools to maintain, control and monitor projects

Topics

- 3.1 Management tools for monitoring and control of projects
- 3.2 Use of management tools for monitoring and controlling projects

Topic 3.1

Learners must understand the management tools used to monitor and control projects:

- progress reports
- budget monitoring reports
- GANTT charts
- Critical Path Analysis
- use of relevant and current project software packages.

Topic 3.2

Learners must be able to use management tools to monitor and control projects:

- updating task status
- re-scheduling uncompleted tasks
- updating project elements

Learning outcome:

4. Review projects at all stages

Topics

- 4.1 Reasons for reviewing projects after completion
- 4.2 Review projects against original proposals

Topic 4.1

Learners must understand why projects are reviewed on completion:

- improve future projects
- enables ability to learn from experience
- identify key resources for future projects
- ensures comparison against achievements to original objectives
- highlights any issues (eg health and safety, problems, training needs, shortages in terms of resources, increases in costs)
- allows for the ability to revise and update plans
- enables completion of an end of project report

Topics 4.2:

Learners must be able to review projects against original proposals.

Guidance for delivery

It is important that the learners have a full understanding of the underpinning knowledge of each of the topics. Very important is the practical application of this knowledge and understanding in the working environment. Learners must be able to apply their knowledge and understanding when working on a range of engineering activities, different types of equipment and working environments. Although content will be delivered in a classroom environment, it is important that learners can relate this knowledge and understanding to actual workshop situations and practical tasks.

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UAN:	L/506/5484
Level:	3
GLH:	60

What is this unit about?

We buy things, we use them, but how much do we know about how they are made? How do companies manage to produce things that (most of the time) do what they are supposed to do, last as long as they are supposed to, and still make a profit? This unit gives you the opportunity to study manufacturing processes and the quality assurance that surrounds them. You will learn how manufacturing lines are organised and managed, how costs are monitored and controlled, along with some of the quality assurance techniques that are commonly used. You will need to remember the statistics you will have learned in unit 306 - Engineering Mathematics and Statistics.

You will be required to research and report upon the different techniques and technologies, and you should take the opportunity to develop your technical report writing technique. Some of the questions you might want to answer during this unit are:

- What methods are used to produce some commonly used items?
- How is a complex manufacturing process planned and managed?
- How are manufacturing costs controlled?
- What quality control measures are applied to manufacturing processes?

Learning outcomes

In this unit, learners will be able to

1. Know manufacturing sectors and methods
2. Understand production planning techniques
3. Understand the management of manufacturing
4. Understand costs associated with manufacturing
5. Understand manufacturing quality assurance methods

Scope of content

This section gives details of the scope of content to be covered in the teaching of the unit to ensure that all the learning outcomes can be achieved.

Learning outcome:

1. Know manufacturing sectors and methods

Topics

- 1.1 Manufacturing sectors
- 1.2 Sustainability and energy efficiency

Topic 1.1

Learners must know the range of manufacturing sectors:

- automotive
 - materials technology
 - manufacturing methods
- aerospace
 - composites
 - manufacturing methods
- electronics
 - component manufacture
 - circuit board manufacture
- marine
 - materials technology
 - manufacturing methods.

Topic 1.2

Learners must know approaches to sustainability and efficiency:

- fuel efficiency
- recycling of manufacturing waste
- waste disposal - neutralisation of toxins,
- hybrid technology

Learning outcome:

2. Understand production planning techniques

Topics

- 2.1 Manufacturing processes
- 2.2 Facilities layout

Topic 2.1

The learner will be able to identify a range of planning methods to optimize production and ensure efficiency during the manufacturing process.

- job (bespoke, one-off etc.)
- batch production
- assembly lines
- continuous production.

Topic 2.2

Learners must understand the different types of facility layouts:

- product layouts
- process layouts
- fixed position layout
- cellular layout
- combination layouts.

Learning outcome:

3. Understand the management of manufacturing and production

Topics

3.1 Production planning

3.2 Production monitoring

Manufacturing of any product requires managing. This ensures delivery deadlines are met and the efficient use of materials and workforce. Unless production is monitored costs can escalate and products become financially unviable. The learner will investigate a range of methods used to monitor the production process.

Topic 3.1

Learners must understand what is involved production planning:

- equipment requirements
- personnel requirements
- scheduling
- materials requirements planning (MRP)
- capacity planning
- stock control
- Just in Time (JIT).

Topic 3.2

Learners must understand what is involved in production monitoring:

- Critical path analysis (CPA)
- Performance Evaluation and Review Techniques (PERT)
- contingency plans
- flow charts
- Gantt charts.

Learning outcome:

4. Understand costs associated with production and manufacturing

Topics

4.1 Estimating and budgeting

4.2 Data analysis and monitoring

Topic 4.1

The learner should understand the requirement to monitor all costs associated with the manufacturing process:

direct costs

- materials
- labour
- overheads

indirect costs

- management functions
- depreciation
- training
- benefit / cost ratio
- pareto analysis
- profit and loss.

Topic 4.2

Learners should understand methods used to monitor and analyse financial data:

- Data collection methods
- Review of manufacturing procedures
- Production reports
- Use of bar and pie charts.

Learning outcome:

5. Understand manufacturing quality assurance methods

Topics

5.1 Quality standards

5.2 Quality procedures

Topic 5.1

The need for a quality system should be considered to ensure customer expectations are met. The use of quality standards and inspection methods when applied to the range of sectors identified in learning outcome 1 should be considered.

- What does 'Quality' mean In a manufacturing context?
- ISO 9000 – Quality management
- Quality documentation

Topic 5.2

Learners must understand procedures used for quality assurance in manufacturing:

- inspection and quality control
- inspection stages
- equipment calibration
- quality deviation procedures
- acceptance/rejection criteria
- remedial action decisions and responsibilities.

Guidance for delivery

It is important that the learners have a full understanding of the underpinning knowledge of each of the topics. Very important is the practical application of this knowledge and understanding in the working environment. Learners must be able to apply their knowledge and understanding when working on a range of engineering activities, different types of equipment and working environments. Although content will be delivered in a classroom environment, it is important that learners can relate this knowledge and understanding to actual workshop situations and practical tasks.

Tutors delivering this unit have opportunities to use a wide range of techniques. Lectures, discussions, seminar presentations, site visits, videos/DVDs, research using the internet or library resources and use of tutors with relevant and appropriate industrial experience are all suitable. Visiting expert speakers could add to the relevance of the subject for learners. The learning outcomes are sequential. Group activities are permissible, but tutors will need to ensure that individual learners have equal experiential and assessment opportunities.

Learning outcome 1 will provide a broad understanding of a range of modern manufacturing sectors. LO 2-5 should be applied to the identified sectors wherever possible to ensure a depth of understanding of the approaches manufacturing companies must adopt to be competitive in a global market place.

A practical approach to applying the understanding developed could be adopted by the inclusion of a scenario to establish a company and applying all the principles from LO 2-5 for the introduction of a product.

Employer engagement

Employer engagement is essential in order to maximise the value of learners' experience. A partnership approach should be adopted where possible with employers with whom the consortium has links, and with employers used for work experience placements.

The use of scenario led contextualised tasks are essential in the delivery and assessment of this unit. Much of the work can be set in the context of case studies of local employers. Visits to companies/shows/exhibitions will enhance this particular part of the unit.

It would be helpful for teachers to develop a method of maintaining contact with a range of employers in the sectors may be able to help with keeping the examples of legislation, policies and codes of practice used in the taught content, up to date.

UAN:	R/506/5485
Level:	3
GLH:	60

What is this unit about?

Robotics is an exciting and quite challenging technology. It combines mechanical and electronic disciplines in a unique way to produce technology that is now at the very centre of manufacturing. You will be able to build up your knowledge of the design and programming of robotic systems and then use your other engineering skills to build and test robotic and control systems. You will learn how to analyse a particular control requirement and then to select the mechanical and software components to satisfy that requirement.

Some of the questions you might want to answer during this unit are:

- How do robots move as they do; what kind of joints do they have?
- How are robot movements made so precise?
- What actually creates the movement?
- Are robots dangerous and do we really need them at all?

Learning outcomes

In this unit, learners will be able to

1. Understand the architecture and uses of computer automated and robotic systems
2. Understand control system operations
3. Understand robotic control and drive systems
4. Apply robotic control programming
5. Use a PLC and a PC (SCADA) to control a simple system

Scope of content

This section gives details of the scope of content to be covered in the teaching of the unit to ensure that all the learning outcomes can be achieved.

Learning outcome:

1. Understand the architecture and uses of computer automated and robotic systems

Topics

- 1.1 Designing automation systems
- 1.2 Physical construction
- 1.3 Implementing robotic systems
- 1.4 Benefits and implications

Topic 1.1

Learners must understand the designs of automation systems:

- systems architecture
 - process
 - inputs & outputs
 - energy source
 - measurement system
 - controller
 - feedback loops
- naming variables in automation systems
 - controlled variable
 - manipulated variable
 - measurement variable
 - disturbance variable
 - error
 - set-point controller output
- mathematical modelling of system components
 - significance
 - uses
 - concept of transfer functions.

Topic 1.2

Learners must understand the construction of a robotic system:

- physical construction of a robotic system
 - jointed manipulator
 - end effector
 - controller
 - programming unit
- movements and joints in robotic systems
 - arm sweep, shoulder swivel, elbow extension, X plane (width movement), Y plane (height movement), Z plane (depth movement), roll, pitch, yaw, prismatic, revolute, symbols for prismatic and revolute joints, six degrees of freedom
- wrist design features
 - three revolute degrees of freedom, accuracy of end effector manipulation
- robotic arms
 - Cartesian, cylindrical
 - polar, jointed arm

- SCARA (Selective Compliance Assembly Robot Arm)
- partial spherical (pendulum)
- multiple joint (spline)
- choosing end effectors
 - vacuum
 - stepper motor driven
 - specialist design.

Topic 1.3

Learners must understand how to implement robotic systems:

- robot classification
 - programmable manipulator
 - pick and place
 - loading and unloading
 - production

- characteristic responses for simple control and robotic systems
 - input/output
 - effect of variables

- design and implementation of a robotic system
 - planning
 - personnel involved
 - application
 - feasibility review
 - development
 - task
 - part presentation
 - handling equipment
 - process machines
 - quality control process
 - mock-up & testing
 - commissioning
 - de-bugging
 - trial runs
 - quality control checks
 - installation
 - pilot production runs
 - parallel running with manual cells
 - final implementation

- explain the physical layouts for robotic systems
 - radial layout
 - in-line track mounted
 - in-line fixed

- robot/automation safety considerations
 - hazards in the vicinity of a robotic system
 - categories B, 1, 2, 3 and 4 systems
 - operator training
 - operator competence
 - emergencies.

Topic 1.4

Learners must understand the benefits and implications of automated systems:

- benefits:
 - increased productivity
 - improved quality
 - increased efficiency
 - improved safety
 - convenience
 - power assistance
 - repeatability
 - accuracy
 - speed
 - use in hazardous areas
- implications:
 - effect on jobs
 - costs:
 - capital
 - variable
 - maintenance
 - upgrade
 - available space
 - loss of production due to failures
 - costs
 - safety.

Learning outcome:

2. Understand control system operations

Topics

- 2.1 Difference between control system types
- 2.2 Classification of control systems
- 2.3 Operation of digital and analogue motion control systems
- 2.4 Functions in a motion control system

Topic 2.1

Learners must understand the differences between types of control systems:

- regulatory/following
- numerical/ servo/sequential.

Topic 2.2

Learners must understand the classifications of controls systems:

- set-point changes
 - infrequent change – regulatory system
 - frequently changed – following system
- processing
 - process control
- continuous system
- batch system
- part manufacturing

- machine control
 - numerical control systems
 - robotic control systems
- category of controller or control
 - programmable logic controller (plc)
 - pc (scada)
 - event sequenced control
 - time sequenced control.

Topic 2.3

Learners must understand the operation of different types of motion control systems:

- digital motion control system:
 - set-point, gain
 - output signal
 - feedback devices
 - actuator types
 - error codes
- analogue motion control system:
 - voltage rectification
 - d.c. bus
 - chopping circuit
 - output section.

Topic 2.4

Learners must understand functions in a motion control system:

- Functions:
 - frequency/speed
 - speed/torque
 - switching frequency/noise.

Learning outcome:

3. Understand robotic control and drive systems

Topics

- 3.1 Power for robotic systems
- 3.2 Configuration and operation
- 3.3 Transmission systems
- 3.4 Using robotic actuators

Topic 3.1

Learners must understand power systems used in robotics:

- hydraulic
 - production of compressed hydraulic power
 - how it is used
 - limitations
 - safety considerations
- pneumatic

- production of pneumatic power
- how it is used
- limitations
- safety considerations
- electrical
 - type of electrical supply (voltage, frequency, source)
 - how it is used
 - limitations
 - safety considerations.

Topic 3.2

Learners must understand the configuration and operation of robotic systems:

- robotic control systems:
 - control element
 - actuator
 - transmission element
 - load
 - sensor
 - feedback
 - comparator
- robotic drive systems:
 - pneumatic cylinder
 - single acting
 - double acting
 - hydraulic cylinder
 - double acting
 - rotary actuator
 - pneumatic
 - hydraulic
 - electro-mechanical solenoid
 - spool valve
 - stepper motor

Topic 3.3

Learners must understand the transmission systems used in robotics:

- gears:
 - spur
 - helical
 - straight bevel
 - spiral bevel
 - worm
 - rack and pinion
 - ball and roller screws
 - pulley drives and tendons
 - linkages
 - bearings

Topic 3.4

Learners should be given the time and facilities to experiment with different types of actuator in a particular control system. They should also be able to choose and justify appropriate actuators for specific applications and present the results in the form of a technical report.

- pneumatic
- hydraulic
- electric
- reasons for choice.

Note: For reasons of availability it may not be possible to access all three types of actuator, so learners should have access to at least **one** actuator type, preferably two, however reports should include the results of personal research on the application, operation and performance of all three types of actuator.

Learning outcome:

4. Applying robotic control programming

Topics

- 4.1 Programming tools for robotic systems
- 4.2 Online and offline programming
- 4.3 Designing robot program using flow charts and block diagram
- 4.4 Using kinematic and isometric diagrams to display robot system information
- 4.5 The relationship and interaction between control systems
- 4.6 Performance specifications for robots
- 4.7 Safety implications of combined discipline systems

Learners should become familiar with the process of designing programs to achieve control of robotic systems for specific tasks. The aim should be to become confident in the use of the tools and procedures, rather than to achieve very complex control packages. Learners must be made fully aware that an industrial robotic device is potentially very dangerous and liable to sudden movement

Topic 4.1

Learners must be able to use programming tools:

- control pendants
- software
- simulation.

Topic 4.2

Learners must be able to use online and offline programming:

- on-line programming:
 - axis limit control
 - point to point, contouring
 - line tracking
- off-line programming:
 - Safety
 - 3D visualisation of a robot arm
 - need for computing ability
 - specialist programming language
 - absolute and incremental co-ordinates
 - trouble shooting
 - planning
 - communication between CAD and CAM systems (Computer Aided Drawing/Computer Aided Manufacture).

Topic 4.3

Learners must be able to design robot programs using flow charts and block diagrams:

- Flow charts:
 - symbols
 - labelling
 - inputs

- Block diagrams:
 - layout
 - process
 - sequence.
 - safety implications of combined discipline systems

Topic 4.4

Learners must understand the use of kinematic and isometric diagrams to display robot system information.

Topic 4.5

Learners must understand the relationship and interaction between control systems:

- robot
- motion

Topic 4.6

Learners must understand performance specifications for robots:

- payload
- normal and maximum
- static and rated
- static and dynamic
- repeatability
- speed
- limit on certain motion, weight restrictions

Topic 4.7

Learners must understand the safety implications of combined discipline systems:

- verification of inputs
- collision detection
- working envelope

Learning outcome:

5. Use a PLC and a PC (SCADA) to control a simple system

Topics

- 5.1 PLC architecture
- 5.2 PLC programming languages and methods
- 5.3 Interface modules
- 5.4 Program a PLC controlled system
- 5.5 PC based (SCADA) systems
- 5.6 Software data linking standards
- 5.7 Methods used to link real I/O to PC based applications via database objects
- 5.8 HMI systems
- 5.9 Configure control interfaces

Topic 5.1

Learners must understand PLC architecture:

- control unit
- programming device
- input / output modules
- memory.

Topic 5.2

Learners must understand and be able to use PLC programming languages and methods:

- industrial standard languages
- IEC 61131-3
- statement list
- structured text
- function block
- sequential function chart
- basic instructions in ladder logic
- examine in open / closed
- output, latched output
- bit / flag instructions
- timers
- counters
- move and logic
- arithmetic and compare

Programming device communications configuration methods:

- upload programmes from a plc
- modify programmes both online and offline
- test programmes and re-evaluate operation
- use software and hardware to troubleshoot problems in a plc based control system
- document and save programmes.

Topic 5.3

Learners must understand the characteristics and methods of configuring different types of interface module:

- digital I/O
- analogue
- remote I/O
- RFID (Radio Frequency Identification) scanning systems
- bar code readers
- camera vision systems.

Topic 5.4

Learners must be able to perform simple operations on a PLC controlled system e.g programme a robot arm to carry out a simple task:

- programming using ladder logic
- communications configuration
- PLC programme download/upload tests

- PLC programme modification
- interface module configuration.

Topic 5.5

Learners must understand the main elements, features and functions of PC based (SCADA) systems:

- linked animated graphics
- PC control of system functions
- display and logging of system errors
- need for archiving of process errors
- alarm functions of variable priority
- display of process trends in various graphical formats.

Topic 5.6

Learners must understand data linking standards used to exchange data between software applications:

- dynamic data exchange (DDE),
- object linking and embedding (OLE).

Topic 5.7

Learners must understand methods used to link real I/O to PC based applications via database objects:

- I/O PLC based
- HMI (human machine interface) based.

Topic 5.8

Learners must understand and be able to use of functions and features available with HMI systems:

- function key control
- touch screen controls
- communication links available with typical systems
- creation of graphical objects and configuring links to PLC and SCADA based systems.

Topic 5.9

Learners must understand the main features and functions of system interfaces:

- PC based operator
- HMI based.

Learners must be able to configure Control interfaces:

SCADA or HMI, graphical interface to include control / animation / alarming / archiving / trends, data exchange link between software applications.

Guidance for delivery

It is important that the learners have a full understanding of the underpinning knowledge of each of the topics. Very important is the practical application of this knowledge and understanding in the working environment. Learners must be able to apply their knowledge and understanding when working on a range of engineering activities, different types of equipment and working environments. Although content will be delivered in a classroom environment, it is important that learners can relate this knowledge and understanding to actual workshop situations and practical tasks.

Tutors delivering this unit have opportunities to use a wide range of techniques. Lectures, discussions, seminar presentations, site visits, videos/DVDs, research using the internet or library resources and use of tutors with relevant and appropriate industrial experience are all suitable. Visiting expert speakers could add to the relevance of the subject for learners. The learning outcomes are sequential. Group activities are permissible, but tutors will need to ensure that individual learners have equal experiential and assessment opportunities.

Although it is likely that the learner will be using training equipment, the same principles should be applied as for a full sized industrial device. Where a particular function is not available the learner should research that function and produce a report on it. It would be useful for the tutor to produce a matrix showing which items can be learned and reinforced practically and which will have to be researched and reported on.

Employer engagement

Employer engagement is essential in order to maximise the value of learners' experience. A partnership approach should be adopted where possible with employers with whom the consortium has links, and with employers used for work experience placements.

The use of scenario led contextualised tasks are essential in the delivery and assessment of this unit. Much of the work can be set in the context of case studies of local employers. Visits to companies/shows/exhibitions will enhance this particular part of the unit.

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UAN:	H/506/5491
Level:	3
GLH:	60

What is this unit about?

Civil engineering is the second-oldest engineering discipline after military engineering, it can be thought of in many contexts and is recognised as professional engineering. You will deal with the design, construction and maintenance of the physical and naturally built environment, including looking at marine, tunnelling, structures, substructures etc.; all that is needed to be able to complete a modern civil engineering project. Civil engineering takes place in the public sector from municipal through to national governments, in the private sector from individual homeowners through to international companies. We all at some point in our lives, undertake some form of civil engineering.

Learning outcomes

In this unit, learners will be able to

1. Know the disciplines associated with civil engineering
2. Understand the design principles and application of civil engineering
3. Understand geology and soil mechanics
4. Know civil engineering construction methods
5. Understand site surveying procedures

Scope of content

This section gives details of the scope of content to be covered in the teaching of the unit to ensure that all the learning outcomes can be achieved.

Learning outcome:

1. Know the disciplines associated with civil engineering

Topics

1.1 Civil Engineering

1.2 Disciplines

Topic 1.1

Learners must know that in addition to design, construction and maintenance, civil engineering involves the following activities or requirements:

- registration and regulation
- permits
- education and licences
- professional recognition as an engineer
- authorized practices
- professional services
- regulations
- technical documentation
- civil engineering associations.

Topic 1.2

Learners must know that the term civil engineering covers a range of disciplines:

- Architectural engineering
- Construction engineering
- Geotechnical engineering
- Environmental engineering
- Geophysics engineering
- Geodesy
- Structural engineering
- Offshore engineering
- Quantity surveying
- Coastal engineering
- Water resources engineering
- Materials engineering
- Municipal or urban engineering
- Forensic engineering
- Atmospheric sciences
- Control engineering
- Transportation engineering
- Earth science
- Earthquake engineering.

Learning outcome:

2. Understand the design principles and application of civil engineering

Topics

- 2.1 Planning and design considerations
- 2.2 Environmental considerations, energy efficiency and service requirements
- 2.3 Roles, responsibilities and obligations
- 2.4 How technology affects design

Topic 2.1

Learners must know the main considerations when planning and designing a civil engineering project:

- general considerations:
 - client's brief
 - aesthetics of the project and the process
 - influence of shape, size and proportion, position, location and structural considerations of a building or an engineering project
- land issues: the effects of green/brown and reclaimed land on a project
- health, safety and welfare:
 - issues in design, maintenance and demolition
 - Construction Design and Management (CDM) regulations
- financial considerations:
 - financial planning including the cost of building
 - the cost of commissioning
 - costs in use
 - life cycle costing
 - cost modelling
- planning and control considerations:
 - legal restraints
 - town and country planning
 - building regulations
 - european legislation
- design considerations:
 - designing for planned use
 - designing for inclusivity and disability
 - designing for change of use
 - designing for versatility
 - relevant legislation.

Topic 2.2

Learners must understand how environmental considerations, energy efficiency and the services required affect the application of civil engineering:

- environmental considerations:
 - the selection of materials and the form(s) of construction
 - use of new and renewable resources
 - use of recycled materials where appropriate
- energy efficiency:

- production of materials
- processing of materials
- services within the building or project
- services required:
 - into and out of the building or project
 - disposal of waste materials from the construction process
 - disposal of waste materials from the use of the building or project
 - availability of services to a building or project

Topic 2.3

Learners must understand the roles and responsibilities of the construction team during the stages of planning and development:

- design
- surveying
- construction
- maintenance
- facilities management.

They must also understand the obligations, responsibilities and liabilities of each party to the process, including both corporate and personal responsibility for health, safety and welfare.

Topic 2.4

Learners must understand how technological advances affect construction:

- new construction processes and methods
- more powerful construction plant
- development of new materials
- Information and Communication Technology (ICT)
- development of new systems and services

Learning outcome:

3. Understand geology and soil mechanics

Topics

- 3.1 Common rock types
- 3.2 Rock materials and rock masses
- 3.3 Soil description and classification, basic soil properties
- 3.4 Primary design parameters for soils

Topic 3.1

Learners must understand that the engineering characteristics of geological materials have a significant impact on civil engineering activities. They should know the description and general classification of common rock types and their geographical/geological distribution:

- mode of formation of igneous, sedimentary and metamorphic rocks:
 - petrographic classification of igneous rocks
 - common stable and unstable minerals
 - the diverse nature of sedimentary rocks
 - grades of metamorphism
- use of rocks as a construction material:

- common usage of geological materials for construction
- the characteristics of the main rock and soil deposits which make them suitable/unsuitable for construction use

Topic 3.2

Learners must know the petrographic classification of rocks and understand the effects of the discontinuous nature of rock mass:

- petrographic and engineering description/classification of rocks to current Codes of Practice
- discontinuous nature of rock mass:
 - differences between rock mass and rock material in construction
 - type and nature of rock discontinuities
 - characteristics of discontinuities which influence the engineering performance of rock materials

Topic 3.3

Learners must know how soils are described and classified and the properties of soil.

- soil description and classification:
 - differences between description and classification
 - classification tests to current Codes of Practice
 - liquidity and consistency indices for fine grained soils
- fundamental soil properties:
 - particulate nature of soils
 - three phase and two phase states
 - soil density
 - moisture content
 - void ratio
 - degree of saturation
 - characteristics of fine grained soil responsible for the development of apparent cohesion.

They must also understand the principle of effective stress and how this affects civil engineering activities:

- controlling influence of effective stress on the strength and deformation of soil
- differences between drained and undrained behavior
- total stress
- pore water pressure and effective stress for simple soil sequence under hydrostatic conditions
- influence of seepage on effective stress.

Topic 3.4

Learners must understand the common tests for the determination of geotechnical design parameters for soils:

- common methods for the determination of strength
- compressibility and permeability to current Codes of Practice

- potential limitations associated with the methods.

They must also understand the role of the ground investigation elements in the measurement of geotechnical parameters::

- the common methods of in-situ testing
- current techniques for the acquisition of soil samples for laboratory testing
- the impact of sample quality on measured parameters.

Learning outcome:

4. Know civil engineering construction methods

Topics

- 4.1 Earthwork activities
- 4.2 Substructure
- 4.3 Superstructures
- 4.4 Tunnelling activities
- 4.5 Hydraulic structures
- 4.6 Marine works
- 4.7 Railway works

Topic 4.1

Learners must know the commonly utilised methods and processes for earthwork activities. They must be able to select appropriate methods and resources for practical applications:

- formation of cuttings and embankments
- ensuring the stability of slopes
- dealing with groundwater problems
- carrying out deep excavations and trenching works.

Topic 4.2

Learners must know the commonly utilised methods and processes for substructures. They must be able to select appropriate methods and resources for practical applications.

- associated piling works
- undertaking drainage works
- constructing culverts/underpasses.

Topic 4.3

Learners must know the commonly utilised forms of superstructures and how they are constructed:

- bridges
- commercial and industrial buildings and structures and leisure facilities.

Topic 4.4

Learners must know the commonly utilised methods and processes for tunnelling activities in both hard rock and soft ground. They must be able to select appropriate methods and resources for practical applications:

- methods of ground support
- cut and cover tunneling
- pipejacking
- mini-tunnelling
- the construction of shafts.

Topic 4.5

Learners must know the commonly utilised methods and processes to construct hydraulic structures. They must be able to select appropriate methods and resources for practical applications:

- constructed of earth rockfill and concrete
- ancillary works
- canal and river works.

Topic 4.6

Learners must know the commonly utilised methods and processes for marine works. They must be able to select appropriate methods and resources for practical applications:

- cofferdams
- caissons
- sea walls
- harbour works and coastal protection activities.

Topic 4.7

Learners must know the commonly utilised methods and processes for undertaking railway works, including the provision of new track and ancillary structures.

Learning outcome:

5. Understand site surveying procedures

Topics

- 5.1 Instruments
- 5.2 Surveying and setting out

Topic 5.1

Learners must know the instruments used for site surveying and what information they are used to obtain:

- linear measurement
 - steel bands
 - sonic measuring devices
 - Electromagnetic Distance Measuring (EDM) instruments
- levels
 - optical (automatic and tilting)
 - water level
 - general construction laser
 - pipe alignment laser
 - electronic/optical
- angular
 - optical and electronic theodolites
 - magnetic compasses and compass attachments to theodolites
 - Combined theodolites and EDMs (Total Station instruments)

- Vertical alignment instruments such as plumb bob, spirit level, optical plumb, laser alignment.

Topic 5.2

Learners must understand how modern surveying equipment is used in surveying procedures:

- linear measurement:
 - errors in using steel tapes
 - corrections for tension, sag, temperature, change of standard length
 - Semi-permanent adjustments to EDMs for temperature, pressure and the curvature of the earth
- levelling:
 - sources of errors in levelling and compensation methods adopted
 - reciprocal levelling
 - flying levels
 - location of Ordnance Bench Mark (OBM)
 - principle and practice of setting up a Temporary Bench Mark (TBM)
 - levelling large areas using grid and radial methods
 - application of tachometric methods
 - direct and indirect methods of contouring
- angular measurement:
 - sources of errors and methods for reducing errors
 - reduction of angular measurement
 - horizontal and vertical angles
 - computation of true horizontal length from slope distance and angle of inclination
- distinction between open, link and closed traverse:
 - use of traverse for area control
 - factors affecting choice of traverse stations
 - bearings (whole circle and quadrant)
 - distinction between grid, true and magnetic north
 - co-ordinate system
 - Ordnance Survey (OS) grid references
 - angular closing error and correction
 - Bowditch correction for misclosure errors
- setting out:
 - principles
 - control of spread of error by working from the whole to the point
 - procedure for co-ordinated setting out
 - appropriate accuracy
 - procedures and practices for setting out ground works, upper floors, road construction, drainage and sewerage works, embankments and cuttings

Guidance for delivery

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Tutors delivering this unit have opportunities to use a wide range of techniques. Lectures, discussions, seminar presentations, site visits, videos/DVDs, research using the internet or library resources and use of tutors with relevant and appropriate industrial experience are all suitable. Visiting expert speakers could add to the relevance of the subject for learners. The learning outcomes are sequential. Group activities are permissible, but tutors will need to ensure that individual learners have equal experiential and assessment opportunities.

