QUALIFICATION HANDBOOK

Level 4 Diploma in Mechanical Engineering (9209-01)

April 2017 Version 3

City & Guilds

Qualification at a glance

Subject area	**Engineering**
City & Guilds number	9209
Age group approved	18+
Entry requirements	To take this qualification, learners should have achieved one of the following: • 2850 Level 3 Diploma in Engineering • 2565 Level 3 Technician Diploma in Engineering • National Diploma in Engineering or a suitable equivalent to any of the above.
Assessment	• Assignments: externally set, internally marked, externally verified. • Dated entry written exam papers
Fast track	N/A
Support materials	• Centre handbook • Assessor Guidance • Assignments • Sample exam questions • Online tutor and learner support material (Smartscreen)
Registration and certification	Consult the Walled Garden/Online Catalogue for last dates

Title and level	City & Guilds number	Accreditation number
Level 4 Diploma in Mechanical Engineering	9209-01	601/5555/3

Version and date	Change detail	Section
v1.1 Nov 2014	NLH added	Individual units
v1.2 Jan 2015	Age 18+ Unit 438 - assignment UAN added QAN added	Page 2 and Section 3 Section 5 Individual units Page 2
v2 Apr 2015	Updates to some learning outcomes and assessment criteria and updated range Test specification information Question paper resources if applicable	Individual units Assessment
v3 Apr 2017	Updated range Updated test specification information and question paper resources	Individual units Assessment

Contents

1 Introduction

This document tells you what you need to do to deliver this qualification.

In the table below is an outline of this qualification at a glance.

Area	Description
Who is this the qualification for?	This Diploma is aimed at learners who • wish to gain employment as an Engineering Technician • wish to progress into higher level Engineering qualifications • intend to advance into the second year of a selected university engineering degree programme. It also aims to contribute to recognition by professional institutions.
What does this qualification cover?	It allows learners to learn, develop and practise the advanced skills required for employment, career progression or university progression in the engineering sector. It will also allow learners to build their knowledge of the principles of mathematics, science and technologies that underpin engineering.
Who did we develop the qualification with?	Please refer to our recognition list on our website.
What opportunities for progression are there?	It allows learners to progress into employment, university or to the following City & Guilds qualifications: • 9209-11 Level 5 Advanced Technician Diploma in Mechanical Engineering or other equivalent City & Guilds qualifications

2 Structure

To achieve the **Level 4 Diploma in Mechanical Engineering**, learners must achieve the **4** mandatory units and a minimum of **7** units from the optional units.

City & Guilds unit number/UAN	Unit title	GLH	NLH
Mandatory units			
Unit 401 J/506/9243	Engineering mathematics	60	150
Unit 428 Y/506/9313	Electrical principles for mechanical engineering	108	150
Unit 429 R/506/9312	Principles of mechanical engineering	58	100
Unit 430 D/506/9314	Engineering fluid mechanics and thermodynamics	43	100
Optional units			
Unit 403 R/506/9245	Quality assurance and control	42	150
Unit 404 Y/506/9246	Human factors in the workplace	60	150
Unit 405 D/506/9247	Engineering planning and scheduling	66	150
Unit 406 M/506/9270	Statistical analysis for engineers	45	100

City & Guilds unit number/UAN	Unit title	GLH	NLH
Unit 407 T/506/9271	Computer Aided Design for manufacture	60	100
Unit 418 H/506/9301	Maintenance of engineering systems and equipment	56	150
Unit 419 M/506/9334	Engineering design	60	150
Unit 421 T/506/9304	Planning and implementing change within businesses	30	100
Unit 422 A/506/9305	Personal and professional development	25	100
Unit 423 F/506/9306	Managing information and knowledge	60	150
Unit 424 T/506/9335	Engineering procurement	60	150
Unit 425 J/506/9307	Principles of composite materials	75	150
Unit 426 L/506/9308	Principles of composites manufacture	60	150
Unit 427 K/506/9333	Developing business improvement plans	35	100
Unit 431 K/506/9316	Principles of mechanical component manufacture	52	150
Unit 432 M/506/9317	Materials engineering	60	150
Unit 433 A/506/9319	Automated machining of materials	40	100

City & Guilds unit number/UAN	Unit title	GLH	NLH
Unit 434 M/506/9320	Industrial robotics	35	100
Unit 435 A/506/9322	Statistical process control	52	100
Unit 436 F/506/9323	Metal fabrication technology	75	150
Unit 437 J/506/9324	Welding technology and practice	35	100
Unit 438 R/506/9326	Quality assurance and testing of welded joints	43	100

3 Centre requirements

Approval

If there is no fast track approval for this qualification, existing centres who wish to offer this qualification must use the **standard** Qualification Approval Process.

Resource requirements

Physical resources and site agreements

The equipment, systems and machinery must meet industrial standards and be capable of being used under normal working conditions.

Centre staffing

Staff delivering this qualification must be able to demonstrate that they meet the relevant occupational expertise requirements, ie they should be occupationally competent or technically knowledgeable in the areas for which they are delivering training with experience of providing training. This knowledge must be to the same level as the training being delivered

Trainers must also

- hold or be working towards a recognised training qualification
- have recent relevant experience in the specific area they will be assessing
- have credible experience of providing training.

Centre staff may undertake more than one role, eg tutor and assessor or internal quality assurer, but cannot internally verify their own assessments.

Assessors and Internal Quality Assurer

Assessors

Although not specifically required for this qualification, City & Guilds recommends that Assessors hold, or are working towards, the relevant Level 3 TAQA qualification, covering the assessment types required for this qualification. Further information about the City & Guilds TAQA qualification can be found at **www.cityandguilds.com**. Assessors must be able to demonstrate clear experience in assessing learning and understand City & Guilds' quality assurance requirements. They must also have the required industry certification and experience as outlined above.

Internal Verifiers / Internal Quality Assurers

Although not specifically required for this qualification, City & Guilds recommends that Internal Verifiers / Internal Quality Assurers hold, or are working towards, the Level 4 TAQA qualification. Further information about the City & Guilds TAQA qualification can be found at **www.cityandguilds.com**. Internal Verifiers / Internal Quality Assurers must be able to demonstrate clear experience in quality assurance

processes and understand City & Guilds' specific quality assurance requirements. They must also have the required industry certification and experience as outlined above.

Continuing professional development (CPD)

Centres must support their staff to ensure that they have current knowledge of the occupational area, that delivery, mentoring, training, assessment and verification is in line with best practice, and that it takes account of any national or legislative developments.

Learner entry requirements

City & Guilds recommends that learners have completed a suitable engineering related qualification at level 3 or above prior to enrolling on the course.
To take this qualification, learners should have achieved one of the following:

- 2850 Level 3 Diploma in Engineering
- 2565 Level 3 Technician Diploma in Engineering
- National Diploma in Engineering
- Physics and Mathematics A Level

or a suitable equivalent to any of the above.

Without evidence of formal qualifications, learners must demonstrate adequate prior knowledge and experience to ensure they have the potential to gain the qualification.

Age restrictions

City & Guilds cannot accept any registrations for learners under 18 years of age.

4 Delivering the qualification

Initial assessment and induction

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

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

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

Support materials

The following resources are available for this qualification:

Description	How to access
Sample exam questions	**www.cityandguilds.com**
Sample schemes of work	**www.smartscreen.co.uk**
Further reading / links	**www.cityandguilds.com**
Equipment lists	**www.cityandguilds.com**
Recognition lists	**www.cityandguilds.com**

5 Assessment

Units 405,407, 418, 419, 421, 422, 423, 424, 427, 430, 433, 434, 436 and 437 are assessed by assignments set by City & Guilds, internally marked by centres and externally verified. These assignments are graded Pass, Merit and Distinction.

All the remaining units are assessed by dated entry written paper, which are also graded Pass, Merit and Distinction. Exam dates are available on the Catalogue and Walled Garden.

The assessments have all been developed with input from experts in the industry.

Please refer to the Assessor Guidance on **www.cityandguilds.com** for general assessment guidance for this qualification.

Summary of assessment requirements

To achieve this qualification, candidates will be required to complete the following assessments successfully:

- **one** dated entry written exam for **each** mandatory unit 401, 428 and 429
- **one** assignment for mandatory unit 430
- **one** dated written exam for **each** chosen optional unit assessed by dated written exam
- **one** assignment for **each** chosen optional unit assessed by assignment.

City & Guilds provides the following assessments:

Unit	Title	Assessment method	Where to obtain assessments
Mandatory units			
9209-401	Engineering mathematics	Dated entry written exam paper 9209-401	Sample exam papers on www.cityandguilds.com
9209-428	Electrical principles for mechanical engineering	Dated entry written exam paper 9209-428	Sample exam papers on www.cityandguilds.com

Unit	Title	Assessment method	Where to obtain assessments
9209-429	Principles of mechanical engineering	Dated entry written exam paper 9209-429	Sample exam papers on www.cityandguilds.com
9209-430	Engineering fluid mechanics and thermodynamics	Assignment 9209-430 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com
Optional units			
9209-403	Quality assurance and control	Dated entry written exam paper 9209-403	Sample exam papers on www.cityandguilds.com
9209-404	Human factors in the workplace	Dated entry written exam paper 9209-404	Sample exam papers on www.cityandguilds.com
9209-405	Engineering planning and scheduling	Assignment 9209-405 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com
9209-406	Statistical analysis for engineers	Dated entry written exam paper 9209-406	Sample exam papers on www.cityandguