Level 3 Advanced Technical Certificate in Engineering (1145-30)

May 2019 Version 1.7

Qualification Handbook

Qualification at a glance

Industry area	Engineering
City & Guilds qualification number	1145-30
Age group	16-19 (Key Stage 5), 19+
Entry requirements	Centres must ensure that any pre-requisites stated in the *What is this qualification about?* section are met.
Assessment	To gain this qualification, candidates must successfully achieve the following assessments: • One externally set, externally moderated assignment • One externally set, externally marked exam, sat under examination conditions
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	This qualification is graded Pass/Merit/Distinction/Distinction* For more information on grading, please see Section 7: Grading.
Approvals	These qualifications require full centre and qualification approval
Support materials	Sample assessments Guidance for delivery Guidance on use of marking grids
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 assignments are subject to external moderation. There is no direct claim status available for this qualification.

Title and level	Size (GLH)	TQT	City & Guilds qualification number	Ofqual accreditation number
Level 3 Advanced Technical Certificate in Engineering	360	600	1145-30	601/4535/3

Version and date	Change detail	Section
1.1 May 2016	Small typographical errors	Throughout
	TQT added for qualifications Assessment component titles amended	1. Introduction
	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
	Enquiries about results Re-sits and shelf-life of assessment results Malpractice Access arrangements and special consideration	8. Administration
	Minor rewording of some Learning Outcomes and Topics, minor revision of some Topics depth	Units 301-306
1.2 July 2016	Depth updated	Unit 303 Topic 2.2
1.3 November 2016	Change of number for exam from 030 to 530	
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 Exam AO weightings	Exam specification
1.6 July 2017	Correction to assessment details	5. Assessment
1.7 May 2019	Wording changed regarding retakes	5. Assessment – Summary of assessment methods and conditions 8. Administration – Re-sits and shelf-life of assessment results

Contents

1 Introduction

What is this qualification about?

The following purpose is for the **City & Guilds Level 3 Advanced Technical Certificate in Engineering**

Area	Description
OVERVIEW	
Who is this qualification for?	This qualification is for you if you are looking to start in the Engineering sector, covering a range of topics allowing you to develop your knowledge and skills. There are no entry requirements for this qualification.
What does this qualification cover?	You will study theoretical aspects of the subject and apply them to practical tasks. Compulsory topics include: • engineering materials • electronics, control and instrumentation • mechanical structures and dynamics • manufacturing methods in engineering • engineering design • engineering mathematics and statistics. 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 and employer.
WHAT COULD THIS QUALIFICATION LEAD TO?	
Will the qualification lead to employment, and if so, in which job role and at what level?	The City & Guilds Level 3 Advanced Technical Certificate in Engineering could lead to employment opportunities for you as a: • skilled machinist • composites technician • measurement and control technician
Why choose this qualification over similar qualifications?	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. The Certificate is likely to be taken alongside other programmes such as GCSEs or AS Levels over a one-year course of study. 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. 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.
Will the qualification lead to further learning?	When you have achieved this qualification you have a choice of seeking employment or going on to further learning. Examples include: • Higher Apprenticeship in Advanced Manufacturing Engineering. • Foundation Degree FdEng in Engineering.
WHO SUPPORTS THIS QUALIFICATION?	
Employer/Higher Education Institutions	The following employers support this qualification: EDF Energy, AMEC, Bosch, Bramble House, MBDA.