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UAN:	Y/506/5486
Level:	3
GLH:	60

What is this unit about?

Aerospace is an exciting and at times quite challenging environment, from your general aviation light aircraft through to commercial jet liner taking passengers to their destinations, through to Military aircraft fighters protecting airspace with space travel as the ultimate transport. This unit combines the engineering principles in which these craft are constructed and maintained; how they stay in the air and manoeuvre and how they are operated safely around the world. You will be able to build up your knowledge on the basic principles and then use your other engineering skills to apply thinking to research and development. You will learn how to understand different operating parameters of various aircraft and then be able to decide the best method of maintaining the different aircraft in order for them to stay operational.

Some of the questions you might want to answer during this unit are:

- How aircraft from the simple design to the more complex are manufactured?
- How do they stay in the air and get to their destination?
- What powers these different aircraft?
- Is air travel, or even space travel the future?

Learning outcomes

In this unit, learners will be able to

1. Understand aircraft and their methods of construction
2. Understand the basic principles of aerodynamics and theory of flight
3. Understand different propulsion systems
4. Understand the operating parameters in which aircraft have to operate
5. Understand continued airworthiness including maintenance requirements
6. Understand research and development within the aerospace industry.

Scope of content

This section gives details of the scope of content to be covered in the teaching of the unit to ensure that all the learning outcomes can be achieved.

Learning outcome:

1. Understand aircraft and their methods of construction

Topics

- 1.1 Aircraft types
- 1.2 Aircraft construction
- 1.3 Aircraft materials

Topic 1.1

Learners must know a range of modern aircraft in current operation in both civilian and military sectors:

- fixed wing
- general aviation
- gliders, micro-lights, hot-air balloons, gyro copters
- rotary wing
- specific weight category classification of aircraft
- unmanned
- space.

Topic 1.2

Learners must know a range of aircraft construction methods:

- truss structure
- geodesic construction
- monocoque
- semi-monocoque
- wing integration
- moulded.

Topic 1.3

Learners must know a range of materials used in the manufacture of both civilian and military aircraft

- metal alloys
- carbon fibre
- fibre reinforced plastics.

They must understand the reasons for the use of these materials, as applicable:

- light weight
- high temperature stability
- corrosion resistance.

Learning outcome:

2. Understand the basic principles of aerodynamics and theory of flight

Topics

- 2.1 Earth's atmosphere
- 2.2 Nature of airflow around aerodynamic bodies
- 2.3 Characteristics of basic wing plan-forms
- 2.4 Basic aircraft control using primary control surfaces
- 2.5 Aircraft stability
- 2.6 Secondary aircraft control surfaces
- 2.7 Forces acting on an aircraft in flight

Topic 2.1

Learners must know the composition and main layers of the Earth's atmosphere. They must understand the effects of increased altitude on different types of aircraft, including the International Standard Atmosphere (ISA) in aviation.

Topic 2.2

The learner must understand the basic airflow around an aerodynamic body and the following terms:

- angle of attack
- lift and drag
- slow speed and high speed stall.

They must also understand how an increase or decrease in speed and altitude affects that body and the additional design requirements built into an aerodynamic body to assist the effects of an increase or decrease in speed and altitude.

Topic 2.3

Learners must understand the characteristics of basic wing plan-forms and how contamination from ice, snow or frost build up can affect a wing plan form.

Topic 2.4

Learners must understand the four main forces acting on an aircraft in flight and how basic aircraft control is achieved using the primary surfaces.

They must also understand the terms flight envelope and load factor.

Topic 2.5

Learners must understand what is meant by the aircraft axes and static and dynamic flight stability. They should also understand the measures that can be taken to enhance stability.

Topic 2.6

Learners must know the secondary aircraft control surfaces and how boundary layer control and high lift devices affect the movement of the aircraft.

Topic 2.7

Learners must understand the forces acting on an aircraft in flight and how these are affected by streamlining and high speed flight.

Learning outcome:

3. Understand different propulsion systems

Topics

- 3.1 Gas Turbine
- 3.2 Piston Engine
- 3.3 Rocket

Topic 3.1

Learners must know gas turbine propulsion systems:

- turbo shaft
- low / high bypass
- ram jet
- turbo prop
- axial.

Topic 3.2

Learners must know piston engine propulsion systems:

- radial / straight
- turbo injector
- naturally aspirated
- altitude.

Topic 3.3

Learners must know and be able to recognize rocket propulsion systems:

- solid fuel
- bi-propellant
- monopropellant
- resistojet.

Learning outcome:

4. Understand the operating parameters in which the aircraft have to operate

Topics

- 4.1 Atmosphere
- 4.2 Legal parameters
- 4.3 Structural
- 4.4 Public safety

Topic 4.1

Learners must know the atmospheric parameters in which the aircraft have to operate:

- temperature
- humidity
- altitude
- oxygen content.

Topic 4.2

Learners must know that there are international and local legislative requirements, plus company rules, which may place restrictions on the operation of aircraft.

Topic 4.3

Learners must know the meaning of the terms stress, strain, bend and twisting in the context of an aircraft structure. They must understand the operating parameters that apply to an aircraft structure:

- normal operating parameters
- extended operating parameters
- limitations
- life expectancy
- life cycles.

Topic 4.4

Learners must know the operating parameters in which aircraft have to operate for civilian safety, military safety and operator safety.

Learning outcome:

5. Understand continued airworthiness including maintenance requirements

Topics

- 5.1 Aviation authorities
- 5.2 Requirements of aircraft design, manufacture and repair
- 5.3 Flight testing
- 5.4 Continued airworthiness

Topic 5.1

Learners must understand what is meant by airworthiness. They must know that there are several aviation authorities (ICAO, EASA, CAA, MAA, FAA, NASA, European Space Agency) and understand their safety role in the aerospace industry.

Topic 5.2

Learners must understand that aircraft design, manufacture and repair must meet certain requirements:

- role of the aircraft design authorities
- certification specifications
- general aircraft certification (airworthiness, registration, noise)
- repair outside norm, directives, operational restrictions.

Topic 5.3

Learners must understand the purpose and use of flight testing:

- responsibility of authorities
- design standards
- limitations
- development testing
- post-production
- post-maintenance.

Topic 5.4

Learners must understand that continued airworthiness is dependent upon maintenance and how this maintenance affects the aircraft and its use. They should know that maintenance activities must be carried out by approved aircraft maintenance organisations and personnel.

Learning outcome:

6. Understand research and development within the aerospace industry

Topics

- 6.1 Investment
- 6.2 Research and development
- 6.3 Testing

Topic 6.1

Learners must know that finance and investment used by the aerospace industry can be raised from private individuals, corporations or government and understand the reasons why these sources may provide finance and investment.

Topic 6.2

Learners must understand the economic, performance and environmental reasons why there is a need for research and development in the aerospace industry. They must know the typical areas of development:

- materials technology
- manufacturing methods
- design innovation.

Topic 6.4

Learners must understand that new developments must be tested comprehensively before commercial implementation to demonstrate that they achieve the required operating parameters. They must know the types of tests commonly used.

Guidance for delivery

It is important that the learners have a full understanding of the underpinning knowledge of each of the topics. Very important is the practical application of this knowledge and understanding in the working environment. Learners must be able to apply their knowledge and understanding when working on a range of engineering activities, different types of equipment and working environments. Although content will be delivered in a classroom environment, it is important that learners can relate this knowledge and understanding to actual workshop situations and practical tasks.

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UAN:	D/506/5487
Level:	3
GLH:	60

What is this unit about?

Energy engineering is a broad field of engineering dealing with energy efficiency, energy services, facility management, plant engineering, environmental compliance and alternative energy technologies. Energy engineering is one of the more recent engineering disciplines to emerge.

Energy minimisation is the purpose of this growing discipline. Often applied to building design, heavy consideration is given to lighting, refrigeration, to both reduce energy loads and increase efficiency of current systems. Energy engineering is increasingly seen as a major step forward in meeting carbon reduction targets.

Power engineering deals with the generation, transmission, distribution and utilization of electric power and the electrical devices connected to such systems including generators, motors and transformers.

Learning outcomes

In this unit, learners will be able to

1. Understand concepts of power systems
2. Recognise the importance of science, mathematics and engineering in power systems
3. Understand the use of thermo-fluids, materials and electrical power and machines in power systems
4. Understand power systems manufacturing and the process measurements of its quality and efficiency
5. Understand the impact of emerging technologies

Scope of content

This section gives details of the scope of content to be covered in the teaching of the unit to ensure that all the learning outcomes can be achieved.

Learning outcome:

1. Understand concepts of power systems

Topics

- 1.1 Background of power systems
- 1.2 Main components of the power system
- 1.3 New generation of renewable energies
- 1.4 Purpose of the power grid

Topic 1.1

Learners must understand the background to power systems:

- fields, materials and devices
- electrostatics and materials
- current flow in materials
- magnetic fields and their applications
- applications.

Topic 1.2

Learners must understand the main components of a power system:

- basic of power systems (generation, transmission, electric motors and other loads)
- basic semiconductor devices
- dc and ac circuits
- power electronics.

Topic 1.3

Learners must understand different forms of renewable energies:

- renewable power
- solar
- wind
- fuel cells
- nuclear
- biofuel
- geothermal.

Topic 1.4

Learners must understand the purpose of the power grid:

- power grid principles
- buying and selling power
- voltage, phase, frequency, load
- power regulation
- buying and selling power.

Learning outcome:

2. Understand the importance of science, mathematics and engineering in power systems

Topics

- 2.1 Purpose of mechanical engineering in power systems and energy generation
- 2.2 Types of maths in power systems
- 2.3 Use of electrical knowledge in power system and energy generation
- 2.4 Engineering communication and materials

Topic 2.1

Learners must understand the purpose of mechanical engineering in power systems and energy generation:

- solids and forces
- statics, mechanics, dynamics
- aerodynamic
- mechanical design
- models of synchronous, induction, and DC machinery.

Topic 2.2

Learners must be able to use maths in the context of power systems:

- algebra
- differentiation
- integration
- series
- vectors
- differential equations
- complex numbers
- calculus.

Topic 2.3

Learners must be able to understand the relationship between the principles of electricity and power systems and energy generation:

- short history of electricity and electronics and proceeds into the characteristics of matter, energy
- introduction to linear circuits components of resistors (r), capacitors (c), inductors (l), transistors, amplifiers and power sources
- examples of the use electrical and electronic components in real world
- fundamentals of electromagnetism
- properties of magnetism.

Topic 2.4

Learners must be able to use engineering communication methods:

- introduction to matlab
- signal generation
- simple signal manipulations
- graphical presentation of results.

Learning outcome:

3. Understand the use of thermo-fluids, materials and electrical power and machines in power systems

Topics

- 3.1 Purpose of thermo-fluids in power systems
- 3.2 Purpose of electrical power and machines

Topic 3.1

Learners must understand the purpose of thermos-fluids in power systems:

- thermo-fluid properties
- thermodynamic processes and simple cycles
- fluid mechanics
- heat and mass transfer.

Topic 3.2

Learners must understand the purpose of electrical power and machines

- introduction to electrical machines
- electrical power transfer
- practical applications
- wind turbine electrical issues
- practical analysis.

Learning outcome:

4. Understand power systems manufacturing and the process measurements of its quality and efficiency

Topics

- 4.1 Route to power system manufacturing
- 4.2 Principles of the process measurements and control of any power system

Topic 4.1

Learners must understand routes to power system manufacturing:

- overall power system
- manufacturing process
- novel approach
- effective power system design
- support structure design
- engineering design and project.

Topic 4.2

Learners must understand the principles of process measurement and system control

- controls techniques and measurements
- system integration
- industrial energy management.

Learning outcome:

5. Understand the impact of emerging technologies

Topics

5.1 Emerging technologies

Topic 5.1

Learners must understand emerging technologies:

- electrical vehicles
- biofuels from waste
- LED lighting
- environmental issues
- economic considerations.

Guidance for delivery

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UAN:	H/506/5488
Level:	3
GLH:	60

What is this unit about?

Automotive is an exciting and challenging environment, from design and development through to manufacture and maintenance. This unit combines the engineering principles in which automotive vehicles are manufactured and maintained. You will be able to build up your knowledge on the basic principles and then use your other engineering skills to applying thinking to research and development.

Learning outcomes

In this unit, learners will be able to

1. Understand principles of vehicle design and performance
2. Understand principles of engine design and performance
3. Understand principles of vehicle systems and technology
4. Understand principles of vehicle maintenance
5. Understand research and development within the automotive industry

Scope of content

This section gives details of the scope of content to be covered in the teaching of the unit to ensure that all the learning outcomes can be achieved.

Learning outcome:

1. Understand principles of vehicle design and performance

Topics

- 1.1 Vehicle design features
- 1.2 Manufacturing techniques
- 1.3 Vehicle performance

Topic 1.1

Learners must understand features of vehicle design:

- light and heavy vehicles
- body type
- body shapes and design
- aerodynamic devices
- transmission
- 5-speed; 6-speed
- range change
- splitter
- four-wheel drive
- multiple axles
- chassis
- laden weight; unladen weight
- power to weight ratio
- use and applications of new technologies
- materials and design methods.

Topic 1.2

Learners must understand vehicle manufacturing techniques:

- automated (robotic)
- hand built
- materials
 - Metals (ferrous, non-ferrous), plastics, plastic steel, glass, rubber, petroleum products, carbon fibre, plastic reinforced fibre, nanomaterials, nanotechnology.

Topic 1.3

Learners must understand vehicle performance monitoring:

- tractive effort; tractive resistance; air; rolling and gradient eg power available, power required
- performance characteristics: performance curves for different vehicles; tractive effort available for different combinations; tractive effort required for types of vehicle eg in laden, unladen conditions; acceleration possible with different combinations of engines; transmissions and vehicles; gradeability; the change in engine speed that results when changing from one gear ratio to another eg various gear ratios and transmission units; the

effects of a change in engine speed produced by a gear change on engine torque, power and fuel consumption, the road speed of a vehicle

- vehicle performance curves: for selecting appropriate vehicles from data calculated Air resistance: air resistance using the formula $RA = K V^2 A$; air resistance variation with engine speed and its effects on fuel economy; Cd, CdA, typical values for light and heavy vehicles; methods used to reduce air resistance of vehicles.

Learning outcome:

2. Understand principles of engine design and performance

Topics

- 2.1 Engine design features
- 2.2 Manufacturing techniques
- 2.3 Engine performance

Topic 2.1

Learners must understand engine design features:

- cylinder bore diameter
- stroke length
- con-rod to crank ratio
- the number and arrangements of cylinders
- overall engine dimensions
- piston design
- compression ratio
- combustion chambers
- camshaft design
- crankshaft design
- emerging technologies - new materials, alternate and multi fuel engine design (Electric, Compressed Natural Gas (CNG), Liquid Natural Gas (LNG), gasoline-electrical hybrid)

Topic 2.2

Learners must understand manufacturing techniques:

- Manufacturing methods:
 - key design factors eg design form, material type and properties, quality requirements, manufacturing equipment, processing capability, costs, skills of labour force, impact on environment; analytical review of manufacturing methods eg alternatives, most suitable, least waste, use of design criteria; decision-making
- Total cost:
 - breakdown of the three major costs eg material, labour and overheads; fixed and variable costs; relationship between manufacturing method and complexity of design eg form, finish and relative costs; break-even analysis
- Standardisation:
 - standards relevant to design form and materials eg BS, ISO, industry-specific; use of standard components, parts and fittings; application of preferred number methods for detection and standardisation; advantages of using standard parts eg design, development, tooling, planning, choice, labour, ease of replacement; interchangeability, cost; conformity with relevant health and safety standards
- Process requirements:
 - factors affecting material requirements eg form, size, weight, quality, processing

method, quantity, availability, service life, and mechanical, electrical and chemical characteristics

- Implementation:
 - timescale, ease of implementation, lifespan/upgradeability
- Methods of assembly:
 - application of analytical and questioning techniques to select the most appropriate method of assembly eg a value engineering approach that evaluates the specification and validity of the product; cost saving techniques eg variations between similar components, sequencing of assembly stages, symmetrical and asymmetrical parts, number of components
- Economic manufacture:
 - automated methods eg ability to feed and assemble components automatically, unidirectional component location, ease of handling, positioning, stacking and accessibility within assemblies; significant features of good design eg location of spigots, flanges, tenons, locating faces, accessibility, alignment, families of parts or groupings
- Materials
 - Metals (ferrous, non-ferrous), plastics, plastic steel, glass, rubber, petroleum products, carbon fibre, plastic reinforced fibre, nanomaterials, nanotechnology

Topic 2.3

Learners must understand the characteristics of engine performance:

- torque; power; mechanical efficiency; thermal efficiency; volumetric efficiency; mean effective pressure; specific fuel consumption; emission control assessment
- Engine performance mapping: graphical account of the role of map data; mapping procedure; visual interpretation of a fuel map and ignition map; fuel/ignition maps for different engine performance applications eg economy, power and torque
- Performance curves: curves eg for spark ignition (SI), combustion ignition (CI) and pressure charged, rotary engines; engine test at various engine speeds; critical evaluation of air/fuel ratio; torque, power; exhaust emissions; fuel consumption; significance of the standards used to measure engine power eg BSAU, DIN, SAE, EEC; application of engine performance curves and design to the selection of appropriate power units for specific tasks.

Learning outcome:

3. Understand principles of vehicle systems and technology

Topics

- 3.1 Vehicle electronic steering and active suspension systems
- 3.2 Vehicle anti-lock braking, traction control, integrated dynamic stability control
- 3.3 Vehicle security, environmental control and passenger protection systems
- 3.4 Diagnostic procedures

Topic 3.1

Learners must understand vehicle steering and suspension systems:

- Advanced power steering:
 - components of integral power steering with electronic control; principles of operation; electrical and hydraulic circuit diagrams; control systems; service and repair procedures and safety aspects; system operation under various conditions eg parking, negotiating bends
- Active suspension and ride control:
 - components of active vehicle chassis management system including self-levelling suspension, ride control, electronic damper control and active rear suspension/axle control; electrical and hydraulic circuit diagrams; system operation under various conditions eg cruise, acceleration, braking, cornering
- Service and repair procedures:
 - manufacturers' recommendations for service and repair; safety aspects to be considered; specialist equipment and tools required; correct test conditions; inter-relationships of systems.

Topic 3.2

Learners must understand braking and stability control:

- Anti-lock braking (ABS):
 - principles of operation and components of an anti-lock braking system eg electrical and hydraulic circuits, system operation under various conditions such as emergency braking, ice
- traction control – Anti Slip Regulations (ASR):
 - principles of operation and components of a traction control system eg electrical and hydraulic circuits; system operation during acceleration, cornering and braking
- service and repair procedures:
 - manufacturers' recommendations for service and repair; safety aspects to be considered; specialist equipment and tools required; correct test conditions; inter-relationships of systems
- integrated dynamic stability control:
 - functional description of system to include operational criteria eg under-steer, lateral acceleration, vehicle rotation speed, steering angle and wheel speeds; corrective strategies eg braking control and engine power regulation; sensing components and electrical/hydraulic circuits

Topic 3.3

Learners must understand security, protection and environmental controls:

- central locking and security:

- components of microprocessor-controlled central locking and thief proofing system; operating principles including infrared control, doppler movement sensing, crash sensing, failsafe and safety features; system operation under various conditions eg attempted break-in, accident; developments in vehicle security systems
- environmental control:
 - components of integral heating and air conditioning system; operating principles; sensing and control functions; system operation under various conditions; developments in vehicle environmental control systems
- passenger protection:
 - components of air bag systems eg front and side impact systems; operating principles; operation of system during frontal and side impact; passenger restraints eg seat belt tensioners and head restraint; developments in driver and passenger impact protection
- service and repair procedures:
 - manufacturers' recommendations for service and repair; safety aspects to be considered; specialist equipment and tools required; correct test conditions

Topic 3.4

Learners must understand fault diagnostic testing procedures:

- eg visual inspection, functional tests and system condition monitoring systems, electrical tests using multi-meters, oscilloscopes and dedicated test equipment on sensors, actuators and control units associated with the above systems, pressure tests on hydraulic systems

Learning outcome:

4. Understand principles of vehicle maintenance

Topics

4.1 Legal and operational implications

4.2 Fleet maintenance management systems

Topic 4.1

Learners must understand legal and operation implications of vehicle maintenance:

- types of vehicle maintenance contract:
 - eg contract hire, lease hire, rental, manufacturer contract, power by the hour, fleet maintenance
- legal and operational implications:
 - contract law; supply of services; construction and use regulations; transport act; plating and testing; environmental legislation
- vehicle maintenance contracts:
 - controls; staffing; records; financial considerations; company taxation; operational factors; operator licensing
- legal requirements:
 - eg operator's licence, construction and use regulations, plating and testing, mot testing, environmental considerations
- implications and processes:
 - responsibilities; staff qualifications; facilities; equipment; human resource; competence; planning; vehicle inspections; defect reporting and rectification; environmental requirements for waste disposal; staff training; licences (MOT)

Topic 4.2

Learners must understand fleet management systems:

- management systems selection criteria:
 - eg based on fleet size, fleet type, type of operation, cost, time, location
- management systems:
 - mileage; time; scheduled; unscheduled; corrective; emergency
- customer requirements:
 - eg frequency, reporting requirements, documentation, emergency situations, overnight servicing/repairs, vehicle inspections
- maintenance control systems selection criteria:
 - eg type of operation, fleet type, fleet size, cost, location of fleet, power by the hour contract
- fleet maintenance control systems:
 - eg centralised, decentralised, manual card operation, computerised operation, computer-based systems and relevant software and hardware
- planning and controlling fleet maintenance:
 - driver defect reporting; vehicle inspection reporting; vehicle maintenance servicing schedules; vehicle testing; maintaining vehicle records

Learning outcome:

5. Understand research and development within the automotive industry

Topics

- 5.1 Investment
- 5.2 Research
- 5.3 Development
- 5.4 Testing

The learner must know examples of research and development within the automotive industry. Looking at the planning, conducting, analysis results, testing. Learners must understand the route to research and development of new and existing technologies.

Topic 5.1

Learners must understand investments made into automotive research:

- new
- existing
- sources.

Topic 5.2

Learners must understand the approaches used for research:

- need
- specification
- requirement.

Topic 5.3

Learners must understand the use of technology in automotive development:

- existing technology
- new technology.

Topic 5.4

Learners must understand how developments are tested as part of research and development:

- parameters
- efficiency.

Guidance for delivery

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UAN:	K/506/5489
Level:	3
GLH:	60

What is this unit about?

More people travel by rail than at any point since the 1920's, when the rail network was around twice its current size. Every year 1.3 billion journeys are made on Britain's railway and 100 million tonnes of freight is transport by rail between ports, factories and shops. A million more trains run every year than just five years ago but the increasing popularity of rail means that, at peak times, there is no space for more trains on the busiest parts of the network. Despite this, demand is still increasing. Over the next 30 years passenger demand for rail will more than double and freight demand is expected to go up by 140%

Therefore the railways are a key part of the UK's transport infrastructure for commuting, leisure and business travel, as well as freight services. The industry recognises that it needs staff with the right skills to deal with the ever-increasing demands. This unit will provide the learner with sufficient knowledge for an introduction into the railway industry, specifically rail engineering which maintains the network of rail track, signalling, communications, electrification systems and of course the following stock and locomotives themselves. These engineering individuals, potentially like yourselves, keeping the UK's rail system running safely, efficiently and effectively.

Learning outcomes

In this unit, learners will be able to

1. Understand the rail transport industry and the associated infrastructure
2. Understand the importance of railway track to operations
3. Understand what rolling stock and traction maintenance involve
4. Understand the importance of signalling and communications to railways
5. Understand the railway electrification system

Scope of content

This section gives details of the scope of content to be covered in the teaching of the unit to ensure that all the learning outcomes can be achieved.

Learning outcome:

1. Understand the rail transport industry and the associated infrastructure

Topics

- 1.1 Trains
- 1.2 Infrastructure
- 1.3 Operations
- 1.4 Social, economical and energetic aspects

Topic 1.1

Learners must understand the history of rail travel:

- Pre-steam
- age of steam
- trains
 - haulage, passenger trains, freight trains
- motive power
 - Steam, electric, diesel, magnetic levitation, horse-drawn, cable, gravity, pneumatics, gas turbine.

Topic 1.2

Learners must understand rail infrastructure:

- right of way
 - land owned / leased
 - gradients
 - route length
 - cuttings
 - bridges
 - tunnels
- trackage
 - rail gauge; standard gauge, broad gauge, narrow gauge, loading gauge
 - ballast
 - turnouts; points and switches
- train inspection systems
 - defect detectors, infrared, ultrasonic audio analysis
- signaling
 - signal box, block signaling, control rooms, track zones, automatic control devices, operating rules
- electrification
 - voltage, direct current, alternating current, third rail, overhead power, transiting
- communication
- stations
 - goods station, passenger stations, underpasses, footbridges, platforms, central stations, transport hubs

Topic 1.3

Learners must understand the operation of rail transport:

- ownership
 - railway companies, government, rolling stock, infrastructure, European Union, train operators
- financing
 - ticket revenue, advertisement, externalities, public service obligation, government, shareholders, operators
- safety
 - derailment, level crossings, grade separation, railway signaling
- maintenance
 - infrastructure assets, inspection, gauging, fastener tightening, rail replacement, capacity, frequency, off-peak hours, rail corrugation, passenger safety, access problems, maintenance equipment.

Topic 1.4

Learners must understand factors affecting rail transport

- energy efficiency
- usage
- social and economic benefits
- development.

Learning outcome:

2. Understand the importance of railway track to operations

Topics

- 2.1 Track structure
- 2.2 Track safety
- 2.3 Track maintenance
- 2.4 Inspection and defects

Topic 2.1

Learners must understand track structure:

- traditional track structure
 - flat-bottom steel rails, continuously welded rails, timber/pre-stressed concrete sleeps, stone ballast, plastic/rubber pads, cut spikes, fastenings
- ballastless track
- ladder track
- continuous longitudinally supported track.

Topic 2.2

Learners must understand approaches to track safety:

- Personal Track Safety certificate (PTS)
- area familiarisation
- COSS CRP briefings
- DC Conductor Rails (DCCR)
- Designated person

- Engineering Supervisor
- Hand Trolley Controller
- Handsignaller
- Lookout/Site Warden and Pee Wee.

Topic 2.3

Learners must understand factors relating to track maintenance:

- Track access limitations
- weather conditions
- peak / off-peak times
- frequency of use
- type of track
- tightening bolts, nuts and screws to specific requirements, filling and replenishing lubricators, cleaning out ditches, drains and catch pits, fixing, fitting or refitting pads, insulators, rail fastenings, fishplates and bolts, applying lubricants – point oiling/fishplate greasing, cutting back/clearing vegetation, removing and disposing of waste, boxing in ballast.
- railgrinder, track renewal train, herbicide, nondestructive testing, HiRail trucks, branch line, siding or stub.
- railway ecosystems.

Topic 2.4

Learners must understand approaches to track inspection and symptoms and causes of defects:

- defect detectors, infrared, ultrasonic audio analysis
- rail adjustment and regulation, adjustment switch setting, sleeper spacing and squaring, ballast re-profiling and boxing-in, operational support for stressing rails, operational support for straightening of rail ends
- operational support for point testing
- conductor rail (pots, anchors)
- tongue lipping, head checking, squats
- corrosion, inclusions, seams, shelling, transverse fissures, wheel burn
- parts of rail – head, web, foot, switchblades, welds, bolt holes
- inspection – lasers, radiography, ultrasonics, low frequency eddy currents, neural network analysis of signals.

Learning outcome:

3. Understand what rolling stock and traction maintenance involve

Topics

- 3.1 Running stock, traction and motive power
- 3.2 Maintenance of rolling stock and traction
- 3.3 Inspection and defects
- 3.4 Maintenance environment

Topic 3.1

Learners need to understand different types of rolling stock:

- steam
- electric
- diesel
- haulage, motive power, passenger trains, freight trains
- carriages
- buffet cars
- hooper cars
- articulated well cars
- intermodal containers
- high speed.

Topic 3.2

Learners need to understand maintenance of rolling stock:

- mechanical components and systems
- electrical components and systems
- hydraulic components and systems
- pneumatic components and systems
- electronic components and systems
- internal fixtures and fittings
- maintenance facilities
- access
- cleaning and stabling
- toilets
- train washing machines
- wheel lathe
- inspection sheds
- shore supplies
- lifting
- bogie drops
- maintenance workshops
- maintenance programmes
- failures
- performance measures
- wheel inspection
- brake inspection.

Topic 3.3

Learners must understand approaches to inspection and symptoms and causes of defects:

- defect detectors, infrared, ultrasonic audio analysis
- operational support
- corrosion, inclusions, seams, shelling, transverse fissures, wheel burn
- inspection – lasers, radiography, ultrasonics, low frequency eddy currents, neural network analysis of signals.

Topic 3.4

Learners must understand environments where maintenance activities take place:

- workshop, site, possession, depot
- overhead electrified areas, conductor rail areas
- electrical
- electronic
- pneumatic
- hydraulic
- toxic gases
- explosive gases
- chemicals
- general waste

Learning outcome:

4. Understand the importance of signaling and communications o railways

Topics

- 4.1 Types of signaling and communication
- 4.2 Safety critical nature of signalling and communications
- 4.3 Maintenance of signalling and communications

Topic 4.1

Learners must understand types of signaling and communication:

- timetable operation
- block signaling
 - manually controlled block
 - permissive and absolute blocks
 - automatic block
 - fixed block
 - moving block
- centralized traffic control
- train detection
 - track circuits
 - axle counters
- fixed signals
 - mechanical signals
 - colour light signals
 - route signaling and speed signaling
 - approach release
- safety systems

- cab signalling
- interlocking
- Communication-Based Train Control (CBTC)

Topic 4.2

Learners must understand the safety critical nature of signalling:

- Paddington and Potters Bar (2002) accident reports
- Hatfield (2002) accident report
- Clapham junction (1988) accident report
- Ladbroke Grove (1999) accident report
- safety culture
- maintenance schedules
- maintenance practices
- continuous improvement management systems
- safety management systems
- quality management systems.

