City & Guilds Level 3 Diploma/Extended Diploma in Advanced Manufacturing Engineering (Development Knowledge) (4515-03/04)

February 2022 Version 3.0

Qualification Handbook

Qualification at a glance

Subject area	Engineering
City & Guilds number	4515
Age group approved	16+
Entry requirements	None
Assessment	Short Answer, Centre Devised or City & Guilds Devised
Approvals	Fast track approval
Support materials	Assessment pack
Registration and certification	Consult the Walled Garden/Online Catalogue for last dates

Title and level	GLH	TQT	City & Guilds qualification number	Ofqual accreditation number
Level 3 Diploma in Advanced Manufacturing Engineering (Development Knowledge)	700	781	4515-03	603/6678/3
Level 3 Extended Diploma in Advanced Manufacturing Engineering (Development Knowledge)	900	989	4515-04	603/6679/5

Version and date	Change detail	Section
1.0 Aug 2020	Document creation	
2.0 June 2021	Added optional City & Guilds devised assessments	4
3.0 Feb 2022	GLH and TQT clarified and highlighted	Qualification at a glance and Total qualification time

Contents

1 Introduction

This document tells you what you need to do to deliver the qualifications:

Area	Description
Who is are the qualifications for?	Those working as mechanical engineers within the engineering and manufacturing sector.
What do the qualifications cover?	This qualification allows learners to develop the knowledge and skills required for employment and/or career progression in the engineering and manufacturing industry sector in general.
What opportunities for progression are there?	Upon completion, apprentices will have achieved the on-programme qualification. This is a mandatory component of the level 3 Metal Fabricator and Engineering Fitter apprenticeship framework. Whilst progression into further study is an option, the intent for this standard is that progression is into one of the job roles defined within the standard as a manufacturing engineer.
Who did we develop the qualification with?	This qualification has been developed in collaboration with GTA England, a membership organization with 31 training providers. Notable Members include Gen2, Siemens and Rolls Royce.
Is it part of an apprenticeship framework or initiative?	Yes. This qualification forms part of the on-programme Metal Fabricator and Engineering Fitter apprenticeship standards. The qualification can also be used for full time students who would like to gain the knowledge that will enable them to progress into further training.

Structure

City & Guilds Level 3 Diploma in Advanced Manufacturing Engineering (Development Knowledge)

All learners must complete the mandatory units (301, 302, 303), plus a minimum of 8 units from the optional group (304-338)

City & Guilds Level 3 Extended Diploma in Advanced Manufacturing Engineering (Development Knowledge)

All learners must complete the mandatory units (301, 302, 303), plus a minimum of 11 units from the optional group (304-338)

Unit number	Unit title	GLH	Credit value
Mandatory			
301	Health and safety in the engineering workplace	50	n/a
302	Communication and teamwork in engineering	50	n/a
303	Applied science and maths for engineering	50	n/a
Optional			n/a
304	Principles of fabrication processes	70	n/a
305	Principles of welding processes	70	n/a
306	Platework fabrication of materials	70	n/a
307	Sheet metalwork fabrication of materials	70	n/a
308	Fabrication and erection of structural steelwork	70	n/a
309	Pattern development for fabrication	70	n/a
310	Pipe and tube fabrication	60	n/a
311	Mechanical principles of engineering systems	50	n/a
312	Engineering maintenance procedures and techniques	60	n/a
313	Principles of electrical and electronic circuits	60	n/a
314	Electrical and electronic measurement, testing and fault diagnosis	60	n/a
315	Principles of three-phase systems	60	n/a
316	Electrical installation	60	n/a
317	Principles and applications of fluid mechanics	60	n/a
318	Engineering drawing	50	n/a
319	Computer aided design	60	n/a
320	Manufacturing planning	60	n/a
321	Properties and application of engineering materials	60	n/a
322	Principles of machining processes	60	n/a
323	Computer aided manufacturing	60	n/a

324	Principles of engineering measurement	60	n/a
325	Project management	60	n/a
326	Further mathematics for engineers	60	n/a
327	Advanced mechanical principles of engineering systems	60	n/a
328	Organisational improvement	60	n/a
329	Business operations in engineering	60	n/a
330	Primary manufacturing processes	60	n/a
331	Principles of composite materials	60	n/a
332	Industrial process control	60	n/a
333	Automation and robotic technology	60	n/a
334	Leading a team	60	n/a
335	TIG welding of materials	70	n/a
336	MIG and FCAW welding of materials	70	n/a
337	MMA welding of materials	70	n/a
338	Electronic circuit design and manufacture	60	n/a

Total Qualification Time

Total Qualification Time (TQT) is the total amount of time, in notional hours, which represents an estimate of the total amount of time expected for a learner to achieve and demonstrate the achievement of the level of attainment a necessary to award a qualification.

TQT is comprised of the following two elements:

1) The number of hours which an awarding organisation has assigned to a qualification for Guided Learning, and
2) An estimate of the number of hours a learner will be likely to spend in preparation, study or any other form of participation in education or training, including assessment, which takes place as directed by - but, not under the immediate guidance or supervision of a lecturer, supervisor, tutor or other education or training provider.

Title and level	GLH	TQT
City & Guilds Level 3 Diploma in Advanced Manufacturing Engineering (Development Knowledge)	700	781

Title and level	GLH	TQT
City & Guilds Level 3 Extended Diploma in Advanced Manufacturing Engineering (Development Knowledge)	900	989

2 Centre requirements

Approval

If your Centre is approved to offer the qualifications:

Level 3 Diploma in Engineering – Welding (2850-30)

Level 3 Diploma in Engineering – Fabrication (2850-31)

Level 3 Diploma in Engineering - Fabrication and Welding (2850-32)

Level 3 Diploma in Engineering - Maintenance, Installation and Commissioning (2850-33)

Level 3 Diploma in Engineering - Mechanical Manufacturing Engineering (2850-34)

Level 3 Diploma in Engineering - Electrical & Electronics Engineering (2850-35)

then you can apply for approval for the new Level 3 Diploma in Advanced Manufacturing Engineering (Development Knowledge) using the **fast track approval form**, available from the City & Guilds website.

Centres should use the fast track form if:

- there have been no changes to the way the qualifications are delivered, and
- they meet all of the approval criteria in the fast track form guidance notes.

Fast track approval is available for 12 months from the launch of the qualification. After 12 months, the Centre will have to go through the standard Qualification Approval Process. The centre is responsible for checking that fast track approval is still current at the time of application.

To offer these qualifications, new centres will need to gain both centre and qualification approval. Please refer to the *City & Guilds Centre Manual* for further information.

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

Internal quality assurance

Approved centres must have effective quality assurance systems to ensure optimum delivery and assessment of qualifications.

Quality assurance includes initial centre approval, qualification approval and the centre's own internal procedures for monitoring quality. Centres are responsible for internal quality assurance and City & Guilds is responsible for external quality assurance.

Standards and rigorous quality assurance are maintained by the use of:

- Internal quality assurance
- City & Guilds external quality assurance.

In order to carry out the quality assurance role, Internal Quality Assurers must have appropriate teaching and vocational knowledge and expertise. Assessor/Verifier (A/V) units are valued as qualifications for the centre, but they are not currently a requirement for this qualification.

Additionally, those involved in internal quality assurance must:

- have experience in quality management/internal verification
- hold or be working towards an appropriate teaching/training/assessing qualification
- be familiar with the occupation and technical content covered within the qualification.

Resource requirements

Centre staffing

Staff delivering these qualifications must be able to demonstrate that they meet the following occupational expertise requirements. They should:

- be occupationally competent or technically knowledgeable in the area[s] for which they are delivering training and/or have experience of providing training. This knowledge must be to the same level as the training being delivered
- have recent relevant experience in the specific area they will be assessing
- have credible experience of providing training.

See also page 16 for details from the assessment strategy on the role of supervisors and managers in the assessment process.

Centre staff may undertake more than one role, eg tutor and assessor or internal verifier, but cannot internally verify their own assessments. They must:

- be technically knowledgeable in the area(s) for which they are delivering training/assessing, with appropriate qualifications.

Learner entry requirements

City & Guilds does not set entry requirements for these qualifications. However, centres must ensure that candidates have the potential and opportunity to gain the qualifications successfully.

Individual employers will set the criteria, but employers who recruit learners without English and Maths at level 1 (or equivalent), must ensure that the learner achieves this requirement and take the test for Level 2, prior to completion of the Apprenticeship.

This qualification is a mandatory component of the on-programme phase of the Engineering Fitter, Engineering Technician and Metal Fabricator Apprenticeship Standards for the following occupational engineering job roles: mechanical fitter, electrical fitter, electronic fitter, instrumentation fitter, pipe fitter, controls and systems fitter, metal fabricator, mechatronics maintenance technician, product design and development technician, toolmaker and tool and die maintenance technician, technical support technician.

The Standard and Assessment plan was designed by Employers. Centres should make themselves familiar with the Standard, Assessment Plan and Employer Occupational Brief requirements, details of which can be found at: https://www.gov.uk/government/collections/apprenticeship-standards

Age restrictions

City & Guilds cannot accept any registrations for candidates under 16 as these qualifications are not approved for under 16s.

3 Delivering the qualification

Initial assessment and induction

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

- if the candidate has any specific training needs,
- support and guidance they may need when working towards their qualifications.
- any units they have already completed, or credit they have accumulated which is relevant to the qualifications.
- the appropriate type and level of qualification.

We recommend that centres provide an induction programme so the candidate fully understands the requirements of the qualification[s], their responsibilities as a candidate, and the responsibilities of the centre. This information can be recorded on a learning contract.

Support materials

The following resources are available for these qualifications:

Description	How to access
Fast track approval form	www.cityandguilds.com
SmartScreen	www.smartscreen.co.uk

Recording documents

Candidates and centres may decide to use a paper-based or electronic method of recording evidence.

City & Guilds endorses several ePortfolio systems, including our own, **Learning Assistant**, an easy-to-use and secure online tool to support and evidence learners' progress towards achieving qualifications. Further details are available at: **www.cityandguilds.com/eportfolios**.

City & Guilds has developed a set of *Recording forms* including examples of completed forms, for new and existing centres to use as appropriate. *Recording forms* are available on the City & Guilds website.

Although new centres are expected to use these forms, centres may devise or customise alternative forms, which must be approved for use by the external verifier, before they are used by candidates and assessors at the centre. Amendable (MS Word) versions of the forms are available on the City & Guilds website.

4 Assessment

Summary of assessment methods

Candidates must:

- successfully complete one assignment for each mandatory unit
- successfully complete one assignment for each chosen optional unit

City & Guilds has written assessments, including a sample assessment, for the following units. These assessments are 'externally set, internally marked.'

- Short answer tests for Mandatory unit 301
- Short answer tests for Mandatory unit 302
- Short answer tests for Mandatory unit 303
- Short answer tests for Optional unit 304
- Short answer tests for Optional unit 305
- Short answer tests for Optional unit 311
- Short answer tests for Optional unit 312
- Short answer tests for Optional unit 313
- Short answer tests for Optional unit 322
- Short answer tests for Optional unit 326
- Short answer tests for Optional unit 327

City & Guilds provides guidance for centres to write their own internally set and marked assessments/assignments. (see separate Centre Devised Assessments guidance).

Centres may choose whether to create their own assessments, or use the assessments devised by City & Guilds.

Assessment Types			
Unit	**Title**	**Assessment method**	**Where to obtain assessment materials**
301	Health and safety in the engineering workplace	Externally set, internally marked assessment Or Centre devised, internally set and marked assessment	**www.cityandguids.com** City & Guilds has written guidance for centres to write their own assessments/assignments.
302	Communication and teamwork in engineering	Externally set, internally marked assessment Or Centre devised, internally set and marked assessment	**www.cityandguids.com** City & Guilds has written guidance for centres to write their own assessments/assignments.
303	Applied science and maths for engineering	Externally set, internally marked assessment Or Centre devised, internally set and marked assessment	**www.cityandguids.com** City & Guilds has written guidance for centres to write their own assessments/assignments.
304	Principles of fabrication processes	Externally set, internally marked assessment Or Centre devised, internally set and marked assessment	**www.cityandguids.com** City & Guilds has written guidance for centres to write their own assessments/assignments.
305	Principles of welding processes	Externally set, internally marked assessment Or Centre devised, internally set and marked assessment	**www.cityandguids.com** City & Guilds has written guidance for centres to write their own assessments/assignments.
306	Platework fabrication of materials	Centre devised, internally set and marked assessment	City & Guilds has written guidance for centres to write their own assessments/assignments.
307	Sheet metalwork fabrication of materials	Centre devised, internally set and marked assessment	City & Guilds has written guidance for centres to write their own assessments/assignments.
308	Fabrication and erection of structural steelwork	Centre devised, internally set and marked assessment	City & Guilds has written guidance for centres to write their own assessments/assignments.
309	Pattern development for fabrication	Centre devised, internally set and marked assessment	City & Guilds has written guidance for centres to write their own assessments/assignments.
310	Pipe and tube fabrication	Centre devised, internally set and marked assessment	City & Guilds has written guidance for centres to write their own assessments/assignments.

311	Mechanical principles of engineering systems	Externally set, internally marked assessment Or Centre devised, internally set and marked assessment	**www.cityandguids.com** City & Guilds has written guidance for centres to write their own assessments/assignments.
312	Engineering maintenance procedures and techniques	Externally set, internally marked assessment Or Centre devised, internally set and marked assessment	**www.cityandguids.com** City & Guilds has written guidance for centres to write their own assessments/assignments.
313	Principles of electrical and electronic circuits	Externally set, internally marked assessment Or Centre devised, internally set and marked assessment	**www.cityandguids.com** City & Guilds has written guidance for centres to write their own assessments/assignments.
314	Electrical and electronic measurement, testing and fault diagnosis	Centre devised, internally set and marked assessment	City & Guilds has written guidance for centres to write their own assessments/assignments.
315	Principles of three-phase systems	Centre devised, internally set and marked assessment	City & Guilds has written guidance for centres to write their own assessments/assignments.
316	Electrical installation	Centre devised, internally set and marked assessment	City & Guilds has written guidance for centres to write their own assessments/assignments.
317	Principles and applications of fluid mechanics	Centre devised, internally set and marked assessment	City & Guilds has written guidance for centres to write their own assessments/assignments.
318	Engineering drawing	Centre devised, internally set and marked assessment	City & Guilds has written guidance for centres to write their own assessments/assignments.
319	Computer aided design	Centre devised, internally set and marked assessment	City & Guilds has written guidance for centres to write their own assessments/assignments.
320	Manufacturing planning	Centre devised, internally set and marked assessment	City & Guilds has written guidance for centres to write their own assessments/assignments.
321	Properties and application of engineering materials	Centre devised, internally set and marked assessment	City & Guilds has written guidance for centres to write their own assessments/assignments.

322	Principles of machining processes	Externally set, internally marked assessment Or Centre devised, internally set and marked assessment	**www.cityandguids.com** City & Guilds has written guidance for centres to write their own assessments/assignments.
323	Computer aided manufacturing	Centre devised, internally set and marked assessment	City & Guilds has written guidance for centres to write their own assessments/assignments.
324	Principles of engineering measurement	Centre devised, internally set and marked assessment	City & Guilds has written guidance for centres to write their own assessments/assignments.
325	Project management	Centre devised, internally set and marked assessment	City & Guilds has written guidance for centres to write their own assessments/assignments.
326	Further mathematics for engineers	Externally set, internally marked assessment Or Centre devised, internally set and marked assessment	**www.cityandguids.com** City & Guilds has written guidance for centres to write their own assessments/assignments.
327	Advanced mechanical principles of engineering systems	Externally set, internally marked assessment Or Centre devised, internally set and marked assessment	**www.cityandguids.com** City & Guilds has written guidance for centres to write their own assessments/assignments.
328	Organisational improvement	Centre devised, internally set and marked assessment	City & Guilds has written guidance for centres to write their own assessments/assignments.
329	Business operations in engineering	Centre devised, internally set and marked assessment	City & Guilds has written guidance for centres to write their own assessments/assignments.
330	Primary manufacturing processes	Centre devised, internally set and marked assessment	City & Guilds has written guidance for centres to write their own assessments/assignments.
331	Principles of composite materials	Centre devised, internally set and marked assessment	City & Guilds has written guidance for centres to write their own assessments/assignments.
332	Industrial process control	Centre devised, internally set and marked assessment	City & Guilds has written guidance for centres to write their own assessments/assignments.

333	Automation and robotic technology	Centre devised, internally set and marked assessment	City & Guilds has written guidance for centres to write their own assessments/assignments.
334	Leading a team	Centre devised, internally set and marked assessment	City & Guilds has written guidance for centres to write their own assessments/assignments.
335	TIG welding of materials	Centre devised, internally set and marked assessment	City & Guilds has written guidance for centres to write their own assessments/assignments.
336	MIG and FCAW welding of materials	Centre devised, internally set and marked assessment	City & Guilds has written guidance for centres to write their own assessments/assignments.
337	MMA welding of materials	Centre devised, internally set and marked assessment	City & Guilds has written guidance for centres to write their own assessments/assignments.
338	Electronic circuit design and manufacture	Centre devised, internally set and marked assessment	City & Guilds has written guidance for centres to write their own assessments/assignments.

Time constraints

The following must be applied to the assessment of this qualification:

- Assessments should take no longer than 2 hours. The duration of each unit assessment is detailed below.

Assessment strategy

All units are assessed by short-answer question tests/assignments. These assessments are graded Pass/Fail only.

Test specifications

The way the knowledge is covered by each test is laid out in the tables below:

Assessment title: 4515-301 Health and Safety in the Engineering Workplace
Assessment type: Externally set short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 90 minutes		
Unit	**Outcome**	**Number of marks**	**%**
301	1. Understand the requirements of health and safety regulations	14	28
301	2. Understand and implement operational safe working practices and procedures	26	52
301	3. Understand how environmental regulations affect the activities of the engineering industry	10	20
	Total	**50**	**100**

Assessment title: 4515-302 Communication and Teamwork in Engineering
Assessment type: Externally set short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 90 minutes		
Unit	**Outcome**	**Number of marks**	**%**
302	1. Understand how to communicate general and technical information in engineering businesses	14	28
302	2. Understand the characteristics of effective teams	24	48
302	3. Understand how to resolve conflict within a team	12	24
	Total	**50**	**100**

Assessment title: 4515-303 Applied Science and Maths for Engineering
Assessment type: Externally set short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
303	1. Apply mathematical methods to engineering problems	20	33
303	2. Understand how the structure of a material influences its properties	18	30
303	3. Understand how the transfer of energy affects materials and engineering systems	22	37
	Total	**60**	**100**

Assessment title: 4515-304 Principles of Fabrication Processes
Assessment type: Externally set short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
304	1. Understand how to classify common materials used in fabrication engineering	15	22
304	2. Understand the principles of bending, rolling, and shearing	12	17
304	3. Understand non-thermal joining methods	19	27
304	4. Understand the principles of oxy-fuel thermal cutting	12	17
304	5. Understand the principles of plasma cutting	4	6
304	6. Understand methods used for finishing fabricated components	8	11
	Total		**100**

Assessment title: 4515-305 Principles of Welding Processes
Assessment type: Externally set short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
305	1. Understand the principles of welding	11	16
305	2. Know how to interpret the standards and conventions used to represent welded joints	11	16
305	3. Understand the effects of distortion and residual stresses due to welding	20	28
305	4. Understand the metallurgical effects of welding	10	14
305	5. Understand how to determine the integrity of welded joints	18	26
	Total	**70**	**100**

Assessment title: 4515-306 Plate Fabrication of Materials
Assessment type: Centre devised short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
306	1. Apply safe working practices whilst fabricating platework	14	23
306	2. Understand the purpose of equipment and tools used with plate materials	22	37
306	3. Understand the methods used to and be able to produce platework fabrications	24	40
	Total	**60**	**100**

Assessment title: 4515-307 Sheet Metalwork Fabrication of Materials
Assessment type: Centre devised short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration:		
Unit	**Outcome**	**Number of marks**	**%**
307	1. Apply safe working practices whilst fabricating sheet metalwork	14	23
307	2. Understand the purpose of equipment and tools used with sheet metal materials	22	37
307	3. Understand the methods used to and be able to produce sheet metal fabrications	24	40
	Total	**60**	**100**

Assessment title: 4515-308 Fabrication and Erection of Structural Steelwork
Assessment type: Centre devised short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
308	1. Understand and apply safe working practices to steelwork fabrication and erection	14	20
308	2. Understand materials used for structural steelwork fabrication.	12	17
308	3. Understand and be able to perform marking out and cutting operations on structural materials	18	26
308	4. Understand and use methods to produce structural steelwork fabrications	26	37
	Total	**70**	**100**

Assessment title: 4515-309 Pattern Development for Fabrication
Assessment type: Centre devised short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
309	1. Be able to determine lines of intersection when developing patterns	16	23
309	2. Be able to develop patterns using parallel line techniques	14	20
309	3. Be able to develop patterns using radial line techniques	12	20
309	4. Be able to develop patterns using triangulation	14	20
309	5. Produce templates of developed patterns	12	17
	Total	**70**	**100**

Assessment title: 4515-310 Pipe and Tube Fabrication
Assessment type: Centre devised short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration:		
Unit	**Outcome**	**Number of marks**	**%**
310	1. Understand health and safety requirements in a pipe and tube fabrication environment	16	27
310	2. Understand how to prepare and plan for the production of pipe and tube fabrications	12	23
310	3. Be able to select and use equipment to fabricate pipe and tube	30	50
	Total	**60**	**100**

Assessment title: 4515-311 Mechanical Principles of Engineering Systems
Assessment type: Externally set short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 90 minutes		
Unit	**Outcome**	**Number of marks**	**%**
311	1. Determine the effects of loading in static engineering systems	18	36
311	2. Determine energy transfer in dynamic engineering systems	9	18
311	3. Understand the characteristics of fluid systems	11	22
311	4. Understand energy transfer in thermodynamic systems	12	24
	Total	**50**	**100**

Assessment title: 4515-312 Engineering Maintenance Procedures and Techniques
Assessment type: Externally set short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
312	1. Plan for maintenance tasks	16	27
312	2. Understand and be able to carry out maintenance procedures	20	33
312	3. Carry out maintenance by dismantling and inspecting components within equipment and systems	14	23
312	4. Reinstate, commission and handover equipment and systems	10	17
	Total	**60**	**100**

Assessment title: 4515-313 Principles of Electrical and Electronic Circuits
Assessment type: Externally set short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
313	1. Understand electrical and electronic engineering principles	20	33
313	2. Understand the functions and applications of electrical and electronic circuit components	32	54
313	3. Understand diagrams used to represent electrical and electronic circuits	8	13
	Total	**60**	**100**

Assessment title: 4515-314 Electrical and Electronic Measurement, Testing and Fault Diagnosis
Assessment type: Centre devised short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test: 014	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
314	1. Understand the function of, and be able to use, electrical and electronic measurement and test equipment	20	33
314	2. Understand the principles of calibration of electrical and electronic measurement and test equipment	16	27
314	3. Understand and be able to carry out fault diagnosis on electrical and electronic circuits	24	40
	Total	**60**	**100**

Assessment title: 4515-315 Principles of Three-Phase Systems
Assessment type: Centre devised short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
315	1. Understand the principles of three-phase systems	26	44
315	2. Understand the operation of three-phase motors and generators	20	33
315	3. Understand monitoring and protection equipment for three-phase systems	14	23
	Total	**60**	**100**

Assessment title: 4515-316 Electrical Installation
Assessment type: Centre devised short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
316	1. Understand sources of information required for electrical installations	22	37
316	2. Understand circuit protection methods and devices	10	17
316	3. Be able to install and test electrical circuits	28	46
	Total	**60**	**100**

Assessment title: 4515-317 Principles and Applications of Fluid Mechanics
Assessment type: Centre devised short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
317	1. Understand the properties of fluids	22	31
317	2. Understand the operation of hydrostatic devices and the action of hydrostatic fluids on immersed surfaces	10	13
317	3. Understand the application of hydrodynamic principles to the flow of fluids	22	31
317	4. Understand the application of aerodynamic flow principles to wind tunnel testing	18	25
	Total	**70**	**100**

Assessment title: 4515-318 Engineering Drawing for Technicians
Assessment type: Centre devised short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
318	1. Understand the purpose of drawings in an engineering environment	12	20
318	2. Understand engineering drawings	24	40
318	3. Be able to produce engineering drawings by hand	24	40
	Total	**60**	**100**

Assessment title: 4515-319 Computer Aided Design (CAD)
Assessment type: Centre devised short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test: 019	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
319	1. Understand the principles of computer aided design (CAD)	28	47
319	2. Be able to use CAD software to produce engineering representations	32	53
	Total	**60**	**100**

Assessment title: 4515-320 Manufacturing Planning
Assessment type: Centre devised short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
320	1. Understand the information required to plan a manufacturing process	12	20
320	2. Understand approaches to production planning	32	53
320	3. Be able to produce a production plan	16	27
	Total	**60**	**100**

Assessment title: 4515-321 Properties and Application of Engineering Materials
Assessment type: Centre devised short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
321	1. Understand the properties of materials	20	33
321	2. Understand methods by which the properties of materials can be changed	12	20
312	3. Understand failure mechanisms in materials	19	32
312	4. Understand thermodynamic heat transfer in materials	9	15
	Total	**60**	**100**

Assessment title: 4515-322 Principles of Machining Processes
Assessment type: Externally set short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
322	1. Understand the equipment used in machining processes	24	40
322	2. Understand the methods of power transmission in machine tools	20	33
322	3. Understand how to apply computer numerical control (CNC) to machine tools	16	27
	Total	**60**	**100**

Assessment title: 4515-323 Computer Aided Manufacturing
Assessment type: Centre devised short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
323	1. Understand the use of Computer Aided Manufacture (CAM) in engineering	14	23
323	2. Understand how CAM equipment is programmed and be able to create programs	28	47
323	3. Understand the operation of CAM equipment	18	30
	Total	**60**	**100**

Assessment title: 4515-324 Principles of Engineering Measurement
Assessment type: Centre devised short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 90 minutes		
Unit	**Outcome**	**Number of marks**	**%**
324	1. Understand the principles of engineering measurement	24	48
324	2. Understand the function of and be able to use measurement equipment	13	26
324	3. Understand the principles of calibration of measurement equipment	13	26
	Total	**50**	**100**

Assessment title: 4515-325 Project Management
Assessment type: Centre devised short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
325	1. Understand the importance of project management	10	16
325	2. Understand how to set up projects	16	27
325	3. Understand how to plan and monitor a project	22	37
325	4. Understand how to communicate project progress and review project performance	12	20
	Total	**60**	**100**

Assessment title: 4515-326 Further Mathematics for Engineers
Assessment type: Externally set short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
326	1. Apply algebraic methods and trigonometry	16	27
326	2. Apply principles of calculus	12	20
326	3. Apply the principles of complex numbers	16	27
326	4. Apply statistical methods in engineering contexts	16	26
	Total	**60**	**100**

Assessment title: 4515-327 Advanced Mechanical Principles of Engineering Systems
Assessment type: Externally set short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
327	1. Determine the effects of loading in static engineering systems and structures	33	55
327	2. Determine the characteristics of rotating systems	12	20
327	3. Determine the operating characteristics of simple lifting machines	15	25
	Total	**60**	**100**