Qualification structure

For the **Level 3 Advanced Technical Certificate in Engineering** 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

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	GLH	TQT
Level 3 Advanced Technical Certificate in Engineering	360	600

Assessment requirements and employer involvement

To achieve the **Level 3 Advanced Technical Certificate in Engineering** candidates must successfully complete **both** mandatory assessment components**.**

Component number	Title
Mandatory	
530	Level 3 Engineering - Theory exam (1)*
031	Level 3 Engineering – Synoptic assignment (1)*

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	
830	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 these qualifications 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 Guidance for delivery Guidance on use of marking grids	Available on the qualification pages on the City & Guilds Website: **www.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 qualification[3];*
- *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;*
- *simulated or provider-based working environments eg hairdressing salons, florists, restaurants, travel agents, small manufacturing units, car servicing facilities;*

[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**

- *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 (e.g. 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
530	Externally marked exam	The exam is **externally set and externally marked**. The exam is 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** The exam specification shows the coverage of the exam across the qualification content. 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.) For exam dates, please refer to the Assessment and Examination timetable.
031	Synoptic assignment	The synoptic assignment is externally set, internally marked and externally moderated. The assignment requires 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. Assignments will be released to centres as per dates indicated in the Assessment and Examination timetable published on our website. 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. 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.

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

The typical assignment brief could be to respond to a design problem for a newly engineered product or adapting an existing product.

This will require the candidate to carry out experiments on a prototype to evaluate the suitability of different materials. Learners will produce a design specification, with drawings, for a design that meets the brief and produce a production plan for its manufacture. They will need to produce a report on developing the design into a commercial product.

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.

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	Level 3 Advanced Technical Certificate in Engineering Typical expected evidence of knowledge, understanding and skills	Approximate weighting (Assignment)
AO1 Recalls knowledge from across the breadth of the qualification.	Mechanical and design calculations, identification of mechanical component parts, technological terms, mechanical theory, manufacturing operations, CAD system operations, product planning terms, product planning theory, report writing principles.	20%
AO2 Demonstrates understanding of concepts, theories and processes from across the breadth of the qualification.	Relationship between mechanical interface of equipment design and human use, relationship between mechanical components, selection of components, capabilities and functionality of load cell, parameters for experimentation, properties of materials and components, manufacturing planning processes, manufacturing processes, structural and design performance characteristics.	20%
AO3 Demonstrates technical skills from across the breadth of the qualification.	Degree of accuracy, features of CAD software used effectively, manual dexterity in experimentation, 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 mechanical components in CAD, representation of mechanical features using CAD, application of understanding of product planning, application of understanding of measurement to testing of mechanical components, application of understanding of material properties and manufacturing processes for the development of a design.	20%
AO5 Demonstrates perseverance in achieving high standards and	Meeting specific requirements of the task, attention to detail when completing drawings and assemblies (accuracy, neatness, annotation,	20%

attention to detail while showing an understanding of wider impact of their actions.	orientation of components, structural integrity, finishing).

Exam specification

AO weightings per exam

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

The way the exam covers the content of the qualification is laid out in the table 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**

*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 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. This process is outlined below. For more detailed information, please refer to 'Marking and moderation - Technicals centre guidance' 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 work[4] the centre is required to conduct internal standardisation to ensure that all work at the centre has been marked to the same standard. It is the Internal Quality Assurer's (IQA'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.

Provision for reworking evidence after submission for marking by the tutor

It is expected that in many cases a candidate who is struggling with a specific piece of work may themselves choose to restart and rectify the situation during their normal allocated time, and before it gets to the stage of it being handed in for final marking by the tutor.

In exceptional circumstances however, where a candidate has completed the assignment in the required timescales, and has handed it in for marking by the tutor but is judged to have significantly underperformed, may be allowed to rework or supplement their original evidence for remarking prior to submission for moderation. For this to be allowed, the centre must be confident that the candidate will be able to improve their performance without additional feedback from their tutor and within the required timescales ie the candidate has shown they can perform sufficiently better previously in formative assessments.

The reworked and/or supplemented original evidence must be remarked by the tutor in advance of the original moderation deadline and the moderator informed of any candidates who have been allowed to resubmit evidence.

The process must be managed through the IQA. The justification for allowing a resubmission should be recorded and made available on request. The use of this provision will be monitored by City & Guilds.

[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.

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 for moderation. 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.

Centres cannot appeal the outcome of moderation for individual candidates, only the moderation process itself. A request for a review of the moderation process should be made to **appeals@cityandguilds.com**.