Topic 4.3

Learners must understand signal maintenance:

- equipment
 - points, train control, power supplies, train detection, on-train signalling systems
 - cab signalling, dark territory, double line automatic signaling, double switching, flagman, overlap, railway semaphore signal, SelTrac, Signal Passed at Danger, Single-line working, Slow Zone, Whistle Post, Wrong-side failure, Template: Railwaysignalling
- warning systems
- obsolete signals
 - purple lights, three-position semaphore signals, Euston to Watford experimental system
- junction signals
- speed restrictions
- location
 - external – trackside, internal – signal box, equipment room, areas to which the public have access. confined spaces, elevated structures, areas containing hazardous conditions

Learning outcome:

5. Understand the railway electrification system

Topics

- 5.1 Types of railway electrification
- 5.2 Advantages/disadvantages
- 5.3 Case studies

Topic 5.1

Learners must understand different types of railway electrification:

- classification
 - standardised voltages

- Overhead Line (OHL)
 - 125Kv, 50Hz, AC overhead
 - Existing
 - Future
- direct current
 - third and fourth rails
 - 650v – 750v dc, third rail (top contact)
 - 630v dc, fourth rail (top contact)
 - 750v dc, third rail (bottom contact)
 - 600v dc, third rail (top contact)
 - 250v dc, third rail (top contact)
 - 110v dc, third rail (top contact)
 - 100v dc, fourth rail
- obsolete systems
- alternating current
 - low-frequency alternating current
 - polyphase alternating current systems
 - standard frequency alternating current.

Topic 5.2

Learners must understand advantages and disadvantages of electrification:

- world electrification
- advantages / disadvantages
 - trade-offs, energy efficiency, external costs, gaps
- non-contact systems.

Topic 5.3

Learners must know examples of electrification:

- West Coast Main Line (WCML)
- London, Tilbury and Southend (LTS)
- West Anglia / Fen Line
- Great Eastern Main Line (GEML)
- East Coast Main Line (ECML)
- Midland Main Line (MML)
- London Paddington to Heathrow Airport
- High Speed 1
- High Speed 2 proposed

Guidance for delivery

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UAN:	
Level:	3
GLH:	60

What is this unit about?

Marine engineering is a fascinating and exciting world, which ranges from the small pleasure craft right up to the largest cargo vessels in the world. This unit combines the engineering principles with which these vessels are constructed and maintained; how they stay afloat and what keeps them moving through the water. It also covers the complex navigation and communication systems that keep the vessel safe and enable it to get to where it needs to go. Here you will be able to build up an overview of knowledge on the basic principles and then use your existing engineering knowledge to understand real systems. You will learn how to understand the interaction between different vessel services on board to make the “journey” efficient and comfortable. You will then be able to put your thinking into practice in knowing how to maintain these vessels.

Learning outcomes

In this unit, learners will be able to

1. Understand the complexity of the marine industry
2. Know the main groups of materials and methods used for marine construction
3. Understand typical repair methods for the main material groups
4. Understand methods of marine propulsion
5. Understand typical marine electrical, navigation and mechanical systems
6. Understand research and development in the marine industry

Scope of content

This section gives details of the scope of content to be covered in the teaching of the unit to ensure that all the learning outcomes can be achieved.

Learning outcome:

1. Understand the complexity of the marine industry

Topics

- 1.1 Types and uses of marine vessels
- 1.2 Categories of marine vessels
- 1.3 Operators of marine vessels
- 1.4 The role of the marine engineer
- 1.5 Maritime law and ship registration

This learning outcome should serve as an introduction to the unit, setting the scene for the learning outcomes that follow.

Topic 1.1

Learners must understand the basic terminology associated with vessel specifications:

- vessel
- boat
- ship
- displacement
- length
- beam
- draft.

Learners must know the range of surface and underwater vessels that are produced, maintained and used by the marine industry (both military and civilian), their typical characteristics, common features and differences:

Surface vessels:

- small craft:
 - sailing dinghy made from wood or composite material
 - Rigid Inflatable Boat (RIB) powered by one or more outboard motors
 - small GRP or metal boat powered an outboard motor
 - small wooden, composite or metal fishing or utility boat powered by an inboard motor
 - specialist sport and racing boats powered by sail, inboard or outboard motors
 - wooden, composite or metal 'leisure' craft powered by sail and/or inboard/outboard motors
 - small working boats with powerful inboard motors eg: tugs
- larger working surface vessels:
 - civilian commercial (cargo and passenger)
 - military
- specialist vessels:
 - oil and gas rigs

undersea vessels

- military submarines
- civilian submarines (manned and ROVs for exploration and maintenance of off-shore rigs and ships)

Topic 1.2

Learners must know the characteristic features of the following classes of vessel:

- container ships, bulk and gas carriers, tankers
- cruise vessels, ferries, RoPax, Ro-Ro and car carriers
- yachts
- multi-purpose vessels
- offshore service vessels
- inland waterway vessels.

Topic 1.3

Learners must understand, in general terms, who owns and operates maritime vessels:

- owner-operators
- contractors
- shipping lines
- oil companies.

They must also know a typical crew structure, including those crew members who must be licenced to operate a vessel:

- Master
- Deck officers
- Engineers
- Navigators
- Radio operators.

Topic 1.4

Learners must understand the different roles that a marine engineer can play in the maritime industry and the career paths leading to these roles:

- naval architect (civil and military design)
- ship and boat building: skilled craftsperson, technician, team leader, line manager.
- on-board ship – engineering officer, skilled technician, mechanic.

Topic 1.5

Learners must understand, in general terms, how and where vessels are registered:

- the existence of international maritime law
- classification societies
- Lloyds of London.

They must also understand:

- The role of insurers and experts to ensure safely engineered design, construction, repairs and maintenance
- Flags of Convenience and the effect on maritime safety of registering under flags of convenience.

Learning outcome:

2. Know main groups of materials and methods used for marine construction

Topics

2.1 Wood

2.2 Metal

2.3 Composite materials

Topic 2.1

Learners must know the wood materials used in traditional boat building:

- hard woods for the keel and frame:
 - oak
 - mahogany
 - teak
- soft woods for the planking:
 - pine (certain varieties)
 - larch
 - cedar
- composites for cladding and decking:
 - marine ply.

They must be able to identify the main construction types used with wood:

- carvel
- clinker
- strip planking
- sheet plywood (including 'stitch and glue')
- cold molding.

They must also know the fixing devices that are commonly used:

- nails, rivets, screws, bolts
- glue
- tree nails (wooden pegs).

Learners should know the tools used in traditional boat building:

- cutting and shaping tools:
 - adze
 - saws
 - chisels
 - planes and spoke shaves.
- power tools:
 - jig saw
 - drill
 - screw driver,
 - band saw
 - sander
 - router.

They must understand that wood materials require waterproofing and rot protection:

- boiled linseed oil (inside only)
- marine or anti-fouling paint
- marine varnish (inside only)
- copper anti-fouling cladding.

Topic 2.2

Learners must know the materials used in building metal vessels:

- steel
- aluminium alloy for hulls and superstructure
- zinc sacrificial plates for cathodic protection
- bronze for propellers and fittings.

Learners must understand how the hull of a cargo ship obtains its stiffness and strength in all directions. They must know and be able to describe the basic construction of the a cargo ship:

- the use of prefabricated block construction for hulls
- the prefabrication of superstructures and the
- welding techniques
- fitting out process
- riveting techniques for repairs.

They must understand that metal hulls and superstructure require protection from corrosion:

- paints and coatings above and below the water line
- anti-corrosion cathodic plates
- preparation for application of protective coatings by etching and shot blasting
- application of protective coatings.

Topic 2.3

Learners must know the composite materials commonly used in modern boat building:

- Glass reinforced polymer (GRP)
- Fibre reinforced polymer (FRP)
- Carbon Fibre Reinforced Composites (CRP)
- honeycomb sandwich
- foam sandwich.

They must understand that these materials can be used to reduce weight, improve performance or, for military vessels, reduce magnetic signature.

They must know how hulls are made from composite materials:

- use of moulds for hull components
- wet lay-up
- pre-preg
- vacuum bagging
- trimming and finishing.

Learners must also know that composite materials may require protective finishes such as gel coat or anti-fouling coatings.

Learning outcome:

3. Understand typical repair methods for the main material groups

Topics

- 3.1 Inspection and repair planning
- 3.2 Wood repairs
- 3.3 Metal repairs

3.4 Composite repairs (FRP)

Topic 3.1

Learners must know the types of damage and deterioration that may affect vessels:

- puncture
- delamination (composites, including plywood)
- corrosion (metals)
- fracture or dis-bonding of joints and members
- wood rot
- osmosis (composites).

Learners must understand the common sources of damage, including the areas of a hull that could be affected:

- striking submerged objects
- collision
- poor maintenance
- grounding
- manufacturing issues.

Learners must know how hulls can be tested to determine if damage has occurred:

- non-destructive testing:
 - visual
 - dye penetrant (metal)
 - ultrasonic (composites and metals)
 - x-ray (metals)
 - magnetic (metals)
 - pressure resistance (wood and composites)
 - moisture meter (wood and composites)
- destructive testing:
 - drilling
 - core (coin) sample for materials testing.

Learners must also know the typical options for re-instatement of damage:

- repair (short term 'patch' until permanent solution available)
- refurbish (longer term repair – structurally more sound – until complete replacement possible)
- replacement (complete renewal of damaged area and components to manufacturer's specification).

Topic 3.2

Learners must know the main techniques to repair wood hulls and understand the reasons for using them:

- commonly used tools
- methods of removing damaged or deteriorated wood
- methods of preparing the edges of the area to be repaired
- types of repair joint:
 - scarf
 - butt
 - sister frame (doubler)
- use of epoxy resin in wooden boat repairs

- re-sealing and caulking.