Assessment title: 4515-328 Organisational Improvement
Assessment type: Centre devised short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
328	1. Understand production activities	12	20
328	2. Understand organisational approaches to business improvement	11	18
328	3. Understand lean manufacturing approaches to business improvement	23	38
328	4. Understand and apply statistical tools used for improvement of manufacturing activities	9	15
328	5. Understand the relationship between human resources and organisational improvement	5	9
	Total	**60**	**100**

Assessment title: 4515-329 Business Operations in Engineering
Assessment type: Centre devised short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
329	1. Understand how an engineering company operates	24	40
329	2. Understand how external factors affect the operation of an engineering company	18	30
329	3. Understand and be able to analyse the factors affecting financial performance of an engineering activity	18	30
	Total	**60**	**100**

Assessment title: 4515-330 Primary Manufacturing Processes
Assessment type: Centre devised short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
330	1. Understand the health and safety requirements that apply to primary manufacturing processes	12	20
330	2. Understand how shaping processes are used with metals, polymers and ceramics	16	27
330	3. Understand how forming processes are used with metals and polymers	16	27
330	4. Understand how composite materials are made by moulding	16	26
	Total	**60**	**100**

Assessment title: 4515-331 Principles of Composite Materials
Assessment type: Centre devised short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
331	1. Understand the principles and components of composite materials	20	34
331	2. Understand how the matrix material influences the manufacture of fibre-reinforced composite materials	12	20
331	3. Understand the materials and techniques used with pre-impregnated (pre-preg) and pre-formed (pre-form) materials	11	18
331	4. Understand the materials and techniques used in dry fibre moulding	9	15
331	5. Understand types of defects arising during the manufacture of composites and how adhesive and bonding materials are used for composite structures	8	13
	Total	**60**	**100**

Assessment title: 4515-332 Industrial Process Control
Assessment type: Centre devised short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
332	1. Understand the principles of industrial process control systems	22	37
332	2. Understand the function of, and be able to program, programmable logic controllers (PLCs)	30	50
332	3. Understand input and output devices used in industrial process control systems	8	13
	Total	**60**	**100**

Assessment title: 4515-333 Automation and Robotic Technology
Assessment type: Centre devised short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 90 minutes		
Unit	**Outcome**	**Number of marks**	**%**
333	1. Understand the principles of robotic operations	14	28
333	2. Understand the operation of sensors	10	20
333	3. Program a robotic system	20	40
333	4. Understand the safe operation of robotic systems	6	12
	Total	**50**	**100**

Assessment title: 4515-334 Leading a Team
Assessment type: Centre devised short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
334	1. Understand approaches to leading a team	18	30
334	2. Understand how teams develop and function	20	33
334	3. Understand types of communication used in engineering businesses	6	10
334	4. Understand how to resolve problems and conflict in the workplace	16	27
	Total	**60**	**100**

Assessment title: 4515-335 TIG Welding of Materials
Assessment type: Centre devised short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
335	1. Understand and apply safe working practices whilst TIG welding	14	20
335	2. Understand TIG welding equipment and shielding gases	18	26
335	3. Perform TIG welding operations.	24	34
335	4. Undertake the testing of welded joints.	14	20
	Total	**70**	**100**

Assessment title: 4515-336 MIG/MAG and Flux Cored Welding of Materials
Assessment type: Centre devised short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
336	1. Understand and apply safe working practices whilst MIG welding	14	20
336	2. Understand MIG welding equipment and shielding gases	18	26
336	3. Perform MIG welding operations	24	34
336	4. Undertake the testing of welded joints	14	20
	Total	**70**	**100**

Assessment title: 4515-337 Manual Metal Arc (MMA) Welding of Materials
Assessment type: Centre devised short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
337	1. Understand and apply safe working practices whilst MMA welding	14	20
337	2. Understand MMA welding equipment	18	26
337	3. Perform MMA welding operations	24	34
337	4. Undertake the testing of welded joints	14	20
	Total	**70**	**100**

Assessment title: 4515-338 Electronic Circuit Design and Manufacture
Assessment type: Centre devised short answer test
Assessment conditions: Supervised examination conditions
Grading: P/X

Test:	Duration: 120 minutes		
Unit	**Outcome**	**Number of marks**	**%**
338	1. Understand and be able to use methods of designing electronic circuits	18	30
338	2. Understand and be able to use PCB production methods	24	40
338	3. Understand and be able to use PCB assembly methods	18	30
	Total	**60**	**100**

Recognition of prior learning (RPL)

Recognition of prior learning means using a person's previous experience or qualifications which have already been achieved to contribute to a new qualification.

RPL is allowed and is also sector specific.

5 Units

Structure of the units

These units each have the following:

- City & Guilds reference number
- Title
- Level
- Guided learning hours (GLH)
- Learning outcomes, which are comprised of a number of assessment criteria.

Unit 301 Health and Safety in the Engineering Workplace

Unit Level:	Level 3
GLH:	50
Unit Aim:	The aim of this unit is for learners to develop their knowledge of health and safety in an engineering workplace. They will learn about the main legislative requirements and the key responsibilities of those working in engineering. Learners will understand typical workplace safe working practices and procedures. They will also develop understanding of how environmental regulations affect the activities of the engineering industry

Learning Outcome

The learner will:

1. Understand the requirements of health and safety regulations

Assessment Criteria

The learner can:

1.1 Explain the purpose of legislation within the engineering industry

1.2 Describe the main requirements of the health and safety regulations applicable to engineering operations

1.3 Explain what is meant by 'as far as is reasonably practicable'

1.4 Explain employers' and employees' responsibilities to maintain health and safety

1.5 Describe the roles, responsibilities and authority of health and safety personnel

Range

AC1.1 Purpose of legislation within the engineering industry

- Why there is a need for the legislation
- That there is legislation to cover every aspect of the workplace
- How the legislation keeps them safe in the workplace
- Who is responsible for compliance with the regulations
- Health and safety culture, training and information.

AC1.2 Regulations:

- The Health and Safety at Work Act
- Management of Health and Safety at Work Regulations
- Provision and Use of Work Equipment Regulations (PUWER)
- Personal Protective Equipment Regulations
- The Control of Noise at Work Regulations
- Manual handling operations regulations 1992
- "Fire Safety Order" 2005.
- Vibration at Work Regulations
- Electricity at Work Regulations 1989
- Display Screen Equipment Regulations
- The Health and Safety (First-Aid) Regulations 1981
- Reporting of Injuries, Diseases and Dangerous Occurrences Regulations
- Control of Substances Hazardous to Health (COSHH).

AC1.4 Responsibilities

Employers, to include:

- minimising risks in the handling, storage and transport of articles and substances
- instruction, training and supervision to maintain high standards of health and safety at work
- maintaining the workplace and its environment to be safe and minimising risk to health
- to provide a statement of general health and safety policy
- provide arrangements for safety representatives and safety committees
- ensure the safety of visitors, contractors and members of the public

Employees, to include:

- work safely so as not to cause injury to self and others in the vicinity
- not to attempt any work task unless trained and authorised to do so
- co-operate with the employer to enable the duties placed on the employer to be performed
- have regard of any duty or requirement imposed upon the employer or any other person under any of the statutory provisions
- not interfere with or misuse anything provided in the interests of health, safety or welfare

AC1.5 Health and safety personnel

- Health and Safety managers
- Health and Safety representatives
- Fire marshals and wardens
- First aid personnel
- Health and Safety Executive Inspectors
- Environmental Health Officers.

Learning Outcome

The learner will:

2. Understand and implement operational safe working practices and procedures

Assessment criteria

The learner can:

2.1 Explain the implementation of management of health and safety

2.2 Explain the process of risk assessment

2.3 Identify safety signs and hazardous substances

2.4 Explain the procedures involved with permits to work and lock out tag out (LOTO)

2.5 Explain the procedures and controls for prevention of electric shock

2.6 Explain the procedures involved when working in confined spaces

2.7 Explain the types of Personal Protective Equipment (PPE) and their uses.

Range

AC2.1 Management of Health and Safety:

- the four C's of positive health and safety (Competence, Control, Co-operation, Communication)
- hierarchy of control: elimination, reduction/substitution, isolation, controls, administration/training/safe system of work, PPE.

AC2.2 Risk assessment:

- Stages of risk assessment
  - identification of hazards
  - evaluation of risks (likelihood, severity, number of people effected)
  - implementation of control measures).

AC2.3 Safety signs:

Types

- Warning
- Mandatory
- Prohibition
- Emergency escape or first aid
- Firefighting.

Applications

- Shape
- Colour
- Pictogram.

AC2.4 Permit to work and LOTO:

- Purpose
- Content
- Types of permit to work, including hot work, electrical, pressure testing
- Persons authorised to issue permits
- Persons allowed to operate within the scope of the permit
- Lock out tag out procedures.
- LOTO accessories (including padlocks).

AC2.5 Electric shock

- Potential hazards arising from the use of electrical equipment

- Checking and inspection of cables
- Earthing
- Use of reduced voltage equipment

  Responding to incidents of electric shock (recognise victims of electric shock, safe methods of isolating electrical supply, safe methods of removal of victim from electricity supply).

AC2.6 Confined spaces:

- Definition of a confined working space
- Specific controls over working in confined spaces
- Safety equipment when working in confined spaces.

AC2.7 PPE:

- Types, including overalls, safety footwear, gloves, safety glasses/goggles, ear muffs, respiratory protective equipment (RPE)
- Types for specialist activities, including working at height (harness), welding, hot work.

Learning outcome

The learner will:

3. Understand how environmental regulations affect the activities of the engineering industry

Assessment criteria

The learner can:

3.1 Explain how the Environmental Management Systems standard (ISO 14001) applies to the engineering industry

3.2 Explain the main requirements of environmental legislation as it applies to the engineering industry

3.3 Describe the sources of energy and their benefits and limitations

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Range

AC3.1 ISO 14001

- Aims and objectives
- Benefits and consequences of ISO 14001

AC3.2 Environmental legislation

- Environmental Protection Act
- Pollution Prevention and Control Act
- Clean Air Act
- Radioactive Substances Act
- Controlled Waste Regulations
- Dangerous Substances
- Hazardous Waste Regulations

AC3.3 Sources of energy

- Fossil (oil, gas, coal)
- Renewable (solar, wind, tidal, biomass, geothermal)
- Nuclear

Unit 302 Communication and Teamwork in Engineering

Unit level:	Level 3
GLH:	50
Unit aim:	The aim of this unit is for learners to develop their understanding of how to communicate general and technical within an engineering business. They will understand the characteristics of effective teams, the causes of conflicts within teams and how these can be addressed.

Learning outcome

The learner will:

1. Understand how to communicate general and technical information in engineering businesses

Assessment criteria

The learner can:

1.1 Describe the principles and methods of communication
1.2 Explain factors that can affect the nature of communication
1.3 Explain barriers to communication and how these can be overcome
1.4 Explain the characteristics of business documentation and their typical uses
1.5 Explain the importance of clearly communicating technical information and the implications of miscommunication.

Range

AC1.1 Principles of communication:

- Two way process
- Exchange of information
- Content that can be understood by the audience

Methods

- Oral
- Non-verbal
- Written
- Formal
- Informal

AC1.2 Factors:

- Content (language, structure, organisation, legal requirements/constraints, relevance)
- Presentation (house style, tone, style)
- Context (audience, location, purpose, timescale)
- Currency.

AC1.3 Barriers to communication:

- Physical
- Technical
- Emotional
- Attitudinal.

AC1.4 Types of business documentation:

- Gantt charts
- Engineering drawings
- Bill of Materials (BoM)
- Production plans
- job cards
- quality test records
- Technical Reports
- Maintenance logs
- Risk assessments
- Emails.

Learning outcome

The learner will

2. Understand the characteristics of effective teams

Assessment criteria

The learner can:

2.1 Explain the roles and responsibilities of a team leader

2.2 Explain different leadership styles and their advantages and disadvantages

2.3 Explain how teams are formed

2.4 Explain the different roles that exist within a team and how these interact with each other

2.5 Explain the characteristics of an effective team.

Range

AC2.1 Roles and responsibilities:

- Setting objectives
- Resource allocation
- Managing workloads
- Motivating staff

- Conflict resolution
- Monitoring performance
- Communication
- Problem solving
- Meeting health and safety requirements.

AC2.2 Leadership styles:

- Autocratic
- Participative
- Delegative
- Teamworking
- Democratic
- Laissez-faire
- Coaching and mentoring.

AC2.3 Stages in team formation:

- Forming
- Storming
- Norming
- Performing.

AC2.4 Team roles as defined by Belbin:

- Co-ordinator
- Shaper
- Completer/finisher
- Implementer
- Monitor evaluator
- Plant
- Resource investigator
- Specialist
- Team worker.

AC2.5 Characteristics:

- Complimentary skills
- Managing time
- Responding to feedback from others
- Participating in group discussions and decision making
- Ability to reach consensus
- Suggesting solutions to problems
- Knowing when to be assertive

- Knowing how to give and receive constructive criticism
- Continuously developing personal attributes/skills.

Learning outcome

The learner will:

3 Understand how to resolve conflict within a team

Assessment criteria

The learner can:

3.1 Explain the difference between the root cause and symptoms of a problem

3.2 Explain the reasons for conflict within teams and ways to avoid them

3.3 Explain methods used to resolve conflict within teams.

Range

AC3.2 Reasons for conflict:

- Working within time constraints
- Insufficient resources
- Conflicting demands on resources
- Failing to achieve objectives
- Budget issues
- Differences of opinion
- Unpopular team leader decisions
- Team member aspirations and/or ambitions
- Individual skill levels
- Team member personalities.

Avoid conflict situations by:

- Compromise
- Considering the viewpoints of others
- Enquiring politely
- Timeliness when seeking advice or assistance
- Avoiding conflict and knowing when to withdraw from the situation
- Agreeing objectives
- Listening carefully
- Following reasonable requests from supervisors
- Offering help when colleagues are in need of assistance.

AC3.3 Methods:

- Negotiation
- Persuasion
- Compromise
- Mediation
- Arbitration
- Democratic.

Unit 303 Applied Science and Maths for Engineering

Unit Level:	Level 3
GLH:	60
Unit Aim:	Engineers apply mathematical methods and scientific knowledge to design effective products, manufacture products and solve problems. In this unit, you will apply mathematical principles of algebra, calculus, trigonometry and statistics to solve engineering problems. You will also develop understanding of the scientific principles that underpin the solutions to many engineering challenges.

Learning Outcome

The learner will:

1. Apply mathematical methods to engineering problems

Assessment Criteria

The learner can:

1.1 Apply arithmetic methods
1.2 Apply the principles of algebra
1.3 Apply the principles of trigonometry
1.4 Apply calculus
1.5 Apply statistical methods
1.6 Use mathematical principles and formulae to solve engineering problems

Range

AC1.1 Arithmetic methods:

- Perform simple arithmetic operations (addition, subtraction, multiplication, division) on integers and decimal numbers
- Work to a specified number of decimal places or significant figures
- Use rules of arithmetical preference (BODMAS) to solve simple equations
- Work to a specified number of decimal places or significant figures
- Use SI units and prefixes (base units: metre (m), kilogramme (kg), second (s), newton (N); compound units: metre per second (m/s), metre per second squared (m/s^2), newton metre (Nm), Pascal (Pa or N/m^2), mass per unit volume (kg/m^3))

- Carry out calculations using fractions and proportions
- Calculate ratios and scales
- Calculate percentages.

AC1.2 Algebraic methods:

- Simplify equations
- Manipulate equations to change the subject
- Apply laws of logarithms
- Use natural logarithms
- Use rules of indices.

AC1.3 Trigonometric methods:

- Apply Pythagoras theorem
- Apply trigonometric **relationships** (sine, cosine and tangent) to determine the dimensions in a triangle
- Apply sine and cosine **rules** to triangles
- Convert between Cartesian (x,y) and polar (r,Θ) co-ordinates where angles are in degrees
- Convert angles between radians and degrees.

AC1.4 Calculus:

- Interpret changes in an engineering system from a graph (straight line, trigonometrical and exponential relationships)
- Express equations of a straight line using a graph
- Determine the equation of a straight line from a graph ($y = mx + c$)
- Determine standard differentials and integrals (limited to functions using addition, subtraction, division, multiplication and powers)
- Calculate maximum and minimum values using differentiation.

AC1.5 Statistics:

- Range
- Cumulative frequency
- Determine averages (mean, mode, median)
- Calculate standard deviation.

AC1.6 Formulae:

- Area of 2D shapes (square, rectangle, triangle, circle, compound shapes)
- Volume of 3D shapes (cube, cuboid, cylinder, cone, compound shapes)
- Mass and density
- Velocity and acceleration
- Pressure
- Statistical process control: calculation of action limits and control limits.

Learning outcome

The learner will:

2. Understand how the structure of a material influences its properties

Assessment criteria

The learner can:

2.1 Describe the typical stress-strain graph for low carbon steel
2.2 Explain how the properties of metal are changed by cold working
2.3 Explain how heat treatment changes the properties of metals
2.4 Describe how polymers are formed from monomers
2.5 Explain how crosslinking affects the properties of polymers
2.6 Explain that the corrosion of metals is a chemical process
2.7 Explain how the rate of corrosion of metals can be reduced.

Range

AC2.1 Stress-strain graph:

- Tensile strength
- Transition zone
- Ultimate tensile strength
- Necking fracture
- Maximum plastic deformation
- Calculation of stress, strain and Young's modulus.

AC2.2 Cold working:

- Dislocation movement and pinning within the atomic structure

AC2.3 Heat treatment:

- Carbon steels: quenching, tempering, normalising and case hardening
- Aluminium alloys: precipitation hardening, annealing.

AC2.4 Polymer formation:

- How alkane structures (methane, ethane, butane and pentane) can be used to form polymers.

AC2.7 Methods to inhibit corrosion

- Separating the metal from its environment (painting, plastic coating)
- Use of the electrochemical series (galvanising, use of a sacrificial anode).

Learning outcome

The learner will:

3. Understand how the transfer of energy affects materials and engineering systems

Assessment criteria

The learner can:

3.1 Explain what is meant by convection, conduction and radiation and how these are used in engineering applications

3.2 Calculate the thermal expansion of a material

3.3 Describe the principal of the conservation of energy

3.4 Carry out calculations of kinetic energy and potential energy

3.5 Calculate the gear ratio, velocity ratio, mechanical advantage and efficiency of mechanical systems

3.6 Explain why metals are better conductors of electricity than ceramics or polymers

3.7 Calculate the current, voltage, power and resistance in electrical circuits.

Range

AC3.4 Calculations:

- Kinetic energy = ½ mv^2
- Potential energy = mgh

AC3.5 Mechanical systems:

- Gear trains
- Pulleys.

AC3.7 Electrical calculations:

- Ohm's law
- Electrical power
- Values of resistors in series and parallel.

Unit 304 Principles of Fabrication Processes

Unit Level:	Level 3
GLH:	70
Unit Aim:	This unit enables the leaner to understand the materials used in fabrication; the principles of bending rolling and shearing; how materials are cut and joined; and how fabricated components are finished.

Learning Outcome

The learner will:

1. Understand how to classify common materials used in fabrication engineering

Assessment Criteria

The learner can:

1.1 Describe the relative properties of materials used in fabrication engineering
1.2 Describe the commercial forms of supply of materials available
1.3 Explain the criteria used for the selection of materials for a given application
1.4 Describe different material structures
1.5 Explain how the structure of a material influences its properties
1.6 Explain how heat treatment changes the properties of metals.

Range

AC1.1 Materials:

- Metallic
  - Carbon steels (low, medium, high)
  - Low alloy steels
  - High yield steels
  - Stainless steels (austenitic, martensitic, ferritic)
  - Aluminium (pure, alloys)
  - Titanium (pure, alloys)
- Clad and coated materials
  - Galvanised steel
  - Tin plated steel
  - Clad steels

    - Anodised aluminium
    - Plastic coated steels
- Non-metallics
    - Polymers (thermosetting, thermoplastic)
    - Composites (glass fibre, carbon fibre, aramid fibre).

AC1.2 Forms of supply:

- Sheet
- Plate
- Bar
- Section (RSJ, channel, column, beam, tee, angle (equal leg, unequal leg)
- Hollow section (square, rectangular, round [tubular])
- Pipe
- Fibre reinforcing materials (FRP).

AC1.3 Selection criteria:

- Strength/weight ratio
- Resistant properties (heat, corrosion, wear resistance)
- Cost
- Weldability
- Mechanical properties (strength, malleability, ductility, rigidity, hardness).

AC1.4 Structures:

- Crystalline (fine grained, coarse grained, effect of grain size upon working properties)
- Chain molecules
- Amorphous.

AC1.5 Metallic structures:

- Fine grained
- Coarse grained
- Normalised grains
- Annealed grains.

AC1.6 Heat treatment:

- Hardening
- Tempering
- Normalising
- Annealing
- Precipitation hardening

Learning outcome

The learner will:

2. Understand the principles of bending, rolling, and shearing

Assessment criteria

The learner can:

2.1 Explain the principles of bending
2.2 Define the term neutral line as applied to bending and rolling
2.3 Explain the purpose of bending allowances
2.4 Explain the purpose of rolling allowances
2.5 Calculate allowances for a range of applications
2.6 Explain the principles of shearing.

Range

AC2.1 Principles of bending:

- Tensile stresses
- Compressive stresses
- Neutral plane
- Springback
- Compensation for springback
- Effect of material thickness
- Effect of material properties on bending.

AC2.3 Bending allowances:

- Definition
- Factors affecting calculations (material thickness, mechanical state, inside radius)
- K factor.

AC2.4 Rolling allowances:

- Definitions (diameter of cylinder, length/height of cylinder, circumference of cylinder)
- Presetting length required to avoid flats.

AC2.5 Applications:

- Bending (thin sheet, thick plate, pipe; right-angle bends, non-right-angle bends)
- Rolling (circular cylinders, elliptical cylinders, chutes).

AC2.6 Principles of shearing:

- Shear angle

- Rake angle
- Material clearance
- Shearing action (area under shear, shear force required)
- Mechanical advantage of lever system for hand-operated shears (bench, hand)
- Principle of moments for lever system for hand-operated shears (bench, hand)
- Piercing and blanking (area under shear, shear force required).

Learning outcome

The learner will:

3. Understand non-thermal joining methods

Assessment criteria

The learner can:

3.1 Explain the reasons for using different bolts, nuts and washers
3.2 Describe how bolts are used to make a joint
3.3 Describe the use of mechanical fastenings to make joints in thin plate
3.4 Describe joint configurations
3.5 Explain the benefits of using jigs and fixtures
3.6 Explain the applications of different types of adhesives
3.7 Describe how adhesives are used to make a joint
3.8 Calculate joining allowances.

Range

AC3.1 Bolts, nuts and washers:

- Bolt types (black bolts, high strength friction grip (HSFG), close tolerance bolts, fitted bolts, load indicating bolts, torshear)
- Nuts (plain, castellated, tapered, load indicating, nyloc)
- Washers (flat, spring, toothed).

AC3.2 Method:

- Cleanliness of contact surfaces
- Correct tensioning
- Hole diameters
- Tolerances
- Alignment of holes

AC3.3 Fastenings:

- Captive nuts
- Studs
- Self-tapping screws

- Special thin plate fastenings
- Rivets (solid, tubular, blind (pop rivets), self-piercing)
- Clinch nuts.

AC3.4 Joints:

- Lap joints
- Flanged joints
- Thermal/mechanical bonded
- Slip joints
- Flexible joints
- Threaded joints.

AC3.5 Benefits:

- Position of component(s)
- Joint alignment
- Mass production/repetitive work
- Distortion control
- Dimensional accuracy
- Economy of operation.

AC3.6 Types of adhesives:

- Heat activated
- Solvent activated
- Impact.

AC3.8 Joining allowances:

- Hole pitch
- Edge distance
- Hole diameters.

Learning outcome

The learner will:

4. Understand the principles of oxy-fuel thermal cutting

Assessment criteria

The learner can:

4.1 Explain the principles of oxy-fuel thermal cutting
4.2 Identify the types of gases available for oxy-fuel thermal cutting
4.3 Describe the flame used for oxy-fuel thermal cutting
4.4 Describe the equipment used for oxy-fuel thermal cutting
4.5 Describe the safe use of oxy-fuel cutting

4.6 Describe the applications of oxy-fuel cutting.

Range

AC4.1 Principles:

- Gas combustion
- Exothermic reaction.

AC4.2 Gases:

- Oxygen
- Acetylene
- Propane.

AC4.3 Flame:

- Conditions
- Neutral
- Oxidising
- Carburising/reducing
- Parts of the flame (inner cone, outer envelope, hottest point).

AC4.4 Equipment:

- Cylinders (identification i.e. colours, safe storage)
- Regulators
- Flash back arrestors
- Hoses
- Hose check valves
- Torches (controls, mixing chambers)
- Nozzles (one-part, two-part, selection related to material thickness)
- Component identification (left/right hand threads, notched nuts).

AC4.5 Safe use:

- PPE
- Cylinder handling and storage
- Gas pressures for cutting
- Safe procedures for flame ignition and extinguishing
- Fume particular and gaseous
- Methods of handling of hot metals
- Leak testing.

AC4.6 Applications:

- Cutting materials to shape (plates, pipes, structural sections)
- Piercing
- Bevel cutting (plates, pipes).

Learning outcome

The learner will:

5. Understand the principles of plasma cutting:

Assessment criteria

The learner can:

5.1 Explain the principles of plasma cutting
5.2 Describe the equipment used for plasma cutting.

Range

AC5.1 Principles:

- Definition of plasma
- Pilot arc
- Transferred arc.

AC5.2 Equipment:

- Torches (water cooled, air cooled)
- Nozzles.

Learning outcome

The learner will:

6. Understand methods used for finishing fabricated components

Assessment criteria

The learner can:

6.1 Describe the removal of surface contaminants prior to finishing
6.2 Explain the common causes of corrosion and degradation
6.3 Explain the methods of corrosion protection
6.4 Describe the application of surface coatings.

Range

AC6.1 Contaminants

- Scale
- Oxide
- Slag
- Excessive weld metal
- Spatter.

Methods:

- Wire brushing
- Sand/bead/ice blasting.

AC6.2 Causes:

- Oxidation of ferrous materials
- Direct chemical attack
- Electrolytic corrosion

AC6.3 Prevention methods:

- Painting
- Corrosion resistant cladding
- Metallic coatings (galvanising, electro-plating)
- Cathodic protection
- Anodic protection.

AC6.4 Application:

- Painting (brush, dip, spray)
- Metallic coatings (hot dip galvanising, electroplating).

Unit 305 Principles of Welding Processes

Unit Level:	Level 3
GLH:	70
Unit Aim:	This unit enables the leaner to understand the principles that enable effective welding to take place, without focusing on specific welding processes. This includes an understanding of the electric arc, welding consumables, joint types and how they are represented, distortion and residual stresses, metallurgical effects of welding and methods of determining the integrity of welded joints.

Learning Outcome

The learner will:

1. Understand the principles of welding

Assessment Criteria

The learner can:

1.1 Explain the characteristics of an electric arc
1.2 Explain the purpose of electrode coverings
1.3 Explain the effects of fluxes and electrode coverings/cores
1.4 Explain the purpose of shielding gases

Range

AC1.1 Electric arc:

- Voltage distribution across the arc
- Heat generation at the cathode and anode
- Arc characteristics (alternating current (AC), direct current (DC))
- Effects and influence of magnetic fields (arc blow)
- Factors that influence metal transfer (surface tension, gravity, electromagnetic (Lorentz) force, hydrodynamic forces due to gas flow, pinch effect).

AC1.2 Coverings:

- Rutile

- Basic
- Cellulosic.

AC1.3 Effects on:

- Arc (facilitates striking, stabilisation, direction)
- Metal transfer (size and frequency of filler metal droplets)
- Protection (atmospheric contamination, during transfer, prevents rapid cooling)
- Solidification (prevents contamination, weld contour, flux effect, additional metal/alloys).

AC1.4 Shielding gases:

- Inert (argon, helium)
- Mixtures containing Ar, He, CO_2, O_2, N_2.

Learning outcome

The learner will:

2. Know how to interpret the standards and conventions used to represent welded joints

Assessment criteria

The learner can:

2.1 Describe the difference between the features of welded joints

2.2 Describe the weld symbols for various joints, processes and preparations

2.3 Interpret weld dimensions as applied to welded joints.

Range

AC2.1 Features:

- General (face, toes, root, weld width, HAZ (heat affected zone) fusion zone (depth of fusion), excess weld metal, penetration, fusion line (boundary))
- Fillet joint profiles (convex, concave, mitred)
- Fillet joints (throat thickness, leg lengths)
- Butt joint (root face, root gap, root radius ('U' butt profile), land ('U' butt profile)
- Angles (bevel, included).

AC2.2 Symbols:

- Joint types (butt, tee, lap, corner, edge)
- Weld Preparations

- Butt (square (open/closed), flanged, single-vee, double-vee, single 'U', double 'U', fillet, single-bevel, double-bevel, single 'J', double 'J')
- Welding process (TIG, MIG, MAG, MMA, resistance (spot, seam))
- Conventions (arrow line, reference line, identification line, symbol, process identification)
- Supplementary information:
  - Fillet welds (nonsymmetrical, symmetrical)
  - Finishing (flush by grinding, flush by machining, convex, concave, toes blended smoothly)
  - Backing (sealing run, permanent, removable)
  - Other (peripheral welds, field/site welds)
  - Numerical indication of welding process.

AC2.3 Weld Dimensioning:

- Fillet welds (leg length, throat thickness, minimum penetration)
- Butt welds (root gaps, included angle, minimum penetration)
- Intermittent welds (weld length, gap, number, staggered symbol).

Learning outcome

The learner will:

3. Understand the effects of distortion and residual stresses due to welding

Assessment criteria

The learner can:

3.1 Explain the reasons for distortion due to welding
3.2 Classify types of distortion
3.3 Explain the methods of distortion control
3.4 Explain the methods of rectifying distortion
3.5 Explain the causes and effects of residual stress during welding
3.6 Explain the methods used to control residual stress.

Range

AC3.1 Reasons for distortion:

- Uneven expansion and contraction
- Degree of restraint.

AC3.2 Types:

- Longitudinal
- Transverse
- Angular
- Buckling

- Bowing
- Dishing
- Twisting.

AC3.3 Control:

- Presetting
- Pre-bending
- Sequencing (skip welding, back-stepping, balanced welding, intermittent welding)
- Tack welding
- Pre and post weld heat treatment
- Joint design
- Chills
- Restraint (clamping, jigs, back-to-back assembly).

AC3.4 Rectification methods:

- Mechanical (peening, jacking, pressing, bending, rolling, hammering, planishing)
- Thermal methods (heat strips, heat triangles)
- Combination of mechanical and thermal methods (hot working).

AC3.5 Residual stress:

- Causes (restraint due to uneven expansion and contraction [natural], restraint due to distortion)
- Effects (pattern across joint cross-section [areas of tension, areas of compression])
- Influence upon mechanical properties in service.

AC3.6 Methods:

- Clamping
- Fixtures
- Back-to-back assembly
- Balanced welding
- Stress relieving methods (normalising, thermal stress relief).

Learning outcome

The learner will:

4. Understand the metallurgical effects of welding

Assessment criteria

The learner can:

4.1 Explain heat distribution during welding
4.2 Describe sources of heat during welding
4.3 Explain the reasons for cracking due to welding.

Range

AC4.1 Heat distribution:

- Movement (thermal gradients, heat flow, weld thermal cycle)
- Material Effects (structure of the weld metal, structure of the parent metal)
- Heat-affected zone (HAZ)
- HAZ subzones (overheated, refining, transition).

AC4.2 Sources of heat:

- Difference between heat and temperature
- Sources of heat production (electric arc, electrical resistance, combustion)
- Means of heat transfer/loss (conduction, convection, radiation)
- Determination of heat input during arc welding (J/s, [k]J/mm)
- Pre- and post-weld heat treatment
- Methods of temperature measurement (pyrometer, temperature indicating crayons).

AC4.3 Cracking:

- Cold-cracking (influence of hydrogen, conditions necessary for cold cracking, influence of stresses, susceptible microstructure, methods of avoiding)
- Reheat cracking (steel type sensitivity; reheat cracking due to heat treatment, or multi-pass welding).

Learning outcome

The learner will:

5. Understand how to determine the integrity of welded joints

Assessment criteria

The learner can:

5.1 Describe the types of weld defects, their causes and prevention
5.2 Describe visual examination methods
5.3 Describe penetrant testing methods
5.4 Describe magnetic particle testing methods
5.5 Describe radiography methods
5.6 Describe ultrasonic testing methods
5.7 Explain mechanical testing methods.

Range

AC5.1 Defects:

- Cracks (longitudinal, transverse, edge, HAZ, crater, centreline, fusion zone, underbead)
- Lack of fusion (root, side wall, inter-run)
- Porosity (scattered, cluster, isolated pore, root, blow holes, worm holes)
- Piping (craters)
- Solid inclusions (slag, copper, tungsten, oxide)
- Lack of penetration
- Undercut
- Oxidation
- Excessive weld metal (including penetration)
- Underfill
- Concavity
- Overlap
- Burn-through.

AC5.2 Visual examination:

- Range of defects detected
- Equipment requirements
- Method.

AC5.3 Penetrant testing:

- Range of defects detected
- Equipment requirements
- Method.

AC5.4 Magnetic particle:

- Range of defects detected
- Equipment requirements
- Method.

AC5.5 Radiographic testing:

- Range of defects detected
- Equipment requirements
- Method (plate, pipe)
- Health and safety considerations.

AC5.6 Ultrasonic testing:

- Range of defects detected
- Equipment requirements
- Method.

AC5.7 Mechanical testing:

- Range of defects
- Impact tests (Izod, Charpy)
- Fracture (nick break)
- Bend tests (root, face, side)
- Macro examination
- Hardness
    - Methods (Vickers, Brinell, Rockwell)
    - Hardness surveys (weld zone, HAZ, parent metal)

Unit 305 Principles of Welding Processes

Supporting Information

Unit Guidance

Current standards should be used where applicable:
Weld symbols (e.g. BS EN 22553)
Numerical indication of welding process (e.g. EN 24063)

Weld defects (e.g. EN 26520)

Unit 306 Platework Fabrication of Materials

Unit level:	Level 3
GLH:	60
Unit aim:	This unit provides the knowledge and skills required for fabricating platework components. Learners will apply safe working practices whilst fabricating platework. They will develop understanding of the purpose of equipment and tools used with plate materials and the methods used to produce platework fabrications.

Learning Outcome

The learner will:

1. Apply safe working practices whilst fabricating platework

Assessment Criteria

The learner can:

1.1 Describe health and safety regulations applicable to platework fabrication
1.2 Assess hazards in the work environment and employ control measures to reduce risks
1.3 Follow safe working practices.

Range

AC1.1 Regulations:

- Health and Safety at Work Act
- Control of Substances Hazardous to Health (COSHH)
- Management of Health and Safety at Work Regulations
- Personal Protective Equipment at Work Regulations
- Noise at Work Regulations.

AC1.2 Hazards:

- Material sharp edges
- Material handling
- Electricity
- Hot metal

- Arc radiation
- Gas cylinders
- Fume
- Fire

AC1.2 Control measures:

- Electricity (protection devices, earthing)
- Hot metal (gloves, tongs)
- Arc radiation (PPE, screening, non-reflective surfaces)
- Gas cylinders
    - Storage (upright, chained, avoid direct heat)
    - Handling (trolleys)
- Fume (LEV systems, air fed masks)
- Fire (good housekeeping, fire extinguishers).

AC1.3 Safe working practices:

- Equipment checks by operator
- Safe start up and shut down procedures
- Safe use of equipment
- Safe handling of cylinders
- Correct manual handling techniques
- Correct use of lifting equipment
- Use of provided PPE.

Learning outcome

The learner will:

2. Understand the purpose of equipment and tools used with plate materials

Assessment criteria

The learner can:

2.1 Explain the purpose, function and applications of marking out tools

2.2 Explain the purpose, function and applications of equipment and tools used for cutting plate

2.3 Explain the purpose, function and applications of equipment and tools used for forming plate.

Range

AC2.1 Tools:

- Scribers

- French chalk
- Scribing blocks
- Centre and dot punch
- Rules
- Tape measures
- Vernier callipers
- Vernier height gauges
- Squares (engineers, adjustable and plate)
- Protractors
- Dividers and trammels
- Laser lines.

AC2.2 Equipment and tools (cutting):

- Drilling machines
- Hole saws
- Shears
- Punches
- Bandsaws
- Thermal cutting (oxy-fuel, plasma)
- Portable angle grinders.

AC2.3 Equipment (forming):

- Rolling machines (pyramid type, pinch, 4-roll, vertical, cone rolling, angle ring forming)
- Folding machines (box and pan, universal, double-arm, simple bar bender, horizontal)
- Press brake (punches, dies)
- Hammers
- Mallets

Learning outcome

The learner will:

3. Understand the methods used to and be able to produce platework fabrications

Assessment criteria

The learner can:

3.1 Mark out the features required for platework fabrications

3.2 Describe methods of assembling and joining platework

3.3 Produce platework fabrications using various assembly methods, joining methods and materials

3.4 Evaluate completed fabrications against specification criteria

3.5 Restore work areas to a clean and safe condition

Range

AC3.1 Marking out:

- Direct marking
- Use of templates
- Tracing/transfer method
- Use of datums (line, edge, point).

AC3.1 Features:

- Circles
- Radii
- Pitch Circle Diameter (PCD)
- Hole centres
- Angles
- Rectangular profiles
- Curved profiles
- Notches/cut outs.

AC3.2, AC3.3 Assembly:

- Alignment methods (straight edge, levels, laser lines, string lines, strong back and wedges, draw cleats)
- Work holding (tack welding, tack bolts, clamps, jigs, fixtures, magnets)
- Tool selection
- Selection of process parameters (height, force requirements as appropriate)
- Bolt tightening sequence
- Bolt locking methods (split pins, castle nuts, adhesives, wiring).

AC3.2, AC3.3 Joining methods:

- Welding (TIG, MIG/MAG, FCAW, MMA)
- Bolting
- Screws

AC3.3 Materials:

- Types (carbon steel, stainless steel, galvanised steel, aluminium)
- Forms (plate >3mm, flat bar, rectangular section, circular section, angle, structural sections).

AC3.3, AC3.4 Fabrications:

- Flanges (rectangular, circular)
- Rectangular (trays, boxes, upstands, elbows, branches)
- Cylindrical (right cylinders, oblique cylinders, elbows, branches, segmental bends)
- Conical (right, oblique)
- Panels (flat, curved, double curvatures)

- Transition pieces (square to round, round to square, twisted)
- Fabrications with combinations of the above forms:

AC3.4 Criteria:

- Dimensional (tolerance +/- 2mm, individual, overall)
- Alignment (weld joints, hole centres, concentricity)
- Squareness
- Freedom from twist
- Parallelism
- Concentricity
- Weld quality
- Presentation (lack of spatter, sharp edges, hole burrs)
- Aesthetics (surface finish, working marks, hammer marks, scribe lines):

AC3.5 Restore work area:

- Cleaning the work area
- Return of unused consumables
- Safe storage of tools and equipment
- Waste disposal (hazardous, recycling)

Unit 306 Platework Fabrication of Materials

Supporting Information

Unit Guidance

For the purpose of this unit plate metal is defined as having a thickness of greater than 3mm.

Unit 307 Sheet Metalwork Fabrication of Materials

Unit Level:	Level 3
GLH:	60
Unit Aim:	This unit provides the knowledge and skills required for fabricating sheet metalwork components. Learners will apply safe working practices whilst fabricating sheet metalwork. They will develop understanding of the purpose of equipment and tools used with sheet metal and the methods used to produce sheet metal fabrications.

Learning Outcome

The learner will:

1. Apply safe working practices whilst fabricating sheet metalwork

Assessment Criteria

The learner can:

1.1 Describe health and safety regulations applicable to sheet metalwork
1.2 Assess hazards in the work environment and employ control measures to reduce risks
1.3 Follow safe working practices.

Range

AC1.1 Regulations:

- Health and Safety at Work Act
- Control of Substances Hazardous to Health (COSHH)
- Management of Health and Safety at Work Regulations
- Personal Protective Equipment at Work Regulations
- Noise at Work Regulations.

AC1.2 Hazards:

- Material sharp edges
- Material handling
- Electricity
- Hot metal

- Arc radiation
- Gas cylinders
- Fume
- Fire

AC1.2 Control measures:

- Electricity (protection devices, earthing)
- Hot metal (gloves, tongs)
- Arc radiation (PPE, screening, non-reflective surfaces)
- Gas cylinders
    - Storage (upright, chained, avoid direct heat)
    - Handling (trolleys)
- Fume (LEV systems, air fed masks)
- Fire (good housekeeping, fire extinguishers).

AC1.3 Safe working practices:

- Equipment checks by operator
- Safe start up and shut down procedures
- Safe use of equipment
- Safe handling of cylinders
- Correct manual handling techniques
- Correct use of lifting equipment
- Use of provided PPE.

Learning outcome

The learner will:

2. Understand the purpose of equipment and tools used with sheet metal materials

Assessment criteria

The learner can:

2.1 Explain the purpose, function and applications of marking out tools

2.2 Explain the purpose, function and applications of equipment and tools used for cutting sheet metal

2.3 Explain the purpose, function and applications of equipment and tools used for forming sheet metal.

Range

AC2.1 Tools:

- Scribers
- French chalk
- Scribing blocks
- Centre and dot punch
- Rules
- Tape measures
- Vernier callipers
- Vernier height gauges
- Squares (engineers, adjustable and plate)
- Protractors
- Dividers and trammels
- Laser lines.

AC2.2 Equipment and tools (cutting):

- Drilling machines
- Hole saws
- Shears
- Guillotines
- Punches
- Bandsaws
- Thermal cutting (plasma)
- Portable angle grinders.

AC2.3 Equipment (forming):

- Rolling machines (pyramid type, pinch, 4-roll, vertical, cone rolling, angle ring forming)
- Folding machines (box and pan, universal, double-arm, simple bar bender, horizontal)
- Press brake (punches, dies)
- Hammers
- Mallets (bossing, hollowing)
- Fly press
- Bead roller/swager (roll types)
- Stretching machines
- Shrinking machines
- Vibratory forming machine
- Hammers (ball pein, planishing, stretching, shrinking, blocking, hollowing)
- Sand bags
- Bench stakes (hatchet, bick iron, funnel, half moon, seaming, creasing iron, horn).

Learning outcome

The learner will:

3. Understand the methods used to and be able to produce sheet metal fabrications

Assessment criteria

The learner can:

3.1 Mark out the features required for sheet metal fabrications

3.2 Describe methods of assembling and joining sheet metal

3.3 Produce sheet metal fabrications using various assembly methods, joining methods and materials

3.4 Evaluate completed fabrications against specification criteria

3.5 Restore work areas to a clean and safe condition

Range

AC3.1 Marking out:

- Direct marking
- Use of templates
- Tracing/transfer method
- Use of datums (line, edge, point).

AC3.1 Features:

- Circles
- Radii
- Pitch Circle Diameter (PCD)
- Hole centres
- Angles
- Rectangular profiles
- Curved profiles
- Notches/cut outs.

AC3.2, AC3.3 Assembly:

- Alignment methods (straight edge, levels, laser lines, string lines)
- Work holding (tack welding, clamps, fixtures, magnets)
- Tool selection
- Selection of process parameters (height, force requirements as appropriate)
- Material allowance
- Bolt tightening sequence
- Bolt locking methods (split pins, castle nuts, adhesives, wiring).

AC3.2, AC3.3 Joining methods:

- Welding (TIG, MIG/MAG, FCAW, MMA)

- Bolting
- Screws
- Riveting.

AC3.3 Materials:

- Types (carbon steel, stainless steel, galvanised steel, aluminium)
- Forms (sheet <3mm, flat bar, rectangular section, circular section, angle).

AC3.3, AC3.4 Fabrications:

- Flanges (rectangular, circular)
- Rectangular (trays, boxes, upstands, elbows, branches)
- Cylindrical (right cylinders, oblique cylinders, elbows, branches, segmental bends)
- Conical (right, oblique)
- Panels (flat, curved, double curvatures)
- Transition pieces (square to round, round to square, twisted)
- Fabrications with combinations of the above forms.

AC3.4 Criteria:

- Dimensional (tolerance +/- 2mm, individual, overall)
- Alignment (weld joints, hole centres, concentricity)
- Squareness
- Freedom from twist
- Parallelism
- Concentricity
- Weld quality
- Presentation (lack of spatter, sharp edges, hole burrs)
- Aesthetics (surface finish, working marks, hammer marks, scribe lines).

AC3.5 Restore work area:

- Cleaning the work area
- Return of unused consumables
- Safe storage of tools and equipment
- Waste disposal (hazardous, recycling).

Unit 307 Sheet Metalwork Fabrication of Materials

Supporting Information

Unit Guidance

For the purpose of this unit sheet metal is defined as having a maximum thickness of 3mm.

Unit 308 Fabrication and Erection of Structural Steelwork

Unit level:	Level 3
GLH:	70
Unit aim:	In this unit, learners will develop the knowledge and skills required to fabricate and erect structural steelwork. They will understand and apply safe working practices to steelwork fabrication and erection as well as understanding the materials used for structural steelwork fabrication. They will also understand and be able to perform marking out and cutting operations on structural materials and understand and use methods to produce structural steelwork fabrications.

Learning Outcome

The learner will:

1. Understand and apply safe working practices to steelwork fabrication and erection

Assessment Criteria

The learner can:

1.1 Describe health and safety regulations applicable to structural steelwork

1.2 Assess hazards in the work environment and employ precautions to reduce risks

1.3 Follow safe working practices.

Range

AC1.1 Regulations:

- Health and Safety at Work Act
- Control of Substances Hazardous to Health (COSHH)
- Management of Health and Safety at Work Regulations
- Personal Protective Equipment at Work Regulations
- Noise at Work Regulations
- Lifting Operations and Lifting Equipment Regulations (LOLER).

AC1.2 Hazards:

- Material sharp edges

- Material handling
- Electricity
- Hot metal
- Arc radiation
- Gas cylinders
- Fume
- Fire

AC1.2 Control measures:

- Electricity (protection devices, earthing)
- Hot metal (gloves, tongs)
- Arc radiation (PPE, screening, non-reflective surfaces)
- Gas cylinders
    - Storage (upright, chained, avoid direct heat)
    - Handling (trolleys)
- Fume (LEV systems, air fed masks)
- Fire (good housekeeping, fire extinguishers).

AC1.3 Safe working practices:

- Equipment checks by operator
- Safe start up and shut down procedures
- Safe use of equipment
- Safe handling of cylinders
- Correct manual handling techniques
- Correct use of lifting equipment
- Use of provided PPE

Learning outcome

The learner will:

2. Understand materials used for structural steelwork fabrication

Assessment criteria

The learner can:

2.1 Compare the suitability of structural steels used in steelwork fabrication

2.2 Describe the forms of supply of structural steels used in steelwork fabrication

2.3 Describe the forms of prefabricated sections and fixtures commercially available

Range

AC2.1 Structural steels:

- Low carbon steels
- Low alloy steels
- High yield alloy steels
- Weather resistant steels (WR 55 grades).

AC2.1 Comparisons:

- Ease of fabrication
- Weldability
- Corrosion resistance
- Mechanical properties (mass, density, strength, strength/weight ratio)
- Cost
- Availability.

AC2.2 Forms of supply:

- Rolled steel angle (equal leg, unequal leg)
- Universal beam
- Universal column
- Rolled steel channel
- Rolled steel joist
- Tee bar
- Hollow sections (circular (pipes, tubes), rectangular)
- Plates (plain, non-slip [durbar, chequer], expanded, pierced and punched)
- Flat bars.

AC2.3 Prefabricated sections:

- Plate girders
- Box girders
- Lattice girders
- Castellated beams
- Cambered beams
- Laced stanchions
- Battened stanchions
- Portal frames.

AC2.3 Fixtures:

- Cleats (beam to beam connections, beam to column connections)
- Columns (base plates, end plates, splice plates)
- Gusset plates.

Learning outcome

The learner will:

3. Understand and be able to perform marking out and cutting operations on structural materials

Assessment criteria

The learner can:

3.1 Carry out marking out operations on structural steelwork to meet specification
3.2 Carry out cutting operations on structural material to meet specification
3.3 Compare methods of cutting structural steelwork using thermal and mechanical methods

Range

AC3.1 Marking out:

- Directly onto steelwork
- Using templates (types: plate, sections, cleats; application of templates: box, battened, part)
- Datums
- Centre lines
- Set out points
- Avoidance of cumulative error in marking out
- Non-slip plate (chequer) avoiding 'wrong hand' or 'mirror image' errors
- Setting out a camber
- Derive the shapes of bolted gusset plates from standard hole pitch and edge distance.

AC3.2 Cutting:
Mechanical:

- Drills
- Tank cutters
- Hole saws
- Rotary shears
- Guillotines
- Universal shearing machine
- Power punch
- Portable angle grinders/sanders.

Thermal:

- Oxy-fuel gas cutting
- Electric arc process

AC3.3 Factors to be compared:

- Cost of equipment
- Suitability
- Versatility

- Accuracy
- Quality of cut.

Learning outcome

The learner will:

4. Understand and use methods to produce structural steelwork fabrications

Assessment criteria

The learner can:

4.1 Carry out fabrication assembly operations to produce welded beam to beam connections from structural steelwork

4.2 Explain joining methods used in structural steelwork and their applications

4.3 Evaluate fabrications for dimensional accuracy and fitness for purpose

4.4 Carry out a trial erection of fabricated sections

Range

AC4.1 Fabrication assembly operations:

- Forming processes (plate rolls [pinch, pyramid],section rolls, beam bender)
- Use of level surfaces for assembling
- Methods used for alignment (strong backs and wedges, draw cleats/lugs, draw bolts)
- Methods of avoiding twist
- Methods of controlling distortion
- Use of stays to maintain shape
- Use of jigs and fixtures and clamping devices
- Use of tack bolts and tack welds
- Removal of all temporary tack welds and the reinstatement of a good surface.

AC4.2 Methods:

Thermal joining techniques:

- Welding (manual metal arc welding, MIG welding, settings and consumables, weld symbols, joint configurations)
- Jigs and fixtures to aid assembly and control distortion.

Mechanical methods of joining:

- Bolts
- Washers.

AC4.3 Factors to evaluate:

- Dimensional (tolerance +/- 2mm, individual, overall)

- Alignment (weld joints, hole centres)
- Squareness
- Angular
- Freedom from twist
- Parallelism
- Weld quality.

AC4.4 Erection:

- Handle, move and lift structural sections safely
- Levelling steelwork and steelwork bases
- Plumbing vertical members
- Checking alignment
- Use of equipment to move or adjust the position of steelwork (pulleys, block and tackle, pull-lifts, hydraulic jacks, podger spanners, drifts, wedges, temporary props and bracings, falsework).

Unit 309 Pattern Development for Fabrication

Unit level:	Level 3
GLH:	70
Unit aim:	This unit enables the leaner to develop the skills and methods required to create flat layouts of 3D forms. Learners will be able to determine lines of intersection when developing patterns and develop patterns using parallel line techniques. They will also be able to develop patterns using radial line techniques and develop patterns using triangulation.

Learning Outcome

The learner will:

1. Be able to determine lines of intersection when developing patterns

Assessment Criteria

The learner can:

1.1 Determine lines of intersection using projection
1.2 Determine lines of intersection using the principle of the common central sphere
1.3 Determine lines of intersection using the method of cutting planes

Range

AC1.1 Lines of intersection between:

- Equal diameter cylinders (at 90^0 and 135^0 on-centre, off-centre)
- Un-equal diameter cylinders (at 90^0 and 135^0 on-centre, off-centre)
- Rectangular sections (at 90^0 and 135^0 on-centre, off-centre)
- Right cylindrical branches onto transformer pieces

AC1.2 Lines of intersection between:

- Cylinder to cylinder (angled, 3-way)
- Cylinder to cones.

AC1.3 Lines of intersection between:

- Right cones to right cones
- Oblique cones to right cones
- Oblique cones to oblique cones
- Right cylinder branches on right cones on- and off-centre
- Right rectangular branches on right cones on- and off-centre
- Cylindrical and rectangular branches on spherical, domed or dished ends.

Learning outcome

The learner will:

2. Be able to develop patterns using parallel line techniques

Assessment criteria

The learner can:

2.1 Apply the parallel line method of pattern development to basic forms
2.2 Apply the parallel line method of pattern development to complex forms

---

Range

AC2.1 Basic forms:

- Segmental bends (right cylindrical and oblique)
- Square or rectangular ducts cut obliquely
- Right cylinders cut obliquely
- Oblique cylinders cut obliquely.

AC2.2 Complex forms:

- Branch pipes on to boiler, shells, dished ends and domed ends
- Cylindrical branches onto right and cylindrical segmental bends to include interpenetration of the branch pipe
- Square and rectangle branches onto right and oblique cones
- Swan neck transition pieces
- Rectangle to rectangle in angular planes
- Twisted side transition pieces (outlets parallel, at 90^0).

Learning outcome

The learner will:

3. Be able to develop patterns using radial line techniques

Assessment criteria

The learner can:

3.1 Apply the radial line method of pattern development to basic forms

3.2 Apply the radial line method of pattern development to complex forms.

Range

AC3.1 Basic forms:

- Right cones and frusta
- Oblique cones and frusta
- Oblique cones cut by a flat surface
- Oblique cones cut by a curved surface
- Two-way breeches piece made from right cones.

AC3.2 Complex forms:

- Right cones in multiple connections of right cylinders and right cones
- Two-way breeches piece made from oblique cones
- Segmental bends
- Tapered segmental bends (‘lobster back bends’).

Learning outcome

The learner will:

4. Be able to develop patterns using triangulation

Assessment criteria

The learner can:

4.1 Apply the triangulation method of pattern development to basic forms

4.2 Apply the triangulation method of pattern development to complex forms

---

Range

AC4.1 Basic forms

- Hoppers based on square or rectangular pyramids
- Square or rectangle to round transformers
- Round to square or rectangle transformers
- Transformers and hoppers on- and off-centre, between parallel planes
- Transformers and hoppers between non-parallel planes
- Long taper right cones
- Oblique cones.

AC4.2 Complex forms:

- Rectangular to round off-set transformers on a roof apex
- Breeches pieces branching from cylindrical main to equal and unequal diameter ducts
- Rectangular kinked sided hoppers (kinked to produce maximum volume, kinked to produce minimum volume)
- Spiral blade segments.

Learning outcome

The learner will:

5. Produce templates of developed patterns

Assessment criteria

The learner can:

5.1 Describe the purpose of templates
5.2 Produce templates for the marking out of fabrications

Range

AC5.1 Purpose:

- Avoid repetitive measurements.
- Minimising material wastage
- Guide the cutting processes
- Checking (lengths, angles, shapes, forms, hole positions).

AC5.2 Production:

- Template production techniques (template shot/loft, setting out floor)
- Tools used (saws, planes, drills, marking gauge, steel rule, compasses, dividers, trammels, protractor, engineers square, flat (plate) square, straight edge, hammers, centre/dot/nipple punches, chalk line and soft chalk, French chalk, coloured and indelible pencils/crayons)
- Template materials (template paper, hardboard, timber, sheet metal, steel plate)
- Information that may be contained on templates
- Drilling requirements
- Cutting instructions
- Datums.

Unit 310 Pipe and Tube Fabrication

Unit Level:	Level 3
GLH:	60
Unit Aim:	In this unit learners will develop the knowledge and skills required to fabricate pipe and tube. They will understand health and safety requirements in a pipe and tube fabrication environment and how to prepare and plan for the production of pipe and tube fabrications. They will also be able to select and use equipment to fabricate and inspect pipe and tube.

Learning Outcome

The learner will:

1. Understand health and safety requirements in a pipe and tube fabrication environment

Assessment Criteria

The learner can:

1.1 Describe the health and safety regulations applicable to pipe and tube fabrication
1.2 Explain the hazards and risks in a pipe and tube fabrication environment
1.3 Explain safe working practices and procedures in a pipe and tube fabrication environment.

Range

AC1.1 Health and safety regulations:

- Health & safety at work act (1974) (HASAWA)
- Control of substances hazardous to health (COSHH)
- Provision and use of work equipment (PUWER)
- Personal protective equipment at work regulations
- Noise at work regulations
- Lifting operations and lifting equipment regulations (LOLER).

AC1.2 Hazards:

- Fire
- Electricity
- Lifting

- Fume
- Arc radiation
- Hot metal
- Hazards associated with the storage
- Handling and use of pressurised gas cylinders.

AC1.3 Practices and procedures:

- Procedures for safely pressure testing
- Procedures for safely cutting materials
- Procedures for safely joining materials
- Procedures for safely forming materials.

Learning outcome

The learner will:

2 Understand how to prepare and plan for the production of pipe and tube fabrications

Assessment criteria

The learner can:

2.1 Describe the information needed to support production requirements and where this may be found
2.2 Calculate data for pipe and tube fabrication
2.3 Describe how to mark out features on pipe/tube in readiness for cutting and bending

---

Range

AC2.1 Sources of information:

- Working drawings
- Standards
- Job cards
- Specifications
- Technical manuals
- Bill of materials
- Pipe layouts
- Flow charts

AC2.2 Calculations:

- Joining and bending allowances
- Angles of cut.

AC2.3 Features:

- Pipe lengths
- Angular cuts
- Bend lines.

Learning outcome

The learner will:

3. Be able to select and use equipment to fabricate pipe and tube

Assessment criteria

The learner can:

3.1 Select, set up and use cutting equipment for pipe and tube fabrication
3.2 Select and use a method to produce a specified bend in a pipe or tube
3.3 Select and use joining methods to assemble pipe and tube fabrications
3.4 Describe inspection techniques to check pipe and tube fabrications
3.5 Explain common defects in pipe and tube fabrications and their causes

---

Range

AC3.1 Cutting equipment:

- Saws
- Grinding machines
- Thermal cutting
- Cutting guidance systems.

Profiles:

- Straight cuts
- Hole profile
- Branch profile
- End preparations

AC3.2 Methods:

- Hot and cold techniques
- Compression
- Draw
- Ram press
- Roll (coil)
- Free bending

- Heat lengths
- Localised cooling.

Configurations:

- Bends in same plane
- Bends in two or more different planes
- Offsets in same plane
- Offsets in two or more different planes (rolled offsets).

AC3.3 Methods:

- Threaded
- Welded
- Adhesive bonded
- Hot air welded
- Soldered
- Brazed
- Compression.

AC3.4 Inspection techniques:

- Visual inspection
- Hydrostatic testing
- Thread insertion check
- Dimensional checks.

AC3.5 Defects:

- Crushed bore
- Puckering
- Split tube
- Misalignment
- Wall thinning
- Weld defects.

Unit 311 Mechanical Principles of Engineering Systems

Unit Level:	Level 3
GLH:	50
Unit Aim:	The development and use of mechanical engineering systems requires an understanding of scientific and mathematical principles. In this unit, learners will develop an understanding of the effects of loading in static engineering systems and energy transfer in dynamic engineering systems. They will gain an initial understanding of the characteristics of fluid systems and energy transfer in thermodynamic systems.

Learning Outcome

The learner will:

1. Determine the effects of loading in static engineering systems

Assessment Criteria

The learner can:

1.1 Calculate the induced direct stress, strain and dimensional change in a component
1.2 Calculate the shear stress and strain in a component subjected to shear loading
1.3 Calculate the factor of safety for a component
1.4 Describe the conditions for static equilibrium
1.5 Calculate the forces required to keep a body in equilibrium
1.6 Calculate the support reactions for a simply supported beam

Range

AC1.1 Components:

- Single material with uniform section
- Direct uniaxial loading
- Young's modulus

AC1.2 Components:

- Single material with uniform section
- Shear modulus

AC1.4 Conditions for static equilibrium:

- ΣFx = 0, ΣFy = 0, ΣM = 0.

AC1.5 Forces:

- Resolution of forces in perpendicular directions
- Up to three forces.

AC1.6 Simply supported beams

- Single point load
- Rectangular section.

Learning outcome

The learner will:

2. Determine energy transfer in dynamic engineering systems

Assessment criteria

2.1 State Newton's three laws of motion
2.2 Solve problems of dynamics of simple systems.

Range

AC2.2 Dynamics:

- Kinetic energy
- Potential energy
- Gravitational force
- Principle of conservation of energy.

Contexts:

- Falling objects
- Collision of two objects in direct alignment.

Learning outcome

The learner will:

3. Understand the characteristics of fluid systems

Assessment criteria

3.1 Describe the characteristics of fluid flow over 2D objects
3.2 Explain the differences between hydraulic and pneumatic power systems

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3.3 Apply gas laws to pneumatic systems

3.4 Calculate pressure in hydraulic systems.

Range

AC3.1 Characteristics:

- Laminar flow
- Separation points
- Turbulence
- Vortices.

AC3.3 Gas laws:

- Charles' Law
- Boyle's Law.

AC3.4 Conditions:

- Incompressible fluid
- Mass flow
- Changes in diameter
- Gradually tapering pipes.

Learning outcome

The learner will:

4. Understand energy transfer in thermodynamic systems

Assessment criteria

4.1 Explain the difference between heat and temperature

4.2 Describe heat transfer mechanisms

4.3 Calculate energy transfer under steady state conditions.

Range

AC4.2 Mechanisms:

- Conduction
- Convention
- Radiation

AC4.3 Calculations:

- Sensible heat

- Latent heat
- Thermal expansion and contraction
- General gas equation (pV T = constant)
- Characteristic gas equation (pV = mRT)
- Heat exchangers (heat transfer, power rating).

Unit 312 Engineering Maintenance Procedures and Techniques

Unit Level:	Level 3
GLH:	60
Unit Aim:	In this unit, learners will develop the knowledge and skills required to undertake engineering maintenance activities. They will be able to plan, understand and carry out maintenance tasks and procedures. They will carry out maintenance by dismantling and inspecting components within equipment and systems. They will also be able to reinstate, commission and handover equipment and systems.

Learning Outcome

The learner will:

1. Plan for maintenance tasks

Assessment Criteria

The learner can:

1.1 Develop a plan for a maintenance activity

1.2 Explain how the work being carried out affects other systems or production facilities

1.3 Plan the resources in order to carry out the maintenance activity

1.4 Describe the documentation required to support the maintenance activity.

Range

AC1.1 Plan:

- Evaluate the type and extent of work to be carried out
- Risk assessment and method statement (RAMS)
- Permit to work and lock out tag out (LOTO)
- Hot work permits
- Dealing with waste oil or other COSHH substances and their safe and legitimate disposal.

AC1.3 Resources:

- Time
- People/personnel
- Tools

- Equipment
- Space
- Support
- Facilities.

AC1.4 Documentation:

- Maintenance procedures
- Technical references
- Maintenance reports
- Test reports
- Technical manuals
- Engineering drawings
- Relevant standards

Learning outcome

The learner will:

2. Understand and be able to carry out maintenance procedures

Assessment criteria

The learner can:

2.1 Explain different types of maintenance and their advantages and limitations

2.2 Carry out planned preventative maintenance activities

2.3 Carry out methods of testing and reviewing system operation

---

Range

AC2.1 Types:

- Planned Preventative Maintenance (PPM)
- Condition Based Maintenance (CBM)
- Scheduled maintenance
- Total productive maintenance (TPM)
- Breakdown and run to failure maintenance.

AC2.2 Planned preventative maintenance activities:

- Visual examination
- Removing excessive dirt and grime
- Replacing consumables (oils, grease, belts, gaskets and seals)
- Checking condition of drive belts, chains, bearings, seals, guards
- Checking operation of all gauges and sensors and monitoring equipment
- Checking condition/deterioration
- Making sensory checks (sight, sound, smell, touch)
- Carrying out equipment self-analysis checks
- Checking alignment of running/sliding components
- Making routine adjustments (drive belts, chains, topping up fluid levels).

AC2.3 Methods:

- Sensory checks (sight, sound, smell and touch)
- Checking operational features such as heat, vibration, emissions
- Carrying out leak checks on connections
- Measuring mechanical and electrical parameters
- Checking operational efficiency
- Checking and comparing against specification
- Making appropriate adjustments
- Recording the results of the tests.

Learning outcome

The learner will:

3. Carry out maintenance by dismantling and inspecting components within equipment and systems

Assessment criteria

The learner can:

3.1 Dismantle equipment or systems

3.2 Perform inspections of components and draw conclusions regarding repair or replacement

3.3 Reassemble equipment or systems

Range

AC3.1 Dismantling:

- Dismantling equipment to unit/sub-assembly level
- Dismantling units to component level
- Proof marking components
- Precautions needed to prevent leakage or sudden release of stored energy
- Methods of preventing damage to, or loss of, components
- Protection of dismantled components from contamination
- Methods of cleaning components.

AC3.2 Inspections:

- Evaluate components for serviceability
- Visual inspection and measuring with calibrated equipment
- Checking bearing surfaces
- Checking for split or worn seals
- Checking for signs of overheating
- Checking condition of filters
- Identifying signs of wear
- Indications of emulsions or oil deterioration
- Checking oil for signs of oxidation and acidity.

AC3.3 Reassembling:

- Replacing all lifed items such as seals, bearings, gaskets
- Replacing damaged, out of specification or defective components
- Setting, aligning and adjusting replaced components

- Tightening fastenings to the required torque
- Replenishing lubricants and lubrication devices
- Using appropriate and approved coding for electrical connections and components
- Checking assembly is complete to the required standard.

Learning outcome

The learner will:

4. Reinstate, commission and handover equipment and systems

Assessment criteria

The learner can:

4.1 Perform recommissioning operations to bring equipment or systems on-line and adjust as required until the working requirements have been fully met

4.2 Restore work areas to a clean and safe condition

4.3 Conduct handover of equipment or systems

Range

AC4.1 Recommissioning:

- Bench testing & pressure testing (pipework and pressure vessels)
- Making 'off-load' checks
- Safety system checks
- Precautions for opening up the system to sources of energy (including steam and electricity)
- Sequence of bringing systems back to the specified working conditions (removal of blanks, operating the system under gradually increasing pressures or loads)
- Set up and test interlocks, sensors and limit switches
- Functionally testing the completed system.

AC4.2 Restore work areas:

- Remove any unused consumables from the work area
- Cleaning the work area
- Putting tools and equipment into safe storage
- Safe and appropriate disposal of materials.

AC4.3 Handover:

- Reporting any defects outstanding or work that could not be completed within the maintenance procedure
- Informing where additional repair work may be needed
- Informing all interested parties of any changes or unusual (temporary or permanent) operating features that may exist in the system, or of any new conditions the work area
- Cancellation of Permit to Work documentation including LOTO removal procedures

- Completion of maintenance and handover reports (information on test data, equipment range and operating parameters, recommendations, spares and consumables used, information on type of maintenance that has been carried out, equipment identification, next maintenance due date).

Unit 313 Principles of Electrical and Electronic Circuits

Unit Level:	Level 3
GLH:	60
Unit Aim:	This unit provides knowledge and understanding of the principles that underpin electrical and electronic circuits. It covers laws and theorems, calculations, the functions and applications of circuit components and the types of diagrams used to represent circuits.

Learning outcome

The learner will:

1. Understand electrical and electronic engineering principles

Assessment criteria

The learner can:

1.1 Explain electrical and electronic circuit terms
1.2 Apply laws and theorems
1.3 Calculate values in series, parallel and combination circuits using appropriate units
1.4 Explain the characteristics and applications of magnetic fields
1.5 Explain the characteristics and applications of electromagnetic induction
1.6 Explain the differences between analogue and digital signals
1.7 Describe the characteristics of sinusoidal wave forms.

Range

AC1.1 Terms:

- Voltage
- Current
- Resistance
- Capacitance
- Power
- Conductivity
- Resistivity.

AC1.2 Laws and theorems:

- Ohm's law
- Watt's law
- Kirchhoff's voltage and current laws
- Faraday's laws
- Lenz's laws
- Direct current (DC) theory
- Alternating current (AC) theory

AC1.3 Values:

- Voltage
- Current
- Resistance
- Capacitance
- Power
- Electrical energy transferred
- Electrical work done
- Potential divider output.

AC1.7 Characteristics:

- Frequency
- Amplitude
- Periodic time
- Peak and peak to peak value
- Instantaneous value
- Average value
- Root mean square (rms)
- Form factor.

Learning outcome

The learner will:

2. Understand the functions and applications of electrical and electronic circuit components

Assessment criteria

The learner can:

2.1 Describe the construction types, functions and applications of resistors

2.2 Describe the construction types, functions and applications of capacitors

2.3 Describe the functions, applications and semiconductor junction characteristics of diodes

2.4 Describe the functions, applications and semiconductor junction characteristics of transistors

2.5 Describe the operation of potential divider circuits

2.6 Describe the principles functions and applications of logic gates and logic circuits

2.7 Describe the operating characteristics and applications of operational amplifier circuits

2.8 Describe the functions and applications of analogue integrated circuits (ICs)

Range

AC2.1 Resistor construction types:

- Carbon film
- Surface mount
- Wire wound
- Variable

Applications of resistors including:

- Current limiting
    - Protecting LEDs
    - Transistor biasing
- As part of a potential divider circuit
- Pull up and pull down circuits
- Amplifier feedback
- Setting the length of delays in timer circuits.

AC2.2 Capacitor construction types:

- Electrolytic
- Mica
- Ceramic
- Plastic
- Paper
- Variable.

Applications of capacitors including:

- Storing electrical energy
- Setting the length of delays in timer circuits
- Filtering
- Smoothing
- Decoupling.

AC2.3 Diodes:

- PN junction
- Zener
- Schottky
- Light-emitting diode (LED)

Applications including:

- Rectification
- Suppressing back emf

- Lighting systems.

AC2.4 Transistors:

- Bipolar
    - NPN
    - PNP
- Field effect
    - JFET
    - MOSFET

Applications including:

- As an interface device
- As an automatic switch
- As an amplifier.

AC2.5 Potential divider circuits:

- Light sensor circuits
- Temperature sensor circuits
- Circuits with sensitivity adjustment.

AC2.6 Principles:

- Truth tables
- Boolean expressions
- De Morgan's theorem
- Karnaugh maps.

Logic gates:

- NOT
- AND
- OR
- NAND
- NOR
- XOR.

Logic circuits:

- Single logic gate circuits
- Combinational logic circuits (up to three gates)
- Sequential logic circuits (up to three gates).

AC2.7 Operating characteristics:

- Gain and loss
- Feedback
    - Positive
    - Negative
- Noise
- Signal-to-noise ratio

Amplifier circuits:

- Inverting amplifiers

- Non-inverting amplifiers
- Summing amplifiers
- Comparators.

AC2.8 Analogue ICs:

- 555 Timers
- Filters
- Voltage regulators
- Amplifiers
- Analogue switches.

Learning outcome

The learner will:

3. Understand diagrams used to represent electrical and electronic circuits

Assessment criteria

The learner can:

3.1 Explain the purpose, benefits and limitations of diagrams used to represent circuits

3.2 Interpret symbols and abbreviations used to represent components in circuit schematics

---

Range

AC3.1 Diagrams:

- Block
- Schematic
- Wiring.

AC3.2 Components:

- Cells
- Batteries
- Resistors
    - Fixed
    - Variable
- Capacitors
    - Polarised
    - Non-polarised
- Diodes
- Switches
    - Single pole single throw (SPST)
    - Single pole double throw (SPDT)
    - Double pole single throw (DPST)
    - Double pole double throw (DPDT)
- Sensors
    - Light dependent resistors
    - Thermistors
    - Photodiodes
- Bipolar transistors
    - NPN

    - PNP
- Field effect transistors
    - JFET
    - MOSFET
- Relays
- Operational amplifiers
- Logic gates
    - NOT
    - AND
    - OR
    - NAND
    - NOR
    - XOR
- Microcontrollers
- Output devices
    - Lamps
    - Light emitting diodes
    - Buzzers
    - Loudspeakers
    - Bells
    - Motors.

Unit 313 Principles of Electrical and Electronic Circuits

Supporting Information

Unit Guidance

This unit could be taught effectively using CAD software to test and simulate the functions of electrical and electronic components and circuits. Centres could also use product analysis to investigate the application of different components.

Unit 314 Electrical and Electronic Measurement, Testing and Fault Diagnosis

Unit Level:	Level 3
GLH:	60
Unit Aim:	This unit provides the knowledge, understanding and skills needed to perform measurement, testing and fault diagnosis on electrical and electronic circuits. It covers the function and use of measurement and test equipment, the principles of equipment calibration and the techniques used to carry out fault diagnosis on circuits.

Learning outcome

The learner will:

1. Understand the function of, and be able to use, electrical and electronic measurement and test equipment

Assessment criteria

The learner can:

1.1 Explain the function, characteristics, benefits and limitations of measurement and test equipment

1.2 Describe the characteristics of waveform signal types

1.3 Select and safely use appropriate measurement and test equipment to measure circuit parameters

1.4 Produce records of measurement and testing using a test record sheet.

Range

AC1.1, 1.3 Measurement and test equipment:

- Multimeter
- Voltmeter
- Ohmmeter
- Ammeter
- Oscilloscope
- Spectrum analyser

- Signal generator
- Function generator
- Logic probe
- Logic pulser
- Insulation resistance tester
- Current tracer
- Frequency meter
- AC bridge
- Virtual instruments.

AC1.2 Types of waveform:

- Sinusoidal
- Square
- Triangle
- Sawtooth
- Ramp
- Pulse.

AC1.3 Parameters:

- Voltage
    - Test point
    - Power supply
- Current
- Resistance
- Power
- Inductance
- Frequency
- Logic state
- Noise and distortion
- Waveform parameters
    - Frequency
    - Amplitude
    - Periodic time
    - Peak value
    - Peak to peak value
    - Root mean square (RMS)
    - Phase shift
    - Offset.

Learning outcome

The learner will:

2. Understand the principles of calibration of electrical and electronic measurement and test equipment

Assessment criteria

The learner can:

2.1 Explain the need for calibration of measurement and test equipment

2.2 Explain the terms used in equipment calibration

2.3 Explain the impact of calibration on quality and safety

2.4 Describe situations when calibration is necessary

2.5 Describe procedures used to validate test equipment functionality.

Range

AC2.2 Terms:

- Accuracy
- Precision
- Repeatability
- Uncertainty
- Resolution
- Linear
- Non-linear
- Zero shift
- Span error.

AC2.4 Situations:

- During manufacture
- Quality control
- Following installation
- Periodic scheduled maintenance
- In response to identified deviation
- After repair or change in environment.

AC2.5 Procedures:

- Reference against standards and known values
- Reference against calibrated equipment
- Zero checks
    - Nulling leads
    - Zeroing meter displays
    - Parallax checks.

Learning outcome

The learner will:

3. Understand and be able to carry out fault diagnosis on electrical and electronic circuits

Assessment criteria

The learner can:

3.1 Explain terms used in fault diagnosis

3.2 Explain the characteristics, benefits and limitations of fault diagnosis techniques

3.3 Select and use appropriate techniques to diagnose faults in analogue and digital circuits

3.4 Interpret sources of information used in fault diagnosis

Range

AC3.1 Terms:

- Fault
- Symptom
- Cause
- Root cause.

AC3.2 Fault diagnosis techniques:

- Six point technique
- Functional testing
- Input to output checks
- Half split method
- Injection and sampling
- Emergent problem sequence
- Component isolation
- Unit substitution.

AC3.3 Types of faults including:

- Failure of components
    - Total failure
    - Partial failure
- Components performing outside of tolerance
- Short circuits
- Open circuit connections
- Intermittent faults
- Power supply faults
- Circuit design faults
- Logic stuck-at faults
- Digital input and output faults.

AC3.4 Sources of information:

- System block diagrams
- Circuit schematics
- Wiring diagrams

- PCB layout diagrams
- Flow charts
- Manufacturers' manuals
- Troubleshooting guides
- Data sheets
- Maintenance logs
- Wiring regulations.

Unit 314 Electrical and Electronic Measurement, Testing and Fault Diagnosis

Supporting Information

Unit Guidance

AC 1.3

Circuits to be measured and tested could include amplifiers, oscillators, low voltage power supplies, low-power transmitters and receivers, microcontroller circuits and programmable logic controller circuits.

Circuits specific to the apprenticeship provider and/or employment setting can also be used as long as all listed parameters are covered.

AC 3.3

Analogue circuits could include audio amplifiers, oscillators, power supplies, multiplexers and demultiplexers.

Digital circuits could include logic circuits, flip-flops/latches, shift registers, counters, frequency dividers, microcontroller-based circuits, encoders and decoders.

Circuits specific to the apprenticeship provider and/or employment setting can also be used as long as all listed fault types are covered.

AC 3.4

Learners should be able to interpret current IET wiring regulations, i.e. BS7671, as relevant to fault diagnosis of electrical circuits.

Unit 315 Principles of Three-Phase Systems

Unit Level:	Level 3
GLH:	60
Unit Aim:	This unit provides knowledge and understanding of the principles that underpin three-phase systems. It covers the differences between single-phase and three-phase systems, calculations of values in three-phase systems, the operation of three-phase motors and the use of monitoring and protection equipment.

Learning outcome

The learner will:

1. Understand the principles of three-phase systems

Assessment criteria

The learner can:

1.1 Explain the differences between three-phase systems and single-phase systems
1.2 Explain the advantages of three-phase systems compared to single-phase systems
1.3 Describe three-phase system configurations
1.4 Explain diagrams of three-phase systems
1.5 Calculate voltage values in three-phase systems
1.6 Calculate current values in three-phase systems
1.7 Calculate values in three-phase systems using the power triangle
1.8 Explain safety procedures that should be followed when working on high voltage equipment

Range

AC1.2 Advantages including:

- Better transmission capacity
- Constant power transfer when load is balanced
- Reduced wiring sizes/costs
- Greater versatility.

AC1.3 System configurations:

- Delta
- Star.

AC1.4 Diagrams:

- Phasor diagrams
- Schematics.

AC1.5 Voltage values:

- Line voltage
- Phase voltage.

AC1.6 Current values:

- Line current
- Phase current.

AC1.7 Values:

- Real power
- Reactive power
- Apparent power
- Phase angle
- Power factor.

AC1.8 Procedures including:

- Following the safe isolation procedure
- Wearing appropriate PPE
- Use of warning notices and signs
- Earthing
- Using a permit-to-work system
- Following guidance and regulations
- Use of interlocks.

Learning outcome

The learner will:

2. Understand the operation of three-phase motors and generators

Assessment criteria

The learner can:

2.1 Describe the principles of operation of three-phase motors and generators

2.2 Describe the characteristics, function and applications of different types of three-phase motors

2.3 Explain the benefits and limitations of different types of three-phase motors

2.4 Explain the characteristics, purpose and function of the parts of three-phase motors and generators

2.5 Explain the purpose and function of motor starters and control gear

2.6 Describe the maintenance requirements for three-phase motors and generators.

Range

AC2.1 Principles of operation:

- Converting electrical energy into mechanical energy (motors)
- Converting mechanical energy into electrical energy (generators)
- Creation of a rotating magnetic field.

AC2.2, 2.3 Motors:

- Squirrel-cage induction motors
- Wound rotor/slip ring induction motors
- Synchronous motors.

AC2.2 Characteristics:

- Frequency
- Speed
- Load
- Torque
- Slip
- Power
- Efficiency.

AC2.4 Parts:

- Stator
- Rotor
- Exciter.

AC2.6 Maintenance requirements including:

- Cleaning of motor
- Checking electrical connections
- Checking rotors, bearings and brushes
- Lubrication of moving parts
- Testing insulation.

Learning outcome

The learner will:

3. Understand monitoring and protection equipment for three-phase systems

Assessment criteria

The learner can:

3.1 Explain the purpose and function of monitoring equipment

3.2 Describe applications of monitoring equipment

3.3 Explain how equipment is used to measure parameters

3.4 Explain the purpose and function of protection equipment

3.5 Describe applications of protection equipment

Range

AC3.1, 3.2, 3.3 Monitoring equipment:

- Multimeter
- Voltmeter
- Ammeter
- Wattmeter
- KVA meter
- KVAr meter
- Power factor meter
- Ohmmeter
- Frequency meter.

AC3.3 Parameters:

- Line voltage
- Phase voltage
- Line current
- Neutral current
- Phase current
- Real power
- Reactive power
- Apparent power
- Power factor
- Resistance
- Frequency.

AC3.4, 3.5 Protection equipment:

- Transformers (current, voltage)
- Relays
- Circuit breakers.

Unit 316 Electrical Installation

Unit Level:	Level 3
GLH:	60
Unit Aim:	This unit provides the knowledge, understanding and skills needed to install electrical circuits in a domestic or commercial environment. It covers the sources of information needed to complete electrical installations, circuit protection methods and devices, and the physical installation and testing of electrical circuits.

Learning outcome

The learner will:

1. Understand sources of information required for electrical installations

Assessment criteria

The learner can:

1.1 Interpret diagrams of electrical circuits

1.2 Interpret current Institution of Engineering and Technology (IET) wiring regulations

1.3 Describe the purpose and requirements of current statutory regulations related to electrical installations

1.4 Explain how certain working areas present an increased risk of electrical shock and how this can be reduced.

Range

AC1.1 Diagrams

- Circuit diagrams
- Schematics
- Wiring diagrams.