Moderation

Moderation is the process where external markers are standardised to a national standard in order to review centre marking of internally marked assessments. These markers are referred to as 'moderators'. Moderators will mark a representative sample of candidates' work 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 correctly, 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 will be made to the marks of the whole cohort, retaining the centre's rank ordering.

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. This may be carried out by the centre based on feedback provided by the moderator, or carried out by the moderator directly.

Moderation applies to all internally marked assignments. Following standardisation and marking, the centre submits all marks and candidate work to City & Guilds via the moderation platform. The deadline for submission of evidence will be available on Walled Garden. See the *Marking and moderation - Technicals Centre Guidance* document for full details of the requirements and process.

In most cases candidate work will be submitted directly to the moderator for moderation. This includes written work, photographic and pictorial evidence, or video and audio evidence. For some qualifications there will be a requirement for moderators to visit centres to observe practical assessments being undertaken. This will be for qualifications where the assessment of essential learner skills can only be demonstrated through live observation. The purpose of these visits is to ensure that the centre is assessing the practical skills to the required standards, and to provide the moderators with additional evidence to be used during moderation. These visits will be planned in advance with the centre for all relevant qualifications.

Post-moderation procedures

Once the moderation process has been completed, the confirmed marks for the cohort are provided to the centre along with feedback from the moderator on the standard of marking at the centre, highlighting areas of good practice, and potential areas for improvement. This will inform future marking and internal standardisation activities.

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.

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 **Level 3 Advanced Technical Certificate in Engineering** will be reported on a four grade scale: Pass, Merit, 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 assignment in this qualification is

Synoptic assignment	Pass mark (%)
031	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	X/P/M/D	60%
Exam	X/P/M/D	40%

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. A 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: 60%	6	12	18
Exam: 40%	6	12	18

The candidate's points for each assessment are multiplied by the % contribution of the assessment and then aggregated. The minimum points required for each qualification grade are as follows:

Qualification Grade	Points
Distinction*	20.5
Distinction	17
Merit	11
Pass	6

Candidates achieving 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.

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 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 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 internally marked assessments.

For further details on enquiries and appeals process and for copies of the application forms, please visit the **appeals page** of the City & Guilds website at **www.cityandguilds.com.**

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 and special consideration

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**

Unit 301 Engineering Materials

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 materials to satisfy particular specifications. You will consider the effects of heat treatment, 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. Identify 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.

Unit 302 Electronics, Control and Instrumentation

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 (Kp), derivative gain (Kd)
- Integral gain (Ki).

Topic 4.6
Learners must be able to use and apply the following formulae:

- controller output = Kp(error + Ki x integral of error + Kd x derivative of error)
- output = $kp(e+ki\int e + kd\, de/dt)$.

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.

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

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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.

Unit 303 Mechanical Structures and Dynamics

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 is 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 ½mv2 and ½Iω2
- stored energy S.E. = ½ 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 = 9.81ms-2)
- Velocity and acceleration using:

$$v = \frac{ds}{dt} \qquad a = \frac{dv}{dt}$$

$$v = u + at, \qquad s = ut + \tfrac{1}{2}at^2$$

$$s = ut + \tfrac{1}{2}at^2 \qquad v^2 = u^2 + 2as$$

- 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 behind engines and heat pumps

Topics

4.1 First Law of Thermodynamics
4.2 Ideal gas law
4.3 The ρ - 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 ρ - V diagram) shows corresponding changes in volume and pressure in a system. They must be able to calculate the work done under constant pressure $W = \rho\Delta V$ 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 the 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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Employer engagement

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Unit 304 Manufacturing Methods in Engineering

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 (e.g.: 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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Unit 305 Engineering Design

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 told 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.

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.

Unit 306 Engineering Mathematics and Statistics

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
- $y=a^x$ 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.

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**

If you have a complaint, or any suggestions for improvement about any of the services that we provide, email: **feedbackandcomplaints@cityandguilds.com**

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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