Topic 3.3

Learners must know the main techniques to repair metal hulls and understand the reasons for using them:

- commonly used tools
- repair of rivets:
 - bobbing
 - frenching
 - ring welding
- replacement of rivets
- caulking (specific to steel vessels)
- plate replacement
 - riveted
 - welded
- preservation, sealing and coating.

Topic 3.4

When considering the repair of composite materials, learners must understand the difference between the structure of a repaired area and that of the original material, and how this will affect the properties of the item being repaired.

Learners must know the main techniques to repair items made from composite materials:

- careful choice of repair materials
- removal of damaged material
- repair of structural members
- repair of skin
 - preparation of the repair section
 - support and insert the repair
 - inspection and test of the repair
 - finish and protection (including gel coat colour match).

Learning outcome:

4. Understand methods of marine propulsion

Topics

- 4.1 Traditional methods
- 4.2 Smaller boat engines
- 4.3 Steam turbines
- 4.4 Diesel engines
- 4.5 Gas turbine engines
- 4.6 Propellers and steering motors

Topic 4.1

Learners must know how both rowing and sail develop the motive power to move a vessel forward. They should know that developments in oars, sails and hull design can improve how vessels travel through, or across the surface of, the water.

Topic 4.2

Learners must understand the use of following motors, and what contribution they make towards the steering of the vessel:

- outboard motors
 - large
 - portable
 - electric
 - pump jet
- inboard motors
 - diesel
 - petrol
 - electric
 - pump jet
 - traditional steam (such as reciprocating engines on heritage craft).

Topic 4.3

Learners must understand how steam power is generated. They must know why coal and heavy fuel are being phased out, and the fuel efficiency and environmental impact of these power sources.

Topic 4.4

Learners must know that the power from a diesel engine is transmitted through a gearbox and shaft to the propeller. They must know the relative size and power of vessels powered by diesel engines, and the typical fuel efficiency and environmental performance of diesel engines.

Topic 4.5

Learners must know that gas turbines are specialist engines installed in military and civilian craft requiring high speed and maneuverability.

Topic 4.6

It should be noted that propellers are normally referred to as 'screws' in marine terminology, however the term 'propeller' will be used here to avoid confusion.

Learners must understand how a propeller works, including cavitation and its prevention and how they are used for steering. They must know how propeller types vary with the size of the vessel, from small outboards to those fitted to the largest vessels, and the materials that are used to make them. They must know the different configurations of propellers:

- Single
- Multiple (up to four)
- Contra-rotating
- Controllable pitch
- Paddle wheels

Learning outcome:

5. Understand typical marine electrical, navigation and mechanical systems

Topics

- 5.1 Electrical power generation and distribution
- 5.2 Ship-borne navigation and identification systems
- 5.3 Ship-borne communications
- 5.4 Mechanical systems
- 5.5 Survival and emergency systems

Topic 5.1

Learners must understand that different types of vessels have different needs for electrical power generation and distribution. This could include, for example:

- electrical generators:
- general equipment circuits
- engine starting
- winch and crane power
- domestic supplies (passenger ships)
- shore supply connection
- emergency power.

They should be able to draw a systems (block) diagram of an electrical system, illustrating the main components, for either large ships or smaller vessels.

They must also understand that these electrical systems all have to be monitored and maintained, usually by the engineering officer and the engineering members of the crew. They must know that condition monitoring can include:

- Visual inspection
- Circuit testing
- Continuous automated monitoring and alerts

Topic 5.2

Learners must understand why GPS has largely taken over from radio and inertial systems as the primary maritime navigation system.

They must know the traditional navigation aids and how they are used, and understand that these are still used when modern systems fail:

- running lights
- visual signals – lights, flags etc.
- compass (magnetic and gyro)
- astro-navigation (using sextant, chronometer and nautical almanac)
- inertial navigation
- radar
- automatic identification systems
- sonar.

Topic 5.3

Learners should know that ship-borne communications can be categorised as terrestrial, satellite and on-board. They should know the communication systems commonly used:

- VHF and UHF for local voice communication
- HF (long range voice and data communication)

- satellite communication (voice/sat-phone, data transmission (data on ship-borne systems and cargo), identification)
- on-board telephone system
- engine order telegraph EOT.

Topic 5.4

Learners should know that a wide variety of mechanical systems are used on board vessels and understand their purpose:

- hydraulic ramps and doors
- adjustable decks
- winches and cranes
- anchor deployment and recovery systems
- water systems
- fuel systems
- heating and ventilation
- pumps and pipework systems
- waste compaction.

Topic 5.5

Learners should know the common maritime survival and emergency systems and understand their purpose and the reasons for having them:

- life preservers
- lifeboat and life raft systems
- emergency beacons and radio communicator
- emergency escape systems
- damage control equipment such as fire pumps
- fire suppression
- life support and personal protective equipment
- emergency repair systems for hull damage.

Learning outcome:

6. Understand research and development in the marine industry

Topics

- 6.1 Investment
- 6.2 Research and development
- 6.3 Testing

Topic 6.1

Learners must know that finance and investment used by the marine industry can be raised from private individuals, corporations or government and understand the reasons why these sources may provide finance and investment.

Topic 6.2

Learners must understand the reasons why there is a need for constant research and development in the highly competitive sub-sectors of the maritime industry. They must know the typical areas of development in marine technology:

- materials technology
- manufacturing methods
- design innovation
- the implementation of new technologies.

Learners must also know that the world's merchant shipping is one of the main world producers of carbon emissions, and this issue is being addressed through new technology.

Topic 6.3

Learners must know how boats and ships are tested, both during the design phase (as models) and during the commissioning. They must understand what information is determined by these tests:

- hydrodynamic testing
- displacement
- maneuverability
- flank speed
- economical speed
- safety.

Guidance for delivery

It is important that the learners have a full understanding of the underpinning knowledge of each of the topics. Very important is the practical application of this knowledge and understanding in the working environment. Learners must be able to apply their knowledge and understanding when working on a range of engineering activities, different types of equipment and working environments. Although content will be delivered in a classroom environment, it is important that learners can relate this knowledge and understanding to actual workshop situations and practical tasks.

Tutors delivering this unit have opportunities to use a wide range of techniques. Lectures, discussions, seminar presentations, site visits, videos/DVDs, research using the internet or library resources and use of tutors with relevant and appropriate industrial experience are all suitable. Visiting expert speakers could add to the relevance of the subject for learners. The learning outcomes are sequential. Group activities are permissible, but tutors will need to ensure that individual learners have equal experiential and assessment opportunities.

Employer engagement

Employer engagement is essential in order to maximise the value of learners' experience. A partnership approach should be adopted where possible with employers with whom the consortium has links, and with employers used for work experience placements.

The use of scenario led contextualised tasks are essential in the delivery and assessment of this unit. Much of the work can be set in the context of case studies of local employers. Visits to companies/shows/exhibitions will enhance this particular part of the unit.

It would be helpful for teachers to develop a method of maintaining contact with a range of employers in the sectors may be able to help with keeping the examples of legislation, policies and codes of practice used in the taught content, up to date.

Appendix 1 Sources of general information

The following documents contain essential information for centres delivering City & Guilds qualifications. They should be referred to in conjunction with this handbook. To download the documents and to find other useful documents, go to the **Centres and Training Providers homepage** on www.cityandguilds.com.

City & Guilds Centre Manual

This document provides guidance for organisations wishing to become City & Guilds approved centres, as well as information for approved centres delivering City & Guilds qualifications. It covers the centre and qualification approval process as well as providing guidance on delivery, assessment and quality assurance for approved centres.

It also details the City & Guilds requirements for ongoing centre and qualification approval, and provides examples of best practice for centres. Specifically, the document includes sections on:

- the centre and qualification approval process
- assessment, internal quality assurance and examination roles at the centre
- registration and certification of candidates
- non-compliance and malpractice
- complaints and appeals
- equal opportunities
- data protection
- management systems
- maintaining records
- internal quality assurance
- external quality assurance.

Our Quality Assurance Requirements

This document explains the requirements for the delivery, assessment and awarding of our qualifications. All centres working with City & Guilds must adopt and implement these requirements across all of their qualification provision. Specifically, this document:

- specifies the quality assurance and control requirements that apply to all centres
- sets out the basis for securing high standards, for all our qualifications and/or assessments
- details the impact on centres of non-compliance

The **centre homepage** section of the City & Guilds website also contains useful information on

Walled Garden: how to register and certificate candidates on line

Events: dates and information on the latest Centre events

Online assessment: how to register for e-assessments.

Useful contacts

UK learners

General qualification information

E: learnersupport@cityandguilds.com

International learners

General qualification information

E: intcg@cityandguilds.com

Centres

Exam entries, Certificates, Registrations/enrolment, Invoices, Missing or late exam materials, Nominal roll reports, Results

E: centresupport@cityandguilds.com

Single subject qualifications

Exam entries, Results, Certification, Missing or late exam materials, Incorrect exam papers, Forms request (BB, results entry), Exam date and time change

E: singlesubjects@cityandguilds.com

International awards

Results, Entries, Enrolments, Invoices, Missing or late exam materials, Nominal roll reports

E: intops@cityandguilds.com

Walled Garden

Re-issue of password or username, Technical problems, Entries, Results, e-assessment, Navigation, User/menu option, Problems

E: walledgarden@cityandguilds.com

Employer

Employer solutions, Mapping, Accreditation, Development Skills, Consultancy

E: business@cityandguilds.com

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About City & Guilds

As the UK's leading vocational education organisation, City & Guilds is leading the talent revolution by inspiring people to unlock their potential and develop their skills. City & Guilds is recognised and respected by employers across the world as a sign of quality and exceptional training.

City & Guilds Group

The City & Guilds Group is a leader in global skills development. Our purpose is to help people and organisations to develop their skills for personal and economic growth. Made up of City & Guilds, City & Guilds Kineo, The Oxford Group and ILM, we work with education providers, businesses and governments in over 100 countries.

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