Circuits:

- Light switching circuits
  - 1-gang
  - 2-gang
  - 1-way

    - 2-way
    - Intermediate
- Power circuits:
    - Ring
    - Radial
    - Fused socket outlet
    - Switched fused spur
    - Cooker
    - Immersion heater
    - Heated towel rail.

AC1.3 Regulations:

- Health and Safety at Work Act
- Electricity Supply Regulations
- Electricity at Work Regulations
- Electrical Equipment (Safety) Regulations
- The Building Regulations (Part P only)
- Construction (Design and Management) Regulations
- Electromagnetic Compatibility Regulations

AC1.4 Working areas:

- Indoor working areas:
    - Bathrooms/shower rooms
    - Saunas
    - Swimming pools
- Outside equipotential zone:
    - Gardens
    - Sheds
    - Ponds
    - Garages/workshops.

Learning outcome

The learner will:

2. Understand circuit protection methods and devices

Assessment criteria

The learner can:

2.1 Explain the purpose, function and applications of overcurrent protection devices

2.2 Explain the purpose and application of circuit protection methods.

Range

AC2.1 Devices:

- Fuses
    - Rewireable
    - Cartridge

- Miniature circuit breaker (MCB)
- Residual circuit device (RCD)
- Residual current breaker with overload protection (RCBO).

AC2.2 Methods:

- Earthing
- Bonding
- Use of protective conductor circuits
- Protecting cables from mechanical damage.

Learning outcome

The learner will:

3. Be able to install and test electrical circuits

Assessment criteria

The learner can:

3.1 Perform calculations related to electrical installations

3.2 Select and use appropriate cable types and sizes

3.3 Install and test different types of light switching circuits in accordance with current IET wiring regulations

3.4 Install and test different types of power circuits in accordance with current IET wiring regulations.

Range

AC3.1 Calculations:

- Cable calculations
    - Design current
    - Voltage drop
    - Use of correction factors
    - Use of tabulated cable ratings
- Maximum demand and diversity factor.

AC3.3 Light switching circuits:

- 1-gang
- 2-gang
- 1-way
- 2-way
- Intermediate

AC3.4 Power circuits:

- Ring
- Radial
- Fused socket outlet
- Switched fused spur

- Cooker
- Immersion heater
- Heated towel rail.

AC3.3, 3.4 Tests:

- Continuity testing
- Polarity testing
- Insulation resistance testing
- Checking operation of switches
- Checking circuit matches diagram
- Visual inspection.

Unit 316 Electrical Installation

Supporting Information

Unit Guidance

AC1.2

Learners should be able to interpret and use current IET wiring regulations, i.e. BS7671, as appropriate for the installation.

AC1.3

Learners must be able to describe the overall purpose and requirements of current statutory regulations that apply to electrical installations only, i.e. Health and Safety at Work Act 1974, Electricity Supply Regulations 1988, Electricity at Work Regulations 1989, The Building Regulations 2010 (particularly Part P), Construction (Design and Management) Regulations 2015, Electrical Equipment (Safety) Regulations 1994 and Electromagnetic Compatibility Regulations 2006.

AC3.2

Learners must select and use cable types appropriate to the installation being undertaken and in accordance with IET wiring regulations. E.g. (as appropriate) single core, multicore, armoured, fire resistant, flexible, non-flexible.

Unit 317 Principles and Applications of Fluid Mechanics

Unit Level:	Level 3
GLH:	70
Unit Aim:	In this unit learners will understand the properties of fluids and the operation of hydrostatic devices. Learners will also develop understanding of the application of hydrodynamic principles to the flow of fluids and how aerodynamic flow principles apply to wind tunnel testing.

Learning Outcome

The learner will:

1. Understand the properties of fluids

Assessment Criteria

The learner can:

1.1 Define the terms fluid, fluid mechanics, fluid statics and fluid dynamics
1.2 Describe the properties of fluids
1.3 Compare forms of fluid flow
1.4 Explain the parameters that affect the performance of lubricated bearings.

Range

AC1.2 Properties:

- Viscosity
- Surface tension
- Capillary action
- Vapour pressure
- Compressibility
- Expansion
- Density
- Specific gravity (relative density)
- Specific weight.

AC1.3 Forms of fluid flow:

- Viscous and inviscid flow
- Internal and external flow
- Compressible and incompressible flow
- Laminar and turbulent flow

- Steady and unsteady flow
- Newtonian and non-Newtonian flow.

AC1.4 Types and parameters:

- Bearings (journal (plain), roller and thrust)

Parameters:

- Dimensions of bearings
- Speed
- Viscosity of lubricants
- Viscous resistance and power loss.

Learning outcome

The learner will:

2. Understand the operation of hydrostatic devices and the action of hydrostatic fluids on immersed surfaces

Assessment criteria

The learner can:

2.1 Explain the operation of hydrostatic devices

2.2 Determine the hydrostatic pressures and forces acting on immersed surfaces.

Range

AC2.1 Operation:

Hydrostatic devices:

- Actuator
- Brake system and (Bramah) press.

Operating parameters:

- Cylinder dimensions
- Input and output forces
- Movements and pressures.

AC2.2 Forces:

Immersed surfaces:

- Retaining walls
- Lock and sluice gates
- Inspection covers
- Hatches (rectangular and circular)

Variables:

- Dimensions
- Density of fluid
- Depth of immersion
- Hydrostatic pressures and forces (thrust)
- Depth of centre of pressure.

Learning outcome

The learner will:

3. Understand the application of hydrodynamic principles to the flow of fluids

Assessment criteria

The learner can:

3.1 Define the principles, formulae and equations relevant to hydrodynamics
3.2 Determine the flow of fluids in pipes using measuring instruments and relevant formulae
3.3 Determine the forces exerted by nozzle vane systems.

Range

AC3.1 Principles:

- Incompressible flow
- Mass and volume flow
- continuity equation
- Bernoulli's theorem
- Reynold's number for laminar and turbulent flow
- D'Arcy's theorem for loss of head due to pipe friction.

AC3.2 Measurement systems:

- Calculations for standard pipe lengths, tapered, tapered and inclined pipes
- Measuring instruments (Venturi meter, orifice plate, manometer and Pitot tube)
- Variables such as mass flow rates, volume flow rates, density of fluid, entry and exit velocities, differences in pressure at entry and exit points.

AC3.3 Nozzle vane systems:
Calculations:

- Stationary nozzles
- Impacting jet
- Stationary plate.

Variables:

- Thrust forces generated by jet

- Forces impinging on vanes
- Reactions to a jet nozzle.

Learning outcome

The learner will:

4. Understand the application of aerodynamic flow principles to wind tunnel testing

Assessment criteria

The learner can:

4.1 Describe the use of wind tunnels for aerodynamic testing

4.2 Explain the parameters involved in determining aerodynamic factors

4.3 Describe the aerodynamic parameters determined by wind tunnel testing.

Range

AC4.1 Scope of use:

- Open and closed
- Measuring equipment (digital instruments, manometers, speed probes and Pitot static tubes)
- Models (aerofoil sections, model aircraft and racing car).

AC4.2 Parameters:

- External flow
- Angle of attack
- Span
- Chord
- Aspect ratio
- Airspeed
- Lift and drag coefficients
- Dynamic pressure
- Ratio of lift and drag forces
- Reynold's number
- Pressurisation effects
- Scale and speed effects on test pieces.

AC4.3 Parameters:

- Testing (practical and theoretical)
- Pressure distribution
- Lift and drag coefficients
- Sown force
- Lift and drag ratio.

Unit 317 Principles and Applications of Fluid Mechanics

Supporting Information

Unit Guidance

Although this is a knowledge unit, effective delivery can be achieved using demonstrations and practical work to help embed the principles and concepts involved. Wherever possible the measuring equipment and test rigs mentioned in the unit specification should be accessible to the learners, either to use or to see used by others.

Where the centre does not have such equipment, arrangements could be made to visit testing centres that do possess the required equipment. If this should prove difficult the use of secondary data is encouraged.

Unit 318 Engineering Drawing for Technicians

Unit level:	Level 3
GLH:	60
Unit aim:	This unit enables the leaner to develop the knowledge and skills to produce engineering drawings. The learner will understand the purpose of drawings in an engineering environment. They will be able to interpret engineering drawings as well as produce drawings for components, assemblies and electrical and fluid power systems.

Learning Outcome

The learner will:

1. Understand the purpose of drawings in an engineering environment

Assessment Criteria

The learner can:

1.1 Describe drawing types and their applications
1.2 Describe the benefits and limitations of different drawing techniques

Range

AC1.1 Types:

- Free-hand sketching
- Oblique
- Isometric
- Orthographic
- Sections
- Schematics
- Circuit diagrams
- Wiring diagrams
- Block diagrams
- Assembly
- General arrangement.

AC1.2 Benefits and limitations, including:

- Speed of production
- Accuracy

- Visual impact

Learning Outcome

The learner will:

2. Understand engineering drawings

Assessment Criteria

The learner can:
2.1 Know the various standards applied to drawing
2.2 Interpret information from engineering drawings

Range

AC2.1 Standards:

- BS8888
- BS3939
- BS2917.

AC2.2 Information:
Information about the items represented:

- Dimensions
- Tolerances (linear, diameter, radius)
- Surface finish
- Manufacturing detail
- Bill of materials.

Drawing information:

- Sheet size
- Scale
- Title block
- Projection (first angle, third angle)
- View (elevation, plan, end, section, auxiliary).

Drawing characteristics:

- Projection symbols (first angle, third angle scale)
- Types of line (outlines, hidden detail, centre line, projection, dimension, leader, construction)
- Section views (including hatching style).

Representation of standard features:

- Screw threads
- Springs
- Splines
- Repeated items
- Webs
- Nuts
- Bolts and pins

- Solid shafts
- Keys and keyways.

Mechanical symbols:

- Balloon
- Diameter
- Counterbore
- Countersink
- Depth
- Centre mark
- Centre line

Geometric Dimensioning and Tolerancing (GDT) symbols:

- Datum
- Parallelism
- Perpendicularity
- Concentricity
- Straightness

Abbreviations:

- General (across flats, centre line, diameter, drawing, material, square)
- Electrical (resistors, capacitors, diodes, transistors, power supplies)
- Mechanical (chamfer, countersunk, hexagon head, radius, thread, undercut, pitch circle diameter).

Electrical symbols:

- Batteries
- Amplifiers
- Resistors
- Capacitors
- Lamps
- Transformers
- Diodes
- Inductors
- Relays
- Transistors
- Wiring
- Switches.

Circuit symbols for hydraulic and pneumatic systems:

- Valves
- Pumps
- Actuators
- Cylinders
- Receivers
- Compressors.

Learning outcome

The learner will:

3. Be able to produce engineering drawings by hand

Assessment Criteria

The learner can:

3.1 Produce drawings of single components
3.2 Produce drawings of assemblies
3.3 Produce diagrams of electrical circuits
3.4 Produce diagrams of hydraulic and pneumatic circuits

Range

AC3.1 Single components, including:

- Components with complex geometries
- Components with selected standard features as listed in LO2.

AC3.2 Assembly drawings:

- Drawings showing the relationship and clearance between parts.

AC3.3, 3.4 Circuit diagrams:

- Functional circuits with a minimum of six different components.

Unit 318 Engineering Drawing for Technicians

Supporting Information

Additional Guidance

AC 3.3 Produce diagrams of electrical circuits

Diagrams of electrical circuits could include:

- Amplifiers
- Timers
- Rectifiers
- Switching circuits
- Comparators
- Lighting circuits

Unit 319 Computer Aided Design (CAD)

Unit Level:	Level 3
GLH:	60
Unit Aim:	This unit provides the knowledge and skills required to produce engineering representations using CAD software. Learners will develop their understanding of the principles of CAD, including its advantages and disadvantages. They will also learn how to produce drawings, schematics and models of products and systems using CAD software.

Learning outcome

The learner will:

1 Understand the principles of computer aided design (CAD)

Assessment criteria

The learner can:

1.1 Explain that CAD is about the use of computers to support all areas of the design process, not just drawing

1.2 Explain the advantages and disadvantages of using CAD software to produce engineering representations

1.3 Explain the difference between CAD drawings and CAD models

1.4 Explain the characteristics, benefits and limitations of different types of 3D modelling

1.5 Interpret standards and regulations relevant to the use of CAD software

1.6 Describe data management procedures for CAD files

1.7 Describe hardware and software requirements for using CAD software.

Range

AC1.2 Advantages including:

- Accuracy
- Speed of use
- Ability to model/simulate functionality
- Ability to visualise designs in 3D
- Ability to create 2D drawings from 3D models

- Ease of design modification
- Links to CAM and CNC equipment
- Reduced need for physical storage.

Disadvantages including:

- Cost and availability of hardware and software
- Potential for cyber security breaches and/or viruses
- Loss of work due to hardware or software failures
- Additional training requirements.

Representations:

- 2D drawings
- 3D models
- Electrical and electronic circuits.

AC1.4 Types of 3D modelling:

- Surface
- Solid
- Wireframe.

AC1.5 Standards and regulations:

- BS 8888
- BS 5070-3
- BS 3939
- BS 2917-1
- The Health and Safety (Display Screen Equipment) Regulations.

AC1.6 Procedures:

- Use of filename conventions and version control
- Ensuring data is stored securely.

AC1.7 Requirements:

- Input and output devices
- Data storage devices and systems
- Computer system requirements (operating system, hard drive space, RAM, processor speed, graphics card).

Learning outcome

The learner will:

2 Be able to use CAD software to produce engineering representations

Assessment criteria

The learner can:

2.1 Produce CAD drawings using different software commands and features

2.2 Produce schematics using different software commands and features

2.3 Produce CAD models using different software commands and features

2.4 Interpret drawings, schematics and models created using CAD software.

Range

AC2.1, 2.4 Drawings:

- Orthographic (first angle, third angle)
- Isometric
- Assembly.

AC2.1 Commands and features, as appropriate to the drawing type:

- Templates
- Grids
- Layers
- Line types
- Views (base, projected, auxiliary, section, detail, break, breakout, overlay, draft)
- Annotations (surface symbols, geometric dimensioning tolerancing (GDT) symbols, balloons, dimensions, tolerances, datums, hole tables, revision clouds and tags)
- Modifying drawings (array, copy, chamfer, extend, erase, fillet, mirror, move, offset, rotate, scale, trim).

AC2.2, 2.4 Schematics:

- Systems with at least six different components
    - Electrical and electronic systems
    - Fluid power systems (hydraulic, pneumatic)
    - Mechanical systems.

AC2.2 Commands and features, as appropriate to the schematic type:

- Use of component symbols and abbreviations
- Placing and joining components
- Simulating functionality (whole system, sub-systems, individual components)

- Converting to printed circuit board (PCB) layout

AC2.3 Commands and features, including:

- Part modelling
    - Creating geometry (extrude, revolve, loft, sweep, rib)
    - Modifying geometry (Boolean operations, shell, split (face, body))
    - Constraints (coincident, concentric, parallel, perpendicular, tangent)
- Assembly modelling
- Rendering
- Creating orthographic drawings from 3D models
- Visual analysis.

Unit 319 Computer Aided Design (CAD)

Supporting Information

Unit Guidance

LO2

Learners may use any suitable CAD software that enables them to develop the skills listed in the assessment criteria for this learning outcome.

AC2.2

Schematics produced must have a minimum of six components (e.g. resistors, capacitors, diodes, power supplies, switches, sensors, transistors, lamps etc).

Unit 320 Manufacturing Planning

Unit Level:	Level 3
GLH:	60
Unit Aim:	In this unit learners will develop understanding of the purpose of manufacturing planning and the factors to be considered when planning manufacturing activities. They will understand how the scale of manufacture affects the planning activity, strategies used for planning and a variety of planning methods, with their advantages and limitations.

Learning Outcome

The learner will:

1. Understand the information required to plan a manufacturing process

Assessment Criteria

The learner can:

1.1 Explain the purpose of production planning
1.2 Describe the factors considered when planning production

Range

AC1.1 Purpose:

- Efficient use of resources
- Making a profit
- Achieving on time deliveries
- Capacity management/demand levelling.

AC1.2 Factors:

- Product specification (engineering drawings, bill of materials)
- Demand (peak, ramp up, stock requirements)
- Capacity (machine hours, man hours, scheduling conflicts)
- Capability of processes
- Timescale
- Budget

- Availability of materials (type and form of materials, consumables, packaging, lead times)
- Economic order quantities for materials
- Planned downtime (maintenance, holidays)
- Client needs
- Stakeholder requirements.

Learning outcome

The learner will:

2. Understand approaches to production planning

Assessment criteria

The learner can:

2.1 Describe scales of production

2.2 Explain how the scale of production influences the method of manufacturing

2.3 Explain strategies used in production planning

2.4 Describe methods of production planning

2.5 Explain the advantages and limitations of methods of production planning.

Range

AC2.1 Scales of production:

- Bespoke / one-off
- Batch (unique, repeating)
- Mass production
- Continuous/flow production.

AC2.2 Influences:

- Level of automation (from manual to fully automated with CNC machines and robotic systems, conveyors, automatic loading, process monitoring)
- Personnel (man hours required, skill level)
- Use of jigs and fixtures
- Use of standard parts
- Capital investment requirements.

AC2.3 Strategies:

- Chase (production matches demand, assemble to order)
- Level production
- Make to stock.

AC2.4, 2.5 Methods:

- Flow charts
- Gantt charts
- Critical path analysis
- Kanban
- Line balancing
- Bottleneck management
- Material requirements planning (MRP)
- Manufacturing resource planning (MRP2).

AC2.4 Advantages and limitations with relation to:

- Suitability for scale of manufacture
- Efficiency in use of resources
- Demand levelling
- Software requirements
- Planning time.

Learning outcome

The learner will:

3. Be able to produce a production plan

Assessment criteria

The learner can:

3.1 Describe the information required in a production plan

3.2 Produce production plans

3.3 Describe how production plans are used to monitor production

Range

AC3.1 Information:

- Engineering specification (engineering drawings, dimensions, tolerances, bill of materials)
- Deadlines
- Materials required
- Form of materials
- Tools and processes to use
- Durations for each activity
- Quality control

- Health and safety considerations
- Traceability.

AC3.2 Planning:

- Sequence of operations
- Avoidance of scheduling conflicts
- Allowance for defect rates
- Contingency planning
- Production of job cards/activity instructions.

AC3.3 Monitoring methods

- Progress through sequence of operations
- Utilisation (processes, bottleneck activity)
- Materials usage
- Stock levels

Unit 320 Manufacturing Planning

Supporting Information

Unit Guidance

This unit could be delivered through case studies or simulated production activities. It is recommended that emphasis is placed on the different methods of planning, covering each method in detail, along with their suitability for different scales of production and their advantages and limitations. It may be beneficial to use examples of specific products that are appropriate for each method to facilitate learners understanding.

When producing a plan for learning objective 3, learners should be able to use at least two different methods. It is not required for learners to produce plans using all of the stated methods.

Unit 321 Properties and Application of Engineering Materials

Unit Level:	Level 3
GLH:	60
Unit Aim:	When designing a product, the material that it is to be made from is selected based on the properties needed for the application. Sometimes it is necessary to modify the properties of the material to meet these needs, or the properties are modified by the processing needed. Further, when designing a product and selecting the material, consideration has to be given to how the product could fail. In this unit you will come to understand the mechanical and physical properties of materials and how these are measured. You will develop knowledge of types of materials, their properties and applications. You will also understand how the properties of a material are affected by their structure and can be changed by processing, how materials fail and thermodynamic heat transfer in materials.

Learning Outcome

The learner will:

1. Understand the properties of materials

Assessment Criteria

The learner can:

1.1 Explain the difference between mechanical and physical properties
1.2 Define the mechanical and physical properties of materials
1.3 Describe types of materials, their relative properties and their typical applications
1.4 Explain the relationship between the structure of a material and its properties
1.5 Describe how the properties of materials are measured

Range

AC1.2 Mechanical properties:

- Strength (tensile, compressive, shear)
- Hardness

- Toughness (and brittleness)
- Ductility
- Elasticity
- Plasticity
- Malleability.

Physical properties:

- Density
- Melting point
- Thermal and electrical conductivity (resistivity)
- Thermal expansivity
- Corrosion resistance
- Specific heat capacity
- Durability
- Hardenability
- Fusibility
- Weldability
- Ability to be recycled.

AC1.3 Types of materials:

- Ferrous metals: cast iron, low carbon steel (<0.30 % carbon), medium carbon steel (0.3-0.7 % carbon), high carbon steel (0.7-1.4 % carbon), stainless steel
- Non-ferrous metals: aluminium and its alloys, copper and its alloys (brass and bronze), zinc, nickel
- Thermoplastic polymers: high impact polystyrene (HIPS), polypropylene (PP), acrylic (PMMA), polytetrafluoroethylene (PTFE), polythene, polyvinyl chloride (PVC), nylon
- Thermosetting polymers: melamine formaldehyde, phenol formaldehyde, urea formaldehyde, epoxy resin, polyester resin
- Elastomers: rubber, neoprene
- Engineering ceramics: silicon carbide, glass
- Composites: glass reinforced plastics (GRP/fibreglass), carbon reinforced plastics (CRP)
- Smart materials: shape memory alloys (SMA), quantum tunnelling composite (QTC), thermochromic materials, photochromic materials, piezoelectric crystals.

AC1.4 Material structure:

- Bonding mechanisms (metallic, covalent, ionic, van der Waal's forces)
- Microstructure (grains, crystallinity)
- Lattice structure in metals (arrangements, interstitial and substitutional alloying, dislocation movement and pinning)
- Crosslinking of polymers.

AC1.5 Measuring methods:

- Tensile testing
- Toughness testing
- Hardness
- Corrosion resistance
- Wear resistance
- Electrical conductivity.

Learning outcome

The learner will:

2. Understand methods by which the properties of materials can be changed

Assessment criteria

The learner can:

2.1 Explain the effect of processing on the structure and properties of materials
2.2 Explain how heat treatment affects the microstructure and properties of metals.

Range

AC2.1 Effects of processing on metals:

- Forming (rolling, forging, moulding/press forming)
- Welding
- Sintering
- Coating
- Hot working
- Cold working.

Effects of processing on thermoplastic polymers:

- Process parameters, including mould temperature, mould/injection pressure.

Effects of processing on thermosetting polymers:

- Process parameters, including moulding pressure and time, mould temperature, curing.

Effects of processing on ceramics:

- Sintering pressing force
- Firing temperature.

Effects of processing on composites:

- Influence of alignment of reinforcement on anisotropy of properties
- Influence of matrix/reinforcement ratio on tensile strength.

AC2.2 Heat treatments:

- Case hardening
- Quench hardening
- Tempering
- Normalising
- Annealing
- Precipitation hardening.

Influences on the microstructure:

- Grain size
- Compositional change
- Phase transformations in steel
- Formation of precipitates.

Learning outcome

The learner will:

3. Understand failure mechanisms in materials

Assessment criteria

The learner can:

3.1 Describe the causes of materials failure
3.2 Explain how corrosion can cause the failure of a metal part
3.3 Explain methods that can be used to manage corrosion in ferrous metals
3.4 Explain the degradation of polymers
3.5 Explain how materials fail due to fatigue and how the risk of this can be reduced
3.6 Explain how materials fail due to creep and how the risk of this can be reduced.

Range

AC3.1 Causes of failure:

- Chemical (corrosion)
- Physical (deformation, fracture).

AC 3.2 Corrosion:

- Oxidation of metals (including rusting of ferrous metals)
- Consumption of material causing perforation
- Reduction in effective thickness leading to increased stress

AC3.3 Methods:

- Painting
- Plastic coating
- Galvanising
- Electrolytic (galvanic) protection.

AC3.4 Causes:

- Solvent attack
- Aging.

AC3.5 Causes of fatigue:

- Cyclic loading below the yield stress
- Progressive crack growth
- Influence of stress raisers.

AC3.6 Materials failure due to creep:

- Three stages of creep
- Influence of temperature and load.

Learning outcome

The learner will:

4. Understand thermodynamic heat transfer in materials

Assessment criteria

The learner can:

4.1 Calculate the change in dimensions of materials due to temperature
4.2 Calculate energy transfer in thermodynamic systems
4.3 Understand the combustion process requirements of fuels

Range

AC4.1 Calculations:

- Expansivity of solid materials
- Expansion and compression of gases using the ideal gas law (pV = nRT).

AC4.2 Calculations:

- Apply the first law of thermodynamics to a system in steady state ($\Delta U = Q - W$)
- Energy transfer, thermal efficiency and work done in major elements of steam plants (including boiler, superheater, turbine, condenser)

AC4.3 Requirements:

- Stoichiometric equations for complete combustion of fuel elements (hydrogen, carbon, sulphur), including theoretical air requirements and products of combustion
- Calculate calorific value of fuels from results of calorimeter measurements.

Unit 322 Principles of Machining Processes

Unit Level:	Level 3
GLH:	60
Unit Aim:	This unit will develop knowledge and understanding of the principles of machining processes. Learners will develop understanding of the equipment used in machining processes, the methods of power transmission in machine tools and how to apply computer numerical control (CNC) to machine tools.

Learning outcome

The learner will:

1 Understand the equipment used in machining processes

Assessment Criteria

The learner can:

1.1 Describe the characteristics of machine equipment
1.2 Explain the structural requirements of machine equipment
1.3 Explain methods of mounting machine equipment
1.4 Explain the importance of tool alignment
1.5 Explain the factors affecting tool alignment
1.6 Explain the methods of achieving tool alignment.

Range

AC1.1 Characteristics:

- Size
- Capacity
- Accuracy
- Production capability.

Machine equipment:

- Lathes (centre, turret)
- Milling machines (horizontal, vertical)
- Drilling machines (bench, pedestal, radial arm, multi-spindle)

- Grinding machines (surface, cylindrical)
- Laser

AC1.2 Structural requirements:

- Strength
- Rigidity
- Stability
- Control of movement
- Structures (box column, rib and box bed, fabricated base).

AC1.3 Mounting:

- Anti-vibration mountings
- Adjustable mountings
- Rag bolt
- Expanding nut.

AC1.5 Factors affecting alignment:

- Slideways (type, accuracy, lubrication, squareness of movement)
- Spindle (concentricity, end float, squareness of planes to spindle, relationship of spindle to guideway, coaxial alignment)
- Bearings
- Movement of lead screws
- Stick-slip
- Lubrication.

AC1.6 Methods of alignment:

- Standard tests
- Straight edge
- Precision level
- Autocollimator and reflector
- Roundness measurement.

Learning outcome

The learner will:

2 Understand the methods of power transmission in machine tools

Assessment Criteria

The learner can:

2.1 Explain the methods used to achieve rotational movement

2.2 Explain the methods used to achieve linear movement

2.3 Explain the methods used to change speeds

2.4 Explain the methods used to control feeds and speeds of hydraulic components

2.5 Explain the methods used to control pneumatic systems in machine tools

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Range

AC2.1 Methods (rotational):

- Belt drives (flat, vee and tooth)
- Gears
- Hydraulic actuators.

AC2.2 Methods (linear):

- Screw drives
- Rack and pinion
- Crank and slider
- Cams and followers
- Hydraulic actuator.

AC2.3 Methods (speeds):

- Gears
- Cone pulleys
- Electrical/electronic.

AC2.4 Methods (hydraulic):

- Hydraulic drives
- Variable capacity pump
- Differential cylinders
- Bleed valves
- Pressure control valves
- Sequence valves.

AC2.5 Methods (pneumatic):

- Variable output compressor
- Directional control valves
- Supply air throttling
- Exhaust air throttling
- Pressure reducing valves
- Pressure operated valves
- Time delay valves.

Learning Outcome

The learner will:

3 Understand how to apply computer numerical control (CNC) to machine tools

Assessment Criteria

The learner can:

3.1 Explain the advantages and limitations of using CNC machine tools against non-CNC machine tools

3.2 Explain the operating principles of CNC machine tools

3.3 Describe how to program and test the operation of a CNC machine tool

Range

AC3.1 Advantages and limitations:

- Rate of production
- Accuracy
- Precision
- Repeatability
- Ability to run unsupervised
- Skill levels
- Ease of programming
- Maintenance requirements
- Cost

AC3.2 Operating principles:

- Open loop system
- Closed loop system
- Use of microcontrollers
- Use of sensors
- Programmable
- Co-ordinate positioning (absolute, incremental).

AC3.3 Program and test:

- Programming (off-line and pendant)
- Direct link to CAD
- Use of sub routines, macros and canned cycles
- Simulating the program.

Unit 322 Principles of Machining Processes

Supporting Information

Unit Guidance

This is a theory unit intended to underpin the development of practical skills. Delivery could be supported by the practical use of equipment.

Unit 323 Computer Aided Manufacturing

Unit Level:	Level 3
GLH:	60
Unit Aim:	A wide variety of computer aided manufacturing (CAM) equipment is used in the engineering industry. In this unit, learners will develop understanding of the range of applications for which CAM equipment is used, the reasons why it is used and its operating principles. They will understand how CAM equipment is programmed, manually write programs and know how programs are communicated to the equipment. They will understand how to set up CAM equipment, the specific hazards associated with this type equipment and how these can be controlled. They will also be able to describe methods of automated material loading and work holding and how the performance of CAM equipment can be monitored.

Learning Outcome

The learner will:

1. Understand the use of Computer Aided Manufacture (CAM) in engineering

Assessment Criteria

The learner can:

1.1 Describe applications of CAM in engineering
1.2 Explain the advantages and limitations of CAM compared to manual processes
1.3 Describe the operating principles of CAM equipment

Range

AC1.1 Applications:

- Subtractive manufacturing (turning, milling, grinding, machining centres)
- Additive manufacturing (3D printing/fused deposition modelling, stereolithography, selective laser sintering)
- Fabrication (plasma cutting, water jet cutting, welding, shearing)
- Robotic systems (pick and place, assembly, welding, paint spraying).

AC1.2 Advantages and limitations:

- Speed

- Accuracy (capability compared to manual control, reduction of human error)
- Precision
- Repeatability
- Ability to produce complex shapes
- Power assistance
- Use in hazardous areas
- Ability to work without constant human supervision
- Skill level of users
- Compatibility with CAD systems
- Programming requirements
- Maintenance
- Cost of equipment.

AC1.3 Principles:

- Generation of a program
- Communication of program to the CAM equipment
- Computer control of the methods used to move the tool and/or manipulate the workpiece
- Use of sensors to provide closed loop feedback control

Learning outcome

The learner will:

2. Understand how CAM equipment is programmed and be able to create programs

Assessment criteria

The learner can:

2.1 Describe the information required to create a program and where this may be found
2.2 Explain terminology used when programming CAM equipment
2.3 Manually create programs to control CAM equipment
2.4 Describe how a program can be generated using a CAD drawing or model
2.5 Describe methods used to evaluate a program
2.6 Explain reasons for simulating the operation of a program
2.7 Explain the methods of communicating the program to the CAM equipment and their advantages and limitations

Range

AC2.1 Information required:

- Required component geometry (dimensions, surface finish, features including faces, holes, slots, pockets, threads, complex profiles)

- Machine type
- Material from which the component is made
- Tooling required
- Sequence of operations
- Critical path
- Feeds and speeds
- Datum
- Tool change location
- Order of indexing.

Information Sources:

- Engineering drawings
- Production plans
- Job cards
- Manufacturers' manuals
- International standards
- Calculations
- Proprietary software.

AC2.2 Terminology, to include:

- Part programs
- Word address
- Conversational
- Lead in
- Lead out
- Sub-routine/labels
- Canned cycles/process pages

AC2.3 Programming in an appropriate language, including:

- Preparatory functions (including metric/imperial units, tool selection, cutting fluids, workpiece loading and holding, tool changing, safety).
- Specifying the sequence of operations
- Determining and specifying position (including axis coordinates (x, y, z), absolute, incremental, polar, Cartesian)
- Manipulation of tooling and work piece (including position, direction, amount of movement)
- Rates of change (including feed rates, speed/spindle rates, start and stop).

AC2.5 Methods:

- Simulation

- Single block
- Rapid override.

AC2.6 Reasons:

- Verify correct operation
- Avoidance of tooling collisions
- Optimisation of sequence of operations
- Optimisation of tool path.

AC2.7 Methods:

- Direct entry into the machine (keyboard, pendant)
- Portable memory devices
- Intranet
- WiFi

Learning outcome

The learner will:

3. Understand the operation of CAM equipment

Assessment criteria

The learner can:

3.1 Explain hazards specific to CAM equipment and how they are controlled
3.2 Explain how to set up CAM equipment
3.3 Describe methods of material loading used by CAM equipment
3.4 Describe methods of work holding used by CAM equipment
3.5 Describe how the performance of CAM equipment can be monitored

Range

AC3.1 Hazards:

- Unscheduled cycle starts
- Ejected workpieces
- Moving parts
- Entanglement
- Flying debris
- Sharp edges
- Heat

Control measures:

- Limiting human access to the working area (including guarding, enclosures/cages, use of interlocks)
- Permit to work and lock off procedures for maintenance
- Personal protective equipment.

AC3.2 Setting up, including:

- Checking tools are fit for purpose
- Securing tools in tool holding devices (including tool holders, turrets, tooling columns/tombstones)
- Setting tool offset
- Setting/referencing datums

AC3.3 Methods of loading, including:

- Bar feeders/pullers
- Face drivers
- Robots
- Conveyors.

AC3.4 Methods of work holding, including:

- Hydraulic vices
- Fixtures
- Vacuum beds.

AC3.5 Monitoring:

- In-process checks (probing, trial cuts, checking tool condition, temperature monitoring)
- Post-process checks (measurement of dimensions and surface finish).

Unit 323 Computer Aided Manufacturing

Supporting Information

Whilst the majority of this unit is knowledge based, learners will need to apply their knowledge to be able to produce programs for CAM equipment. The type of equipment to be programmed is not specified and could be determined by the resources available in the centre. The programs should be written using code appropriate to the available resources.

It is recommended that prior to studying this unit learners should have undertaken one or more units involving basic machining, to develop supporting understanding relating to machine elements, component features and the basic machining techniques required to produce a variety of features.

Unit 324 Principles of Engineering Measurement

Unit Level:	Level 3
GLH:	50
Unit Aim:	This unit provides the knowledge, understanding and skills needed to use engineering measuring equipment. It covers the principles of engineering measurement, the function and use of measurement equipment and the principles of equipment calibration.

Learning Outcome

The learner will:

1. Understand the principles of engineering measurement

Assessment Criteria

The learner can:

1.1 Explain the purpose of measurement in engineering
1.2 Explain terms used in engineering measurement
1.3 Interpret units of measurement
1.4 Convert between SI and imperial units
1.5 Explain the difference between subjective and objective measurements
1.6 Explain the differences between analogue and digital signals
1.7 Describe the main elements of a measuring system
1.8 Explain the benefits and limitations of sampling compared to a full inspection
1.9 Explain the principles of sampling.

Range

AC1.1 Purpose:

- To ensure quality (quality control, quality assurance)
- To support the ability to meet tolerances
- To ensure specification criteria and standards are met
- To support maintenance (fault diagnosis, inspection, testing)
- To gather statistical data for analysis.

AC1.2 Terms:

- Precision

- Tolerance
- Accuracy
- Repeatability
- Range
- Capability
- Error
- Uncertainty
- Traceability
- Sensitivity
- Sampling
- Calibration.

AC1.3 Units of measurement:

- SI units (metric)
- Imperial units
- Base and derived units.

AC1.7 Measuring system elements:

- Sensing element
- Data processing
- Presentation method to end user.

AC1.9 Principles of sampling:

- Statistical distribution
- Process capability (definition, calculation)
- Calculation of sample sizes
- Application of statistical process control (SPC)
- Application of 6 sigma for high-volume manufacture.

Learning outcome

The learner will:

2. Understand the function of and be able to use measurement equipment

Assessment criteria

The learner can:

2.1 Explain the function and applications of measuring equipment
2.2 Explain the benefits and limitations of measurement equipment
2.3 Describe the operation of measuring equipment
2.4 Select and safely use appropriate measurement equipment to measure engineered products

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2.5 Produce records and reports of measurement results

Range

AC2.1-2.4 Equipment:

- Rules
- Callipers (Vernier, digital)
- Micrometers (outside, inside, depth)
- Protractors
- Ammeters
- Voltmeters
- Ohmmeters
- Multimeters
- Oscilloscopes
- Signal generators
- Pulse generators
- Logic probes
- Insulation resistance testers
- Impedance meters
- Comparators
- Guages (slip, go/no-go)
- Dial test indicators
- Coordinate measuring machines
- Data loggers
- Virtual instruments
- Recording and display equipment.

Learning outcome

The learner will:

3. Understand the principles of calibration of measurement equipment

Assessment criteria

The learner can:

3.1 Explain the need for calibration of measurement equipment
3.2 Explain the terms used in equipment calibration
3.3 Explain the impact of calibration on quality, productivity and safety
3.4 Describe situations when calibration is necessary
3.5 Describe procedures used to validate measurement equipment functionality

Range

AC3.2 Terms:

- Accuracy
- Precision
- Uncertainty
- Resolution
- Validity period
- Linear
- Non-linear
- Zero shift
- Span error.

AC3.4 Situations:

- During manufacture
- Quality assurance
- Quality control
- Following installation
- Periodic scheduled maintenance
- In response to identified deviation
- After repair or change in environment.

AC3.5 Procedures:

- Reference against standards and known values
- Reference against calibrated equipment
- Zero checks

Unit 324 Principles of Engineering Measurement

Supporting Information

Unit Guidance

AC 2.5
Learners can be provided with pre-existing engineered products or components on which to conduct their measurements. Alternatively, or in addition to this, the teaching of this unit could be linked with other practical units in which they could measure engineered products that they themselves have produced.

Unit 325 Project Management

Unit Level:	Level 3
GLH:	60
Unit Aim:	Project management is the skill of being able to plan, monitor and co-ordinate the tasks involved to successfully turn an idea or activity into a required outcome. In this unit you will come to understand why project management is important and develop knowledge and understanding of how to plan, monitor and co-ordinate projects, communicate project progress and review the outcomes of engineering projects.

Learning Outcome

The learner will:

1. Understand the importance of project management

Assessment Criteria

The learner can:

1.1 Explain the principles of project management

1.2 Explain the benefits of project management.

Range

AC1.1 Principles:

- Project lifecycle: initiation, planning, implementation, closure
- Defined objectives
- Identification of constraints and resources
- Defined roles and responsibilities
- Resource management
- Development, implementation and monitoring of a project plan
- Risk management.

AC1.2 Benefits:

- Completion on schedule
- Compliance with the requirements of the initial brief
- Efficiency of resource use

- Improved customer satisfaction
- Reduced susceptibility to disruption from risks
- Learning from experience
- Development of staff in the project team.

Learning outcome

The learner will:

2. Understand how to set up projects

Assessment criteria

The learner can:

2.1 Explain the main considerations when reviewing project proposals

2.2 Describe the types of resources needed to complete projects

2.3 Explain the roles and responsibilities within project teams.

Range

AC2.1 Considerations:

- Required outcome
- Identification of stakeholders
- Timescale
- Budget
- Materials
- Tools and processes
- Personnel
- Competition for resources
- Legal requirements.

AC2.2 Types of resource:

- Time
- Budget
- Human resources/personnel in the project team
- Physical resources: materials, tools and processes, IT requirements
- Access to expert knowledge
- Authority to drive progress/position power.

AC2.3 Roles and responsibilities:

- Project manager

- Specialist knowledge and skills from different areas of the organisation: design, supply chain/purchasing, manufacturing.

Learning outcome

The learner will:

3. Understand how to plan and monitor a project

Assessment criteria

The learner can:

3.1 Explain the methods used to plan projects and their advantages and disadvantages

3.2 Explain risks associated with project progress and risk mitigation actions

3.3 Describe methods of monitoring projects.

Range

AC3.1 Planning methods:

- Flow charts
- Gantt charts
- critical path analysis
- PERT (project evaluation and review technique)
- Use of current and relevant project management software.

AC3.2 Risks:

- Changing requirements
- Unrealistic estimated times and costs
- Unexpected costs
- Equipment failure/breakdowns
- Safety issues
- Inadequate communication
- Inadequate project management.

Mitigation actions:

- Contingency planning
- Additional time for tasks
- Additional or alternate resources.

AC3.3 Monitoring:

- Management by stages/task
- Management by exception/addressing deviations from plan
- Monitoring of task completion
- Progress reports
- Budget monitoring reports
- Updating task status.

Learning outcome

The learner will:

4. Understand how to communicate project progress and review project performance

Assessment criteria

The learner can:

4.1 Explain how to communicate project progress to stakeholders

4.2 Explain the reasons for reviewing projects on completion.

Range

AC4.1 Methods of communication:

- Progress updates on project plans
- Progress meetings
- Budget reports
- Graphical representations of progress
- Use of a visual display board
- Project logbooks.

AC4.2 Reasons:

- Comparison of outcomes against original objectives
- Highlight any outstanding issues: health and safety, performance of the outcome, training needs, resource availability
- Identify areas for improvement
- Learn from experience
- Improve future projects
- To identify key resources for future projects.

Unit 325 Project Management

Supporting Information

Unit Guidance

This unit could be delivered effectively through the use of case studies. However, it is expected that learners will have practical experience of using the stated tools and methods to plan and monitor small projects.

It is recommended that the largest proportion of time for delivery is allocated to learning outcome 3, covering methods of planning, risk mitigation and monitoring.

Unit 326 Further Mathematics for Engineers

Unit Level:	Level 3
GLH:	60
Unit Aim:	Engineers apply mathematical methods and scientific knowledge to design effective products, calculate process parameters, assess whether components meet specification requirements, evaluate the performance of products and to solve problems. In this unit, you will apply mathematical principles of algebra, trigonometry, calculus, complex numbers and statistics to solve engineering problems.

Learning Outcome

The learner will:

1. Apply algebraic methods and trigonometry

Assessment Criteria

The learner can:

1.1 Solve problems using equations
1.2 Determine numbers in a sequence or series
1.3 Apply trigonometric methods to solve problems
1.4 Interpret and express graphical representations of problems.

Range

AC1.1 Use of equations:

- Resolve simultaneous equations
- Use quadratic equations
- Calculate safety factors for engineering components and systems.

AC1.2 Sequences and series:

- Arithmetic progression
- Geometric progression
- Power series.

AC1.3 Trigonometry:

- Identify characteristics of a sine wave (amplitude, periodic time, frequency)
- Use trigonometric identities to solve engineering problems (tan = sin/cos, cot = 1/tan, sec = 1/cos, cosec = 1/sin)
- Apply the sine rule and cosine rule to determine the dimensions of a triangle.

AC1.4 Graphical representations:

- Interpret and plot equations of exponential and logarithmic functions
- Interpret and plot equations of trigonometric functions (sin, cos, tan)
- Interpret and plot equations of polynomial functions.

Learning outcome

The learner will:

2. Apply principles of calculus

Assessment criteria

The learner can:

2.1 Apply the principles of differentiation
2.2 Apply the principles of integration

Range

AC2.1 Principles of differentiation:

- Represent the derivative of f(x)using the notation f'(x) or dy/dx
- Know that differentiation represents rate of change
- Determine standard derivatives of functions that include basic mathematical operators:
  - Exponentials
  - Logarithms
  - Trigonometric functions (sin, cos)
  - Reciprocals
  - Polynomials
- Apply product, quotient and chain rules to determine derivatives
- Determine first and second order derivatives
- Apply differentiation to:
  - Rate of change of a phenomena, including charge rate, determination of velocity (from position) and acceleration
  - Gradients
  - Maxima and minima
  - Stationary points.

AC2.2 Principles of integration:

- Know that integration is the reverse of differentiation
- Determine standard derivatives of functions including basic mathematical operators and:
  - Exponentials
  - Reciprocals
  - Trigonometric functions (sin, cos)
  - Polynomials
- Determine definite and indefinite integrals
- Apply rules for integration by parts, substitution and partial fractions
- Apply integration to:
  - Areas
  - Volumes of revolution
  - Centres of mass
  - Mean and root mean square (rms) values of a function.

Learning outcome

The learner will:

3. Apply the principles of complex numbers

Assessment criteria

The learner can:

3.1 Describe what is meant by a complex number
3.2 Carry out mathematical operations using complex numbers
3.3 Represent complex numbers on a graph
3.4 Solve engineering problems involving Cartesian and polar coordinates.

Range

AC3.1 Definition:

- Definition of a complex number (a + jb)
- Real and imaginary parts
- Powers of j.

AC3.2 Mathematical operations:

- Addition and subtraction of complex numbers in algebraic form
- Conjugation of complex numbers
- Multiplication and division of complex numbers in algebraic form
- Use complex numbers in the context of electrical and electronic problems.

AC3.3 Graphical representation:

- Represent complex numbers using an Argand diagram
- Represent complex numbers as phasor diagrams
- Add and subtract phasors in complex form.

AC3.4 Cartesian and polar coordinates:

- Definitions and properties of Cartesian (x,y) and polar (r,Θ) coordinates
- The polar form of a complex number
- Conversion between Cartesian and polar, where angles are in degrees or radians
- Addition, subtraction, and multiplication and division of numbers in polar form, by numerical calculation and graphical representation
- Calculate polar and Cartesian coordinates in the context of machine tool paths.

Learning outcome

The learner will:

4. Apply statistical methods in engineering contexts

Assessment criteria

The learner can:

4.1 Solve problems involving normal distribution of data
4.2 Solve problems involving binomial distribution
4.3 Apply statistical methods to process control
4.4 Explain the benefits and limitations of using statistical process control, relative to quantity of parts being manufactured.

Range

AC4.1 Solve problems involving normal distribution:

- Determine mean, median and modal averages
- Calculate range, variance, cumulative frequency and standard deviation.

AC4.2 Solve problems involving binomial distribution:

- Identify conditions for application of a binomial distribution and the discrete random variables
- Use formula to calculate distribution (including notation)
- Calculate mean, variance and standard deviation.

AC4.3 Statistical methods:

- Calculate process capability values (C_P and C_{PK})
- Calculate the action (warning) and control limits for a statistical process control (SPC) control chart
- Interpret the data shown on an x-bar and r chart
- Calculate sample size and frequency.

Unit 326 Further Mathematics for Engineers

Supporting Information

Unit Guidance

It is recommended that this unit is studied after unit 303, Applied science and maths for engineering. This unit builds on the basic mathematics skills and knowledge developed in that unit.

Unit 327 Advanced Mechanical Principles of Engineering Systems

Unit Level:	Level 3
GLH:	60
Unit Aim:	All mechanical systems consist of parts working together to produce a desired output. The design and use of these systems requires understanding of the forces acting on them and their operating characteristics. In this unit, you will develop understanding of the loading in pin jointed framed structures, structural members and simply supported beams. You will also develop initial understanding of the characteristics of rotating systems and the operating characteristics of simple lifting machines.

Learning Outcome

The learner will:

1. Determine the effects of loading in static engineering systems and structures

Assessment Criteria

The learner can:

1.1 Calculate stress and strain in components under various conditions
1.2 Determine forces in perpendicular directions
1.3 Calculate the forces required to keep a body in equilibrium
1.4 Apply Bow's notation to pin-jointed frameworks
1.5 Determine the forces in loaded pin-jointed frameworks
1.6 Calculate the first and second moment of area of different sections
1.7 Determine the forces at various points on a beam
1.8 Use bending theory to solve problems relating to beams.

Range

AC1.1 Conditions:

- Different diameters
- Compound bars made from two different materials
- Thermally induced stress and strain
- Determination if a structural member is a strut or a tie.

AC1.2 Resolution of forces:

- $F_X = F \cos \theta$
- $F_Y = F \sin \theta$.

AC1.3 Equilibrium:

- Up to three forces
- Application of conditions for static equilibrium ($\Sigma F_V = 0$, $\Sigma F_H = 0$, $\Sigma M = 0$)
- Vector addition.

AC1.5 Frameworks:

- Simply supported
- Cantilever.

Types of loading:

- Vertical
- Horizontal
- Inclined
- Point (concentrated)
- Uniformly distributed
- Combination of point and uniformly distributed.

Methods of determining forces:

- Method of sections
- Determination of both magnitude and direction (compressive or tensile) of the force.

AC1.6 Sections:

- Rectangular
- Circular
- Trapezoidal
- Compound shapes.

AC1.7 Types of beam:

- Simply supported, with and without overhangs
- Cantilever.

Types of loading:

- Up to two points
- Uniformly distributed
- Combination of point and uniformly distributed.

Forces:

- Reaction forces
- Determination of bending moments (including drawing bending moment diagrams)
- Determination of shear force (including drawing shear force diagrams).

AC1.8 Problems:

- Maximum stress
- Maximum load
- Beam dimensions
- Radius of curvature
- Calculate deflections at mid-span under load.

Bending equation $M/I = \sigma/y = E/R$

Learning outcome

The learner will:

2 Determine the characteristics of rotating systems

Assessment criteria

The learner can:

2.1 Evaluate the characteristics of a body rotating about an axis
2.2 Solve problems involving systems with uniform angular acceleration
2.3 Solve problems involving systems with uniform centripetal acceleration

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Range

AC2.1 Bodies:

- Disc
- Flywheel
- Bar.

Characteristics:

- Angular displacement
- Angular velocity ($\omega = \theta / t$)
- Angular acceleration ($\alpha = \omega_2-\omega_1) / t$)
- Rotational kinetic energy ($KE = ½ I\omega^2$)
- Moment of inertia ($I = Mk^2$, $I = MD^2/8$)
- Radius of gyration ($r = (I/m)^{½}$)
- Inertia torque ($T = I\alpha$)
- Mechanical work ($W = T\theta$)
- Power ($P = \omega t$).

AC2.2 Problems:

- Angular speed ($\omega = v / r = 2\pi f$, $\omega_2 = \omega_1 + \alpha t$).

AC2.3 Problems:

- Centripetal acceleration ($\alpha = v^2 / r = \omega^2 r$)
- Centripetal force ($F = mv^2 / r = m\ \omega^2 r$).

Learning outcome

The learner will:

3 Determine the operating characteristics of simple lifting machines

Assessment criteria

The learner can:

3.1 Calculate the operating parameters of simple lifting mechanisms
3.2 Apply the angle of friction to motion on simple inclined planes
3.3 Solve problems involving the use of square thread screw jacks.

Range

AC3.1 Mechanisms:

- Pulley blocks
- Simple gear train winch.

Operating parameters:

- Mechanical advantage (force ratio)
- Velocity ratio
- Input motion or effort

- Load raised
- Work
- Energy
- Efficiency.

Equations include:

- $M_A = F_L / F_E = \eta VR$
- $\eta = F_L X_L / F_E X_E$,

AC3.3 Types of problems:

- Velocity ratio
- Angle of the plane
- Diameter of the screw jack
- Calculation of coefficient of friction
- Effort needed to raise or lower a load
- Efficiency when raising or lowering a load
- Length of handle
- Work done.

Equations include:

- $VR = 2\pi E / p$
- $\mu = \tan \beta$
- $\text{Tan } \alpha = p / \pi D$
- $F_T = F \tan (\beta - \alpha)$
- $F = F_T D / 2r$
- $\eta = p / (\pi D \tan(\beta \pm \alpha))$.

Unit 327 Advanced Mechanical Principles of Engineering SystemsAdvanced Mechanical Principles of Engineering Systems

Supporting Information

Unit Guidance

It is recommended that this unit is studied after unit 11, Mechanical properties of engineering systems.

Unit 328 Organisational Improvement

Unit Level:	Level 3
GLH:	60
Unit Aim:	Efficient, effective processes can provide an organisation with competitive advantage and maximise return on investment. In many organisations there is the potential to improve the effectiveness and efficiency of existing activities. In this unit you will develop understanding of the context of production activities in which organisational improvement is sought. You will come to understand a variety of approaches that will improve the performance of an organisation and their advantages and limitations. These include different approaches to organising activities, lean manufacturing, methods that apply statistics and an understanding of the relationship between human resources and production management.

Learning Outcome

The learner will:

1. Understand production activities

Assessment Criteria

The learner can:

1.1 Explain how the scale of production affects the approach to manufacturing

1.2 Explain the activities involved in different stages of production and how these affect performance

1.3 Explain how production planning considerations affect operational performance

1.4 Explain the use of quality assurance and quality control within organisations.

Range

AC1.1 Scale of manufacturing:

- One-off/bespoke
- Batch
- Mass
- Continuous.

Effect of scale of manufacturing in terms of:

- Level of automation
- Use of production aids (jigs, fixtures, moulds and templates)
- Organisation of the resources (functional, product-oriented)
- Skill of the workers.

AC1.2 Activities:

- Design
- Purchasing/supply chain
- Manufacturing
- Fabrication and assembly
- Finishing
- Quality.

Effect on performance in terms of:

- Cost
- Lead time.

AC1.3 Production planning considerations:

- Selection of tools and processes
- Availability and form of materials
- Availability of personnel
- Testing and inspection
- Health and safety guidance
- Documentation and layouts
- Standard operating procedures
- Timescales
- Scheduling
- Monitoring.

AC1.4 Use of quality assurance (QA) and quality control (QC):

- Difference between QA and QC
- Purpose of quality standards
- Effectiveness of quality management systems
- Roles and responsibilities of the Quality Manager.

Learning outcome

The learner will:

2. Understand organisational approaches to business improvement

Assessment criteria

The learner can:

2.1 Explain the purpose of continuous improvement activities
2.2 Explain methods of organising manufacturing resources and their advantages and limitations
2.3 Explain the principles of total quality management (TQM)
2.4 Explain how visual management approaches contribute to performance.

Range

AC2.1 Purpose:

- Meaning of continuous improvement and kaizen
- Difference between effectiveness and efficiency
- Productivity as a measure of effectiveness and efficiency
- Improving effectiveness by focussing on what adds value and eliminating what does not add value
- Improving efficiency for activities that add value
- Reductions in cost and lead time
- Improvements in product performance, quality and safety.

AC2.2 Methods of organising manufacturing resources:

- Production lines
- Cellular manufacture
- Flexible manufacturing
- Push (make to stock) production
- Pull (demand driven) production
- Production levelling.

AC2.3 Principles of TQM:

- Focus on the customer
- Commitment of all employees
- Produce quality work the first time
- Have a strategic approach to improvement
- Improve continuously
- Encourage mutual respect and teamwork.

Learning outcome

The learner will:

3. Understand lean manufacturing approaches to business improvement

Assessment criteria

The learner can:

3.1 Explain the seven wastes
3.2 Explain the purpose and method of value stream mapping (VSM)
3.3 Explain the principles of 5S workplace organisation and how these are applied in the workplace
3.4 Explain the principles of set-up reduction (single minute exchange of die/SMED) and how it is applied to manufacturing processes
3.5 Explain the principles of total productive maintenance (TPM) and how it is applied to manufacturing facilities
3.6 Explain the principles of kanban and its advantages and limitations
3.7 Explain the advantages and limitations of just in time (JIT) manufacture.

Range

AC3.1 Wastes:

- Overproduction
- Inventory
- Motion
- Defects
- Over-processing
- Waiting
- Transport

AC3.2 VSM:

- Walking the process
- Categorising activities as different types (including process, movement and inventory)
- Identifying activities that add value and activities that do not add value
- Identifying where improvements can have the highest impact.

AC3.3 5S:

- Sort
- Set in order
- Shine
- Standardize
- Sustain.

AC3.4 Principles of SMED:

- Conversion of 'internal' activities to external
- Improvement in overall output of production facilities when applied to limiting (bottleneck) manufacturing processes.

AC3.5 Principles of TPM:

- Reduced equipment failure
- Reduced requirements for set-up and adjustments
- Prevention of idling and minor stops
- Avoiding need to reduce process speed
- Eliminating process defects
- Maintaining process yield
- Overall equipment effectiveness (OEE) as a measure of maintenance effectiveness

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Learning outcome

The learner will:

4. Understand and apply statistical tools used for improvement of manufacturing activities

Assessment criteria

The learner can:

4.1 Explain and calculate the process capability of manufacturing processes
4.2 Explain the use of statistical process control and its benefits and limitations
4.3 Explain the use of six sigma in high volume manufacturing and its benefits and limitations.

Range

AC4.1 Process capability:

- Reasons for a tolerance on the dimensions of manufactured parts
- Difference between C_P and $C_{PK.}$

AC4.2 SPC:

- Use of x-bar and R control charts
- Calculation of action limits and control limits

Learning outcome

The learner will:

5. Understand the relationship between human resources and organisational improvement

Assessment criteria

The learner can:

5.1 Describe the characteristics of an effective team

5.2 Explain how leadership style impacts on human resources and business performance.

Range

AC5.1 Characteristics:

- Clear team goals
- Clear roles
- Clear lines of authority and decision making
- Group norms set for working together
- Appropriately trained and skilled team members
- Effective and timely communication
- Opportunities for personal and professional development.

AC5.2 Leadership styles:

- Behavioural
- Autocratic
- Participative
- Delegative.

Unit 328 Organisational Improvement

Supporting Information

Unit Guidance

This unit could be delivered effectively through the use of case studies.

Unit 329 Business Operations in Engineering

Unit Level:	Level 3
GLH:	60
Unit Aim:	In this unit, learners with develop knowledge and understanding of how engineering businesses operate. Learners will understand the type, functions and structure of engineering companies and the sectors in which they operate. They will develop understanding of how external factors can affect the operation of engineering companies. They will also understand and be able to analyse the factors affecting financial performance of an engineering activity.

Learning Outcome

The learner will:

1. Understand how an engineering company operates

Assessment criteria

The learner can:

1.1 Explain the different functional areas of an engineering company

1.2 Describe the sectors in which engineering companies operate

1.3 Explain the typical structures of engineering companies and their advantages and limitations

1.4 Explain how the size of an engineering company affects its activities

Range

AC1.1 Functional areas:

- Research and development (R&D)
- Design
- Manufacture
- Materials supply and control
- Production planning and control
- Sales and marketing
- Maintenance & technical support
- Project planning and management
- Quality assurance and control
- Human resources
- Finance.

AC1.2 Sectors:

- Aerospace
- Agriculture, forestry, farming and fishing (Primary)
- Automotive
- Building services
- Chemical
- Civil engineering
- Defence
- Electrical and electronic
- Healthcare
- Manufacturing
- Marine
- Petrochemical
- Power generation (renewables, non-renewables, nuclear)
- Telecommunications
- Waste management.

AC1.3 Structures:

- Product orientated
- Functional
- Hierarchical
- Matrix.

AC1.4 Influence of size:

- Expertise
- Strategy
- Communication
- Specialisation of skills
- Scale of manufacture
- Performance management
- Information systems
- Working procedures.

Learning outcome

The learner will:

2. Understand how external factors affect the operation of an engineering company

Assessment criteria

The learner will:

2.1 Explain the factors that affect the situation in which an engineering company operates

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2.2 Explain the external factors that directly impact on an engineering company
2.3 Explain how legislation impacts on the operation of engineering businesses.

Range

AC2.1 Indirect factors:

- Social (workforce skill levels and training requirements, social mobility, fair trade, ethical considerations, population demographics)
- Technological
- Environmental (requirements of ISO 14001, hierarchy of environmental controls, product end of life strategy, increased use of renewable energy resources, recycling)
- Economic (Gross National Product (GNP), Gross Domestic Product (GDP), Balance of payments, interest rates, exchange rates, employment rate)
- Political.

AC2.2 Direct factors:

- Markets
- Competitors
- Geographic location
- Transportation requirements
- Consumers
- Social trends
- Availability of sustainable resources.

AC2.3 Legislation and Regulations:

- Health and Safety at Work 1974
- Employment Act 2008
- Factories Act 1961
- Fire Precautions Act 1971
- Data Protection Act 1998
- Employment Equality (Age) Regulations 2006
- Management of Health and Safety at Work Regulations 1999
- Provision and Use of Work Equipment Regulations 1998
- Control of Substances Hazardous to Health (COSHH) Regulations 2002
- Lifting Operations and Lifting Equipment Regulations 1998
- Manual Handling Operations Regulations 1992
- Personal Protective Equipment at Work Regulations 1992
- Confined Spaces Regulations 1997
- Electricity at Work Regulations 1989
- Control of Noise at Work Regulations 2005
- Reporting of Injuries Diseases and Dangerous Occurrences Regulations 2013

- Working Time Regulations 1998
- Workplace (Health, Safety and Welfare) Regulations 1992
- Health and Safety (First-Aid) Regulations 1981
- The Data Protection Act 2018.

Learning outcome

The learner will:

3. Understand and be able to analyse the factors affecting financial performance of an engineering activity

Assessment criteria

The learner will:

3.1 Explain the factors which influence the costs of an engineering company
3.2 Explain financial measures used in engineering companies
3.3 Use financial measures to evaluate business decisions.

Range

AC3.1 Cost information:

- Time
- People
- Capital facilities
- Tools
- Materials
- Bought-in services
- Cost of capital
- Taxation.

AC3.2 Measures:

- Income
- Expenditure
- Profit and loss
- Dividend
- Direct and indirect costs
- Fixed and variable costs
- Marginal costing
- Cost of manufacture
- Asset
- Depreciation
- Price.

AC3.3 Measures:

- Break-even point
- Return on investment
- Pay-back time.

Unit 330 Primary Manufacturing Processes

Unit Level:	Level 3
GLH:	60
Unit Aim:	Primary manufacturing processes are used to manufacture products from raw materials. These include shaping processes, which involve a change in state of the material, and forming processes, which involve deforming the material. Both types of process are characterised by minimal changes in the volume of the material, little waste and the use of moulds or formers. In this unit, you will develop understanding of a broad range of primary manufacturing processes used with metals, polymers, ceramics and composite materials. This will include the safety considerations, principles of the processes and how they are used.

Learning Outcome

The learner will:

1. Understand the health and safety requirements that apply to primary manufacturing processes

Assessment Criteria

The learner can:

1.1 Explain the difference between shaping and forming processes

1.2 State the main requirements of health and safety legislation and codes of practice that relate to the practical use of primary manufacturing processes

1.3 Understand the methods of reducing risks when using primary manufacturing processes

Range

AC1.2 Legislation:

- Health and Safety at work act
- Provision and Use of Work Equipment Regulations (PUWER)
- Control of Substances Hazardous to Heath (COSHH) Regulations
- Lifting Operations and Lifting Equipment Regulations
- Manual Handling Operations Regulations (MHOR)
- Personal Protective Equipment (PPE) at Work Regulations
- Control of Noise at Work Regulations

- Relevant codes of practice.

AC1.3 Methods of reducing risks:

- Activities specific to the processes specified in this unit
- Training staff
- Safe use of tools and equipment
- The use of guards, screens, ventilation
- Use of personal protective equipment (PPE)
- Good housekeeping.

Learning outcome

The learner will:

2. Understand how shaping processes are used with metals, polymers and ceramics

Assessment Criteria

The learner can:

2.1 Explain the techniques used to cast metals

2.2 Explain the moulding techniques used with polymers

2.3 Explain how ceramic products are formed by powder metallurgy

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Range

AC2.1 Metal casting techniques:

- Sand casting
- Gravity die casting
- Pressure die casting
- Investment casting.

Details to include:

- Metals applicable to the process (carbon steels, stainless steels, cast iron; aluminium, copper, zinc, nickel, titanium, and their alloys)
- Form of material supply (ingots, scrap, recycled material)
- Production of moulds (patterns, cores, dies, mould materials, use of releasing agents; features of the mould, including runners, risers and sprues)
- Casting of the material
- Removal of the casting and finishing (ejection, knock out, fettling and dressing)
- Influence of the process on finishing requirements.

AC2.2 Moulding techniques used with polymers:

- Injection moulding
- Rotational moulding.

Details to include:

- Polymers applicable to process (thermoplastics including polystyrene, polyethylene, acrylonitrile butadiene styrene (ABS), nylon, polycarbonate, polypropylene; thermosetting plastics)
- Purpose of additives added during the process (stabilisers, flame retardants, fillers/bulking agents, plasticisers, antistatics, pigments, lubricants)
- Types of moulds (two plate, three plate, combination, split, unscrewing)
- Operation of the process
- Influence of process parameters on the moulded product (temperature, pressure, speed/timings)
- Common errors and how they can be rectified (flash, short short, distortion, colour deviation).

AC2.3 Powder metallurgy:

- Ceramics applicable to the process (metallic oxides, nitrides and carbides)
- Preparation of the powder (blending and compacting)
- Influence of process parameters on the product (temperature, pressure).

Learning outcome

The learner will:

3. Understand how forming processes are used with metals and polymers

Assessment criteria

The learner can:

3.1 Explain the techniques used to form products from metals

3.2 Explain the techniques used to form products from polymers

Range

AC3.1 Metal forming techniques:

- Extrusion (direct, indirect, impact)
- Forging (drop, pressure, upset)
- Folling (hot, cold)
- Presswork
- Metal spinning.

Details to include:

- Metals applicable to the process (carbon steels, stainless steels; aluminium, copper and their alloys)
- Operation of the process.

AC3.2 Forming techniques used with polymers:

- Vacuum forming
- Blow moulding
- Rotational moulding
- Compression moulding
- Extrusion.

Details to include:

- Polymers applicable to process (thermoplastics including high impact polystyrene (HIPS), polyvinyl chloride (PVC), acrylonitrile butadiene styrene (ABS), polycarbonate, polypropylene)
- Function of additives during the process (plasticisers, antistatics, heat stabilisers, lubricants)
- Features of moulds and formers as applicable to the process (single moulds, male/female, split, draft angle, avoidance of overhangs, mould materials)
- Operation of the process
- Influence of process parameters on the moulded product (temperature, pressure, speed/timings)

- Common errors and how they can be rectified (flash extending from the parting line, inconsistent wall thickness, distortion, burning).

Learning outcome

The learner will:

4. Understand how composite materials are made by moulding

Assessment criteria

The learner can:

4.1 Explain that composites comprise of two or more materials which are separately identifiable within the structure of the material

4.2 State the different types of matrix and fibre reinforcement used in polymer matrix composites

4.3 Explain how polymer matrix composites are manufactured using a mould

4.4 Explain the differences between manufacturing polymer matrix composites using dry fibre and pre-preg reinforcement

4.5 Explain the causes of common defects in composite products.

Range

AC4.2 Types of matrix:

- Epoxy
- Polyester
- Vinyl ester
- Phenolic.

Types of fibre reinforcement:

- Materials (glass, carbon, aramids, polyethylene)
- Characteristics (continuous filament, uni-directional, woven, chopped strand, roving, braids, tapes).

AC4.3 Manufacture of composite materials:

- Mould features (mould materials, corners, surface profiles)
- Use of release films
- Layout of the fibre reinforcement
- Application of resin (for dry fibre reinforcement)
- Polymerisation reaction/curing (influence of temperature, pressure and environmental conditions on curing; use of a vacuum bag and oven or autoclave)
- Removal of excess material
- Safe disposal of waste.

AC4.4 Differences between dry fibre and pre-preg reinforcement:

- Application of resin and infusion into the matrix.
- Use of templates
- Cutting
- Price
- Set-up cost
- Productivity rate.

AC4.5 Common defects:

- Voids
- Disbands and delamination
- Porosity.

Unit 330 Primary Manufacturing Processes

Supporting Information

Unit Guidance

This unit could be delivered through a series of detailed product analyses, focussed on products selected to cover the range of processes. Although this is a knowledge unit, understanding could also be facilitated through a series of short practical activities, each using a different manufacturing process.

Unit 331 Principles of Composite Materials

Unit Level:	Level 3
GLH:	60
Unit Aim:	Composite materials comprise of two or more materials which are separately identifiable within the structure of the material. They can offer combinations of properties which are not available in other types of material. Composite materials are used in a wide variety of applications, ranging from parts for aircraft and racing car bodies, to bathtubs and sewer pipes, to the structures of buildings and bridges. In this unit you will come to understand the types of composite material and their constituents, along with their properties and applications. You will develop understanding of the different methods used to manufacture fibre-reinforced composites, the defects that can arise during manufacture and how these can be detected.

Learning Outcome

The learner will:

1. Understand the principles and components of composite materials

Assessment Criteria

The learner can:

1.1 Explain what is meant by a composite material

1.2 Describe different types of composite materials

1.3 Describe the types of reinforcement and core structures used in composite materials

1.4 State the types of materials used for fibre reinforcement

1.5 Explain how the arrangement and quantity of the fibre reinforcement affects the properties of the composite material

1.6 Describe typical applications of composite materials

1.7 Describe the properties and characteristics of composite materials and compare these to non-composite materials used in similar applications

1.8 Explain specific health and safety and environmental requirements for handling and manufacturing composite materials.

Range

AC1.1 Meaning of a composite:

- Composites comprise of two or more materials which are separately identifiable within the structure of the material
- The difference between composite materials and metal alloys or chemical mixtures.

AC1.2 Types of composite material:

- Polymer matrix composites (PMC)
- Metal matrix composites (MMC)
- Ceramic matrix composites (CMC).

AC1.3 Types of reinforcement and core structures:

- Fibre in a matrix
- Particulate in a matrix
- Honeycombs
- Foams.

AC1.4 Types of fibre:

- Glass
- Carbon
- Aramids
- Thermoplastic fibres
- Metal
- Ceramic
- Metal
- Natural fibres

AC1.5 Arrangement of the fibre reinforcement:

- Unidirectional continuous (roving)
- Aligned continuous
- Aligned discontinuous
- Random discontinuous (chopped strand mat (CSM))
- Woven, including braids and stitched.

AC1.6 Applications:

- Examples of applications specific to sectors of the engineering industry (including aircraft, automotive, marine, power generation, construction, civil engineering, rail).

AC1.7 Properties:

- Strength
- Toughness
- Stiffness (rigidity)
- Thermal stability
- Strength to weight ratio
- Chemical resistance.

AC1.7 Characteristics:

- Weight
- Cost
- Lifespan
- Sustainability
- Degradation
- Repair
- Assembly.

AC1.8 Requirements:

- Bulk storage
- Temperature control of work areas
- Ventilation of work areas
- Protection of respiratory system
- Implications of long- and short- term exposure to fibres, solvents and matrix materials
- Fire protection
- COSHH
- Safe disposal of waste (fibre, resin systems, offcuts).

Learning outcome

The learner will:

2. Understand how the matrix material influences the manufacture of fibre-reinforced composite materials

Assessment criteria

The learner can:

2.1 Describe the principles of polymer chemistry applicable to composite materials

2.2 Explain the differences between thermoplastic and thermoset matrix materials

2.3 Explain the processes used in the manufacture of thermoset composite materials

2.4 Explain the processes used in the manufacture of thermoplastic composite materials

2.5 Explain the use of additional materials in resin systems.

Range

AC2.1 Principles:

- Polymerisation
- Reaction
- Curing

AC2.2 Differences:

- Structural (cross-linking)
- Response to increased temperature (softening/reforming of thermoplastics)
- Mechanical properties (strength, stiffness)
- Chemical (corrosion resistance).

AC2.3 Processes (thermosets):

- Hand layup
- Resin infusion systems
- Resin transfer
- Filament winding
- Pultrusion
- Hot press.

AC2.4 Processes (thermoplastics):

- Hot press
- Extrusion
- Compression moulding.

AC2.5 Additional materials:

- Additives
- Fillers
- Pigments
- Fire retardants

Learning outcome

The learner will:

3. Understand the materials and techniques used with pre-impregnated (pre-preg) and pre-formed (pre-form) materials

Assessment criteria

The learner can:

3.1 Explain the differences between pre-preg and pre-form materials

3.2 Describe laminate preparation and consolidation

3.3 Describe the techniques used for manufacturing components from pre-preg materials

3.4 Explain advantages and disadvantages of using pre-preg and pre-form materials

Range

AC3.1 Differences:

- Material consistency
- Application
- Usage
- Storage requirements

AC3.2 Preparation:

- Use of templates
- Nesting
- Cutting
- Use of release films
- Bagging materials
- Safe disposal of waste

AC3.3 Techniques:

- Use of heat and pressure
- Autoclave
- Vacuum bag and oven (out of autoclave).

AC3.4 Advantages and disadvantages:

- Price
- Set-up cost
- Productivity rate
- Labour
- Quality control.

Learning outcome

The learner will:

4. Understand the materials and techniques used in dry fibre moulding

Assessment criteria

The learner can:

4.1 Identify materials used in dry fibre moulding

4.2 Explain the principles of manufacturing techniques used in dry fibre moulding

4.3 Explain advantages and disadvantages of using dry fibre moulding techniques

Range

AC4.1 Materials:

- Cores

- Fibres
- Resins.

AC4.2 Techniques:

- Fibre placement
- Resin infusion
- Resin transfer
- Filament winding
- Pultrusion.

AC4.3 Advantages and disadvantages:

- Price of materials
- Set-up cost
- Productivity rate
- Labour
- Quality control
- Wastage.

Learning outcome

The learner will:

5. Understand types of defects arising during the manufacture of composites and how adhesive and bonding materials are used for composite structures

Assessment criteria

The learner can:

5.1 Explain defects in composite materials and their causes

5.2 Describe methods used to detect defects in composite materials

5.3 Describe the use of adhesive and bonding agents in composite structures.

Range

AC5.1 Types of defects:

- Voids and cavities
- Disbonds and de-lamination
- Porosity
- Wrinkling
- Bridging.

Causes of defects:

- Contamination and insufficient cleanliness
- Incorrect process control
- Environmental variations
- Equipment failure.

AC5.2 Detection methods:

- Visual surface inspection
- Tap testing
- Thermography
- X-ray
- Shearography
- Ultrasonic.

AC5.3 Use of adhesives and bonding agents:

- Surface preparation, using mechanical, abrasion or solvent means
- Methods of applying the adhesive and bonding material
- Influence of temperature, pressure and environmental conditions on the curing of the product.

Unit 332 Industrial Process Control

Unit Level:	Level 3
GLH:	60
Unit Aim:	This unit provides knowledge, understanding and skills relating to industrial process control. It covers the principles of industrial process control systems and the function of different types of programmable logic controllers (PLCs). It also covers the programming of PLCs and the input and output devices used in industrial process control systems.

Learning outcome

The learner will:

1. Understand the principles of industrial process control systems

Assessment criteria

The learner can:

1.1 Describe the characteristics of process control systems
1.2 Explain the differences between open and closed-loop control systems
1.3 Explain the advantages and disadvantages of open and closed-loop control systems
1.4 Explain the principles and purpose of block diagrams
1.5 Describe the operating principles and applications of different modes of control
1.6 Explain the differences between sequential and continuous control systems
1.7 Describe the architecture and applications of hierarchical control systems.

Range

AC1.1 Characteristics:

- Self-regulation
- Time constant
- Reaction rate
- Lags
- Exponential growth and decay

AC1.3 Advantages and disadvantages:

- Cost

- Complexity
- Accuracy
- Reliability
- Stability
- Ability to reduce noise
- Impact on gain
- Creation of oscillatory response.

AC1.4 Principles:

- Input, process and output
- Transfer functions
- Signals
- Feedback
- Summing points
- Take-off points
- Reduction techniques.

AC1.5 Modes of control:

- Two-step control
- Three-term control (proportional, integral, derivative, proportional-integral-derivative).

AC1.7 Hierarchical control systems:

- Distributed control systems (DCS)
- Supervisory control and data acquisition (SCADA).

Learning outcome

The learner will:

2. Understand the function of, and be able to program, programmable logic controllers (PLCs)

Assessment criteria

The learner can:

2.1 Explain the benefits and limitations of PLCs
2.2 Describe the function, characteristics and applications of different types of PLCs
2.3 Describe hardware and software requirements for PLCs
2.4 Describe the characteristics, benefits and limitations of PLC programming languages
2.5 Produce and fault find PLC programs
2.6 Use different methods to test and simulate PLC programs
2.7 Describe methods of storing PLC programs
2.8 Describe maintenance procedures for PLCs.

Range

AC2.2 Types of PLC:

- Fixed I/O
- Modular
- Rack mounted.

AC2.3 Requirements:

- Central processing unit (CPU)
- Communication ports (including: ethernet, USB, parallel, serial/COM, wifi)
- I/O ports
- Power supply
- Operating system.

AC2.4 Languages:

- Ladder logic
- Function block diagrams
- Structured text
- Instruction lists
- Sequential function charts.

AC2.5 Programs to include:

- Responding to sensors and switches
- Control of output devices
- Timers
- Counters
- Comparators
- Logic functions (AND, OR, NOT, NAND, NOR, XOR)
- Control loops.

AC2.6 Testing and simulating methods:

- Functional testing
- User testing
- Simulating operating conditions
- Checking that the program performs the required actions accurately, efficiently and safely.

AC2.7 Methods:

- Saving files (use of appropriate filenames, formats and version control)
- Creating backups
- Using different types of storage media

AC2.8 Maintenance procedures:

- Identifying and troubleshooting hardware and software issues

- Dealing with problems as they occur (including understanding and interpreting error messages, input and/or output devices not performing as expected)
- Solving download problems
- Checks to connections (input and output devices, peripherals).

Learning outcome

The learner will:

3. Understand input and output devices used in industrial process control systems

Assessment criteria

The learner can:

3.1 Describe the purpose, function and applications of input devices

3.2 Describe the purpose, function and applications of output devices

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Range

AC3.1 Input devices including:

- Mechanical switches
- Sensors (temperature, pressure, level, flow, magnetic, optical, proximity, torque, pH)
- Smart sensors and devices.

AC3.2 Output devices including:

- Electrical, electronic and mechatronic (actuators, motors, solenoids, relays, visual displays, audio output devices)
- Pneumatic and hydraulic (cylinders, pumps, valves).

Unit 333 Automation and Robotic Technology

Unit Level:	Level 3
GLH:	50
Unit Aim:	This unit develops learners' understanding of the principles of robotic systems. They will understand the elements that they are comprised of, including sensors and control systems. Learners will develop their understanding of how to program these systems and the requirements for safe operation.

Learning Outcome

The learner will:

1. Understand the principles of robotic operations

Assessment Criteria

The learner can:

1.1 Describe the elements of a robotic system
1.2 Identify the operating parameters of a robotic system
1.3 Describe power transmission systems used in robotics
1.4 Describe methods of controlling a robotic system

Range

AC1.1 Elements:

- Sensors
- Logic circuits, microcontrollers
- Actuators
- Grippers
- Arm, wrist, shoulder
- Gearing, gears, belts, chains.

AC1.2 Parameters:

- Working envelope
- Degrees of freedom
- Range of movement
- Speed of actions.

AC1.3 Power transmission systems:

- Pneumatic
- Hydraulic
- Electrical (servo and non-servo controlled, gearing).

AC1.4 Methods:

- Programmable (microprocessor, microcontroller, computer-based controllers)
- Air logic

Learning outcome

The learner will:

2. Understand the operation of sensors

Assessment Criteria

The learner can:

2.1 Describe the function and characteristics of sensors used in robotic applications
2.2 Explain the applications of sensors

Range

AC2.1, AC2.2 Sensors, including:

- Light
- Sound
- Temperature
- Contact
- Proximity
- Ultrasonic
- 2D 3D vision
- Pressure
- Tilt
- Accelerometer.

Learning outcome

The learner will:

3. Program a robotic system

Assessment Criteria

The learner can:

3.1 Produce and fault find programs
3.2 Apply programming methodologies
3.3 Use different methods to test and simulate programs

Range

AC3.1 Programs to include:

- Responding to sensors and switches
- Control of actuators
- Controlling the manipulation of the robotic system in different axes
- Repetition of task
- Feedback.

AC3.2 Programming methodologies:

- Teaching by demonstration
- Teaching by pendant
- Simulation/offline programming using software.

AC3.3 Methods:

- Initial running of draft program
- Simulated analysis using software
- Functional testing
- Retesting
- Making revisions to programs.

Learning outcome

The learner will:

4. Understand the safe operation of robotic systems

Assessment criteria

The learner can:

4.1 Describe the safe operation of a robotic system
4.2 Explain the maintenance requirements for a robotic system.

Range

AC4.1 Safe operation:

- Segregation of robotic system from people (use of guards, cages, screens, light curtains, no entry zones)
- Emergency stop systems
- Operative training and instruction requirements.

AC4.2 Requirements:

- Isolation of robotic systems prior to undertaking maintenance
- Maintenance schedules for components
- Maintenance logs and records.

Unit 333 Automation and Robotic Technology

Supporting Information

Unit Guidance

This unit would provide an ideal opportunity for learners to visit a robotics based manufacturing production facility. This would enable the operations engineers to be engaged in debate and discussion on the operation, function and maintenance of their robots.

LO1 covers the introduction to robotics, the different components that make up a robot and how these are controlled using computer systems. Online videos of robotic operations would benefit learners understanding of how a robot is assembled and the many different applications that robots can be used for.

LO3 learners should program a range of functions so some evaluation of functionality can be gained.

Unit 334 Leading a Team

Unit Level:	Level 3
GLH:	60
Unit Aim:	An effective team leader can be the difference between the team achieving its objectives and failure. Leaders guide and motivate their team, communicating what is required and resolving conflicts. In this unit, you will develop understanding of the approaches used in leading a team and how a team functions. You will also understand the importance of effective communication and conflict resolution.

Learning Outcome

The learner will:

1. Understand approaches to leading a team

Assessment Criteria

The learner can:

1.1 Explain the difference between leading and managing
1.2 Explain the roles and responsibilities of a team leader
1.3 Explain different leadership styles and their advantages and disadvantages
1.4 Describe the behavioural characteristics of effective team leaders

Range

AC1.2 Roles and responsibilities:

- Understanding the objectives of the organisation
- Setting objectives for the team
- Resource allocation
- Managing workloads
- Motivating staff
- Monitoring performance
- Communication
- Conflict resolution
- Problem solving

- Meeting health and safety requirements
- Coaching and developing staff.

AC1.3 Management styles:

- Autocratic
- Participative
- Delegative.

AC1.4 Characteristics:

- Takes responsibility
- Inclusive
- Agile
- Professionalism.

Learning outcome

The learner will:

2. Understand how teams develop and function

Assessment Criteria

The learner can:

2.1 Explain the typical stages in the development of a team
2.2 Explain the different functional roles that can exist within a team and how these interact with each other
2.3 Explain how members work effectively within a team

Range

AC2.1 Stages in development:

Tuckman's stages of group development:

- Forming
- Storming
- Norming
- Performing.

AC2.2 Team roles:

The roles in a team defined by Belbin:

- Co-ordinator
- Shaper
- Completer/finisher

- Implementer
- Monitor evaluator
- Plant
- Resource investigator
- Specialist
- Team worker.

AC2.3 Work effectively:

- Completing activities as required
- Supporting other team members
- Participation in group discussions and decision making
- Suggesting solutions to problems
- Giving and receiving constructive criticism
- Responding to feedback from others
- Time management.

Learning outcome

The learner will:

3. Understand types of communication used in engineering businesses

Assessment criteria

The learner can:

3.1 Explain the principles of communication
3.2 Describe types of business communication and their typical uses

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Range

AC3.1 Principles of communication:

- Two-way process
- Types of communication (oral, written, non-verbal)
- Formal/informal.

AC3.2 Types of business communication:

- Face-to-face (informal, interviews)
- Meetings (team, informal)
- Visual displays/noticeboards
- Project plans and Gantt charts
- Production schedules

- Bill of materials (BOM), working drawings and job instructions
- Risk assessments
- Technical reports
- Spreadsheets
- Emails.

Learning outcome

The learner will:

4. Understand how to resolve problems and conflict in the workplace

Assessment criteria

The learner can:

4.1 Explain the difference between the root cause and symptoms of a problem
4.2 Explain the reasons why there may be conflict in work situations
4.3 Explain approaches to avoid conflict in work situations
4.4 Explain methods used to resolve problems and conflict.

Range

AC4.2 Reasons for conflict:

- Unrealistic objectives
- Failing to achieve objectives
- Differences of opinion
- Differences of understanding
- Unpopular team leader decisions
- Working within time constraints
- Team member aspirations and/or ambitions
- Individual skill levels
- Team member personalities.

AC4.3 Approaches:

- Listening carefully
- Knowing when to withdraw from the situation
- Following reasonable requests from supervisors
- Considering the viewpoints of others
- Compromise
- Seeking clarification politely
- Timeliness when seeking advice or assistance
- Offering support when colleagues need assistance.

AC4.4 Methods:

- Negotiation
- Persuasion
- Compromise
- Mediation
- Arbitration.

Unit 335 TIG Welding of Materials

Unit Level:	Level 3
GLH:	70
Unit Aim:	The unit is concerned with the technology and practices involved in the application of TIG welding. It describes the safe working practices required for TIG welding, develops an understanding of the welding equipment and consumables and the ability to perform TIG welding operations in a variety of situations. It also involves understanding the defects which may arise and how these can be detected and avoided during welding.

Learning Outcome

The learner will:

1. Understand and apply safe working practices whilst TIG welding

Assessment Criteria

The learner can:

1.1 Describe health and safety regulations applicable to TIG welding
1.2 Assess hazards in a welding environment
1.3 Apply control measures to reduce risks
1.4 Follow safe working practices.

Range

AC1.1 Regulations:

- Health and Safety at Work Act
- Control of Substances Hazardous to Health (COSHH)
- Management of Health and Safety at Work Regulations
- Personal Protective Equipment at Work Regulations
- Control of Noise at Work Regulations.

AC1.2 Hazards:

- Fume
- Heat

- Electricity
- Arc radiation
- Compressed gases.

AC1.3 Control measures:

- Fume (LEV systems, air fed masks)
- Heat (gauntlets, tongs, quenching tank, marking as “hot”)
- Electricity (emergency procedures in the event of shock, protection devices, earthing)
- Arc radiation (PPE, screening, warnings, non-reflective surfaces)
- Compressed gases
    - Storage and handling of gas cylinders (upright, chained, avoid direct heat).

AC1.4 Safe working practices:

- Safe start up and shut down procedures
- Equipment checks by operator
- Safe use of equipment.

Learning outcome

The learner will:

2. Understand TIG welding equipment and shielding gases

Assessment criteria

The learner can:

2.1 Describe the welding equipment for TIG welding
2.2 Describe the functions of TIG welding equipment
2.3 Explain the effect of electrical characteristics on the welding process
2.4 Describe the functions of the shielding gas equipment
2.5 Explain the effects of the shielding gas on the welding process.

Range

AC2.1 Welding equipment:

- Power sources (transformer, transformer/rectifier, inverter, generator)
- Torches (water cooled, air cooled, flexible/fixed neck)
- Electrodes (pure tungsten, ceriated, zirconiated, lanthanated, thoriated)
- Ancillary (return clamps, purging equipment, foot switches, on-torch controls)
- Other equipment (angle grinders, linishers, wire brushes).

AC2.2 Functions:

- Output characteristics of the power sources

- Gas lenses
- Electrodes
- Purging equipment (tents, pipe plugs, tape, backing plates, drag shields).

AC2.3 Effects of electrical characteristics:

- Current type (AC, DC)
- Electrode polarity (DCEN, DCEP, AC)
- Weld bead profile
- Weld penetration
- Pulse (frequency, peak, background, slope in, slope out)
- Voltages (open circuit, arc).

AC2.4 Shielding gas equipment:

- Types (manifolds, cylinders)
- Regulators (fixed, single stage, two-stage)
- Gas flow meters
- Solenoid valves.

AC2.5 Effect of the shielding gas:

- Gas types (argon, helium, argon/helium mixtures)
- Weld pool/arc area protection
- Heat input
- Weld geometry
- Penetration profile
- Travel speed.

Learning outcome

The learner will:

3. Perform TIG welding operations

Assessment criteria

The learner can:

3.1 Select appropriate welding consumables

3.2 Understand welding procedure specifications (WPS)

3.3 Produce welded joints in a range of positions

3.4 Restore work areas to a clean and safe condition on completion of welding operation.

Range

AC3.1 Consumables:

- Filler wires:
  - Materials (steel, stainless steel, aluminium)

- Storage (segregation, protection of bare wires)
- Dimensional (diameters, lengths)

- Shielding gases (to current standards).

AC3.2 WPS:

- Welding process
- Parent metal
- Consumables (filler wire, shielding gas)
- Pre-welding activities (cleaning, pre-heat)
- Welding parameters (current range, gas flow rate)
- Joint type (butt, lap, tee, corner)
- Joint preparation (shape, geometry)
- Welding positions (PA, PB, PC, PD, PE, PF, PG)
- Number and arrangement of welding beads
- Electrodes (type, diameter)
- Electrical conditions (AC, DC electrode polarity)
- Shielding gas
- Control of heat input
- Post-weld heat treatment (normalising, stress relief).

AC3.3 Welds:

- Arc initiation (scratch, lift, high frequency)
- Welding techniques (different positions, autogenous/use of filler wire, single and multi-pass welds)
- Electrical measurement (ammeters, voltmeters).

AC3.4 Restore work area:

- Cleaning the work area
- Return of unused consumables
- Safe storage of tools and equipment
- Waste disposal (hazardous, recycling).

Learning outcome

The learner will:

4. Undertake the testing of welded joints

Assessment criteria

The learner can:

4.1 Describe the types of weld defects, their causes and prevention

4.2 Complete non-destructive weld testing

4.3 Complete destructive weld testing.

Range

AC4.1 Imperfections:

- Cracks (transverse, longitudinal, crater, HAZ)
- Inclusions (tungsten, non-metallic compounds)
- Lack of fusion (side wall, root, inter-run)
- Voids (porosity, worm holes, crater pipes)
- Lack of penetration
- Undercut
- Excess weld metal (root, build up)
- Cold lap.

AC4.2 Non-destructive testing:

- Visual inspection
- Penetrant testing.

AC4.3 Destructive testing:

- Nick break (preparation, interpretation)
- Macroscopic (preparation, interpretation).

Unit 335 TIG Welding of Materials

Supporting Information

Unit Guidance

Where current standards are stated in the assessment criteria the following are examples:
Filler wires

- BS EN 1668 - steel
- BS EN 12072 – stainless steel
- EN ISO 18273 – aluminium

Shielding Gases

- BS EN 439

Welding positions

- EN ISO 6947

Quality levels for imperfections

- BS EN 5817

Unit 336 MIG/MAG and Flux Cored Welding of Materials

Unit Level:	Level 3
GLH:	70
Unit Aim:	The unit is concerned with the technology and practices involved in the application of MIG welding. It describes the safe working practices required for MIG welding, develops an understanding of the welding equipment and consumables and the ability to perform MIG welding operations in a variety of situations. It also involves understanding the defects which may arise and how these can be detected and avoided during welding.

Learning Outcome

The learner will:

1. Understand and apply safe working practices whilst MIG welding

Assessment Criteria

The learner can:

1.1 Describe health and safety regulations applicable to MIG welding
1.2 Assess hazards in a welding environment
1.3 Apply control measures to reduce risks
1.4 Follow safe working practices.

Range

AC1.1 Regulations:

- Health and Safety at Work Act
- Control of Substances Hazardous to Health (COSHH)
- Management of Health and Safety at Work Regulations
- Personal Protective Equipment at Work Regulations
- Control of Noise at Work Regulations.

AC1.2 Hazards:

- Fume

- Heat
- Electricity
- Arc radiation
- Compressed gases.

AC1.2 Precautions:

- Fume
- Heat
- Electricity
- Arc radiation
- Compressed gases.

AC1.3 Control measures:

- Fume (LEV systems, air fed masks)
- Heat (gauntlets, tongs, quenching tank, marking as “hot”)
- Electricity (emergency procedures in the event of shock, protection devices, earthing)
- Arc radiation (PPE, screening, warnings, non-reflective surfaces)
- Compressed gases
    - Storage and handling of gas cylinders (upright, chained, avoid direct heat).

AC1.4 Safe working practices:

- Safe start up and shut down procedures
- Equipment checks by operator
- Safe use of equipment.

Learning outcome

The learner will:

2. Understand MIG welding equipment and shielding gases

Assessment criteria

The learner can:

2.1 Describe the welding equipment for MIG welding
2.2 Describe the functions of MIG welding equipment
2.3 Explain the effect of electrical characteristics on the welding process
2.4 Describe the functions of the shielding gas equipment
2.5 Explain the effects of the shielding gas on the welding process.

Range

AC2.1 Welding equipment:

- Power sources (transformer, transformer/rectifier, inverter, generator)
- Welding torch (water cooled, air cooled, push, push/pull, reel on gun)
- Welding torch peripherals (harness, contact tips, liners, shrouds)
- Ancillary (return clamps, purging equipment, rotating tables)
- Other equipment (angle grinders, linishers, wire brushes).

AC2.2 Functions:

- Output characteristics of the power sources
- Welding torch
- Purging equipment (tents, pipe plugs, tape, backing plates, drag shields).

AC2.3 Effects of electrical characteristics:

- Current type (AC, DC)
- Electrode polarity (DCEN, DCEP)
- Heat input/distribution
- Metal transfer modes (dip, spray, globular, pulse)
- Weld bead profile
- Weld penetration
- Welding current features (relationship between wire feed speed and welding current, synergic control)
- Voltages (open circuit, arc).

AC2.4 Shielding gas equipment:

- Types (manifolds, cylinders)
- Regulators (fixed, single stage, two-stage)
- Gas flow meters
- Solenoid valves
- CO_2 gas heaters.

AC2.5 Effect of the shielding gas:

- Pure gas types (argon, helium, carbon dioxide)
- Gas mixtures (argon/carbon dioxide, argon/carbon dioxide/oxygen, argon/oxygen, argon/helium)
- Weld pool/arc area protection
- Heat input
- Weld geometry
- Penetration profile
- Travel speed
- Mode of metal transfer.

Learning outcome

The learner will:

3. Perform MIG welding operations

Assessment criteria

The learner can:

3.1 Select appropriate welding consumables
3.2 Understand welding procedure specifications (WPS)
3.3 Produce welded joints in a range of positions
3.4 Restore work areas to a clean and safe condition on completion of welding operation.

Range

AC3.1 Consumables:

- Solid electrodes:
  - Materials (steel, stainless steel, aluminium)
  - Composition (alloys, chemicals, deoxidisers, copper coating)
  - Properties (strength, elongation, impact resistance)
  - Storage (segregation, protection of bare wires)
  - Dimensional (diameters, reel weights, bulk)
- Flux cored electrodes:
  - Self-shielded
  - Gas-shielded
  - Cores (basic, rutile, low hydrogen)
  - Materials (Steel, stainless steel)
  - Composition (alloys, chemicals, deoxidisers, copper coating)
  - Properties (strength, elongation, impact resistance)
  - Storage (segregation, protection of bare wires)
  - Dimensional (diameters, reel weights, bulk).

- Shielding gases (to current standards):
  - Pure gas types (argon, helium, carbon dioxide)
  - Gas mixtures (argon/carbon dioxide, argon/carbon dioxide/oxygen, argon/oxygen, argon/helium)
  - Gas pressure requirements
  - Flow rate.

AC3.2 WPS:

- Welding process
- Parent metal
- Consumables (filler wire, shielding gas)

- Pre welding activities (cleaning, pre-heat)
- Welding parameters (voltage range, gas flow rate, wire feed speed)
- Joint type (butt, lap, tee, corner)
- Joint preparation (shape, geometry)
- Welding positions (PA, PB, PC, PD, PE, PF, PG)
- Number and arrangement of welding beads
- Electrical conditions (DCEN, DCEP)
- Shielding gas
- Control of heat input
- Post-weld heat treatment (normalising, stress relief)

AC3.3 Welded Joints:

- Joint type (butt, lap, tee, corner)
- Welding positions (PA, PB, PC, PD, PE, PF, PG)
- Single and multi-pass welds
- Removal of slag where required.

AC3.4 Restore work area:

- Cleaning the work area
- Return of unused consumables
- Safe storage of tools and equipment
- Waste disposal (hazardous, recycling).

Learning outcome

The learner will:

4. Undertake the testing of welded joints

Assessment criteria

The learner can:

4.1 Describe the types of weld defects, their causes and prevention
4.2 Complete non-destructive weld testing
4.3 Complete destructive weld testing

Range

AC4.1 Imperfections:

- Cracks (transverse, longitudinal, crater, HAZ)
- Inclusions (slag, non-metallic compounds)
- Lack of fusion (side wall, root, inter-run)
- Voids (porosity, worm holes, crater pipes)
- Lack of penetration
- Undercut
- Excess weld metal (root, build up)

- Cold lap.

AC4.2 Non-destructive testing:

- Visual inspection
- Penetrant testing.

AC4.3 Destructive testing:

- Nick break (preparation, interpretation)
- Macroscopic (preparation, interpretation).

Unit 336 MIG/MAG and Flux Cored Welding of Materials

Supporting Information

Unit Guidance

Where current standards are stated in the assessment criteria the following are examples:

Filler wires

- BS EN 440 - steel
- BS EN ISO 14343 – Stainless steel
- BS EN 1011 – Aluminium

Shielding Gases

- BS EN 439

Welding positions

- EN ISO 6947

Quality levels for imperfections

- BS EN 5817

Unit 337 Manual Metal Arc (MMA) Welding of Materials

Unit Level:	Level 3
GLH:	70
Unit Aim:	The unit is concerned with the technology and practices involved in the application of MMA welding. It describes the safe working practices required for MMA welding, develops an understanding of the welding equipment and consumables and the ability to perform MMA welding operations in a variety of situations. It also involves understanding the defects which may arise and how these can be detected and avoided during welding.

Learning Outcome

The learner will:

1. Understand and apply safe working practices whilst MMA welding

Assessment Criteria

The learner can:

1.1 Describe health and safety regulations applicable to MMA welding
1.2 Assess hazards in a welding environment
1.3 Apply control measures to reduce risks
1.4 Follow safe working practices

Range

AC1.1 Regulations:

- Health and Safety at Work Act
- Control of Substances Hazardous to Health (COSHH)
- Management of Health and Safety at Work Regulations
- Personal Protective Equipment at Work Regulations
- Control of noise at Work Regulations.

AC1.2 Hazards:

- Fume
- Heat

- Electricity
- Arc radiation.

AC1.3 Control measures:

- Fume (LEV systems, air fed masks)
- Heat (gauntlets, tongs, quenching tank, marking as “hot”)
- Electricity (emergency procedures in the event of shock, protection devices, earthing)
- Arc radiation (PPE, screening, warnings, non-reflective surfaces).

AC1.4 Safe working practices:

- Safe start up and shut down procedures
- Equipment checks by operator
- Safe use of equipment.

Learning outcome

The learner will:

2. Understand MMA welding equipment

Assessment criteria

The learner can:

2.1 Describe the welding equipment for MMA welding
2.2 Describe the functions of MMA welding equipment
2.3 Explain the effect of electrical characteristics on the MMA welding process
2.4 Identify the types and characteristics of electrode coverings
2.5 Explain the effects of the electrode covering on the welding process.

Range

AC2.1 Welding equipment:

- Power sources (transformer, transformer/rectifier, inverter, generator)
- Electrode holders (types, leads)
- Ancillary (return clamps, purging equipment)
- Other equipment (angle grinders, linishers, wire brushes).

AC2.2 Functions:

- Output characteristics of the power sources
- Electrodes
- Purging equipment (tents, pipe plugs, tape, backing plates, drag shields).

AC2.3 Effects of electrical characteristics:

- Current type (AC, DC)
- Electrode polarity (DCEN, DCEP)
- Heat input/distribution
- Weld bead profile
- Weld penetration
- Voltages (open circuit, arc).

AC2.4, 2.5 Covering types:

- Basic (composition, benefits, applications)
- Rutile (composition, benefits, applications)
- Cellulosic (composition, benefits, applications).

AC2.5 Effect of the electrode covering:

- Weld pool/arc area protection
- Slag production (thermal blanket, solidification protection, impurities removal)
- Heat input
- Weld geometry
- Penetration profile
- Welding position
- Hydrogen control.

Learning outcome

The learner will:

3. Perform MMA welding operations

Assessment criteria

The learner can:

3.1 Select appropriate MMA welding electrodes
3.2 Understand welding procedure specifications (WPS)
3.3 Produce welded joints in a range of positions
3.4 Restore work areas to a clean and safe condition on completion of welding operation.

Range

AC3.1 Electrodes:

- Classification to current standards
- Materials (steel, stainless steel)
- Composition (alloys, chemicals, deoxidisers)
- Properties (strength, elongation, impact resistance)
- Storage (segregation, protection from damp)
- Dimensional (diameters, lengths).

AC3.2 WPS:

- Welding process
- Parent metal
- Consumables (electrode type, diameter)
- Pre welding activities (cleaning, pre-heat of joint, pre-heating of electrodes)
- Welding parameters (current range, current type)
- Joint type (butt, lap, tee, corner)
- Joint preparation (shape, geometry)
- Welding positions (PA, PB, PC, PD, PE, PF, PG)
- Number and arrangement of welding beads
- Electrical conditions (DCEN, DCEP)
- Control of heat input
- Post-weld heat treatment (normalising, stress relief).

AC3.3 Weld types:

- Joint type (butt, lap, tee, corner)
- Welding positions (PA, PB, PC, PD, PE, PF, PG)
- Single and multi-pass welds
- Removal of slag.

AC3.4 Restore work area:

- Cleaning the work area
- Return of unused consumables
- Safe storage of tools and equipment
- Waste disposal (hazardous, recycling).

Learning outcome

The learner will:

4. Undertake the testing of welded joints

Assessment criteria

The learner can:

4.1 Describe the types of weld defects, their causes and prevention
4.2 Complete non-destructive weld testing
4.3 Complete destructive weld testing.

Range

AC4.1 Imperfections:

- Cracks (transverse, longitudinal, crater, HAZ)
- Inclusions (slag, non-metallic compounds)
- Lack of fusion (side wall, root, inter-run)
- Voids (porosity, worm holes, crater pipes)
- Lack of penetration

- Undercut
- Excess weld metal (root, build up)
- Cold lap.

AC4.2 Non-destructive testing:

- Visual inspection
- Penetrant testing.

AC4.3 Destructive testing:

- Nick break (preparation, interpretation)
- Macroscopic (preparation, interpretation).

Unit 337 Manual Metal Arc (MMA) Welding of Materials

Supporting Information

Unit Guidance

Where current standards are stated in the assessment criteria the following are examples:
Electrodes classification

- BS EN ISO 2560 - Steel
- BS EN ISO 3581 – Stainless steel

Welding positions

- EN ISO 6947

Quality levels for imperfections

- BS EN 5817

Unit 338 Electronic Circuit Design and Manufacture

Unit Level:	Level 3
GLH:	60
Unit Aim:	This unit provides the knowledge, understanding and skills needed to design, manufacture and assemble electronic circuits. It covers modelling and prototyping methods, how CAD software is used to simulate and analyse circuits, the methods used to produce printed circuit boards (PCBs) and how they are assembled with components.

Learning outcome

The learner will:

1. Understand and be able to use methods of designing electronic circuits

Assessment criteria

The learner can:

1.1 Describe methods of producing models and prototypes of circuits

1.2 Explain the benefits and limitations of different circuit modelling and prototyping methods

1.3 Produce models and prototypes of circuits using different methods

1.4 Explain how simulation program with integrated circuit emphasis (SPICE) software is used to perform circuit analysis techniques.

Range

AC1.1, 1.2, 1.3 Modelling and prototyping methods:

- Virtual methods:
  - Use of CAD software to draw and simulate circuit schematics
  - Use of CAD software to draw and simulate PCB layouts
- Physical methods:
  - Breadboarding
  - Use of stripboards
  - Use of modular kits.

AC1.3 Circuits:

- Circuits with a maximum of four active devices each

AC1.4 Analysis techniques:

- Direct current (DC) analysis
- Alternating current (AC) small-signal analysis
- Mixed-mode analysis
- Transient analysis
- Pole-zero analysis
- Distortion analysis
- Sensitivity analysis
- Noise analysis
- Thermal analysis.

Learning outcome

The learner will:

2. Understand and be able to use PCB production methods

Assessment criteria

The learner can:

2.1 Describe the layers that make up a PCB

2.2 Explain the characteristics, benefits and limitations of PCB types

2.3 Describe how PCBs are produced using different methods

2.4 Explain the benefits and limitations of PCB production methods

2.5 Use at least one production method to manufacture single sided PCBs

2.6 Explain the purpose and application of PCB finishing techniques.

Range

AC2.1 Layers:

- Substrate
- Copper
- Solder mask
- Silkscreen.

AC2.2 PCB types:

- Single sided
- Double sided
- Multi-layer
- Flexible
- Chip on board (COB).

AC2.3, 2.4, 2.5 Production methods:

- Etching

- CAM/CNC milling.

AC2.6 Finishing techniques:

- Solder mask over bare copper (SMOBC)
- Tinning
- Plating
- Lacquering.

Learning outcome

The learner will:

3. Understand and be able to use PCB assembly methods

Assessment criteria

The learner can:

3.1 Describe PCB assembly methods

3.2 Explain the benefits, limitations and applications of PCB assembly methods

3.3 Use manual techniques to assemble single sided PCBs

3.4 Perform functional tests on assembled PCBs.

Range

AC3.1, 3.2 Assembly methods:

- Through-hole assembly
- Surface mount technology (SMT):
  - Use of pick and place machines
  - Use of solder pastes
  - Quality assurance methods
- Wave soldering
- Flow/reflow soldering
- Automated assembly.

AC3.3 Manual techniques:

- Drilling holes for components
- Mounting components
- Soldering
- Trimming component leads/legs
- De-soldering.

AC3.3 PCBs:

- Circuits with a maximum of four active devices each

AC3.4 Functional tests:

- Measuring input/output signals (whole circuit, sub-systems)
- Measuring test-point voltages.

Unit 338 Electronic Circuit Design and Manufacture

Supporting Information

Unit Guidance

AC 1.4

SPICE stands for simulation program with integrated circuit emphasis. It is an open source, public domain circuit simulator engine used by a wide range of educational and commercial CAD packages.

AC 1.3 and 3.3

Candidates only need to be able to produce models and prototypes of, and assemble circuits with, a maximum of four active devices each (such as transistors and integrated circuits) and their associated passive components (such as resistors, capacitors and inductors).

AC 2.5

Although candidates must have knowledge of both etching and CAM/CNC milling PCB production methods, they only need to be able to use one of these methods to physically produce PCBs.

Appendix 1 Relationships to other qualifications

Links to other qualifications

This qualification has no connections to other qualifications.

Appendix 2 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 contains detailed information about the processes which must be followed and requirements which must be met for a centre to achieve 'approved centre' status, or to offer a particular qualification, as well as updates and good practice exemplars for City & Guilds assessment and policy issues. 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
- Complaints and appeals
- Equal opportunities
- Data protection
- Management systems
- Maintaining records
- Assessment
- Internal quality assurance
- External quality assurance.

Our Quality Assurance Requirements encompasses all of the relevant requirements of key regulatory documents such as:

- Regulatory Arrangements for the Qualifications and Credit Framework (2008)
- SQA Awarding Body Criteria (2007)
- NVQ Code of Practice (2006)

and sets out the criteria that centres should adhere to pre and post centre and qualification approval.

Access to Assessment & Qualifications provides full details of the arrangements that may be made to facilitate access to assessments and qualifications for candidates who are eligible for adjustments in assessment.

The **centre homepage** section of the City & Guilds website also contains useful information on such things as:

- **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.

Centre Guide – Delivering International Qualifications contains detailed information about the processes which must be followed and requirements which must be met for a centre to achieve 'approved centre' status, or to offer a particular qualification. Specifically, the document includes sections on:

- The centre and qualification approval process and forms
- Assessment, verification and examination roles at the centre
- Registration and certification of candidates
- Non-compliance
- Complaints and appeals
- Equal opportunities
- Data protection
- Frequently asked questions.

Linking to this document from web pages

We regularly update the name of documents on our website, therefore in order to prevent broken links we recommend that you link to our web page that the document resides upon, rather than linking to the document itself

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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 including, Employer Recognition: Endorsement, Accreditation and Quality Mark, Consultancy, Mapping and Specialist Training Delivery	**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. We offer over 500 qualifications across 28 industries through 8500 centres worldwide and award around two million certificates every year. City & Guilds is recognised and respected by employers across the world as a sign of quality and exceptional training.

City & Guilds Group

Our vision is for a world in which everyone has the skills and opportunities to succeed. We support over 4 million people each year to develop skills that help them into a job, develop on that job and to prepare for their next job. As a charity, we're proud that everything we do is focused on achieving this purpose. Whether that's through delivering work-based learning programmes that build competency, providing flexible pathways that support lifelong employability or through the City & Guilds Foundation funding initiatives that help remove barriers to work and learning.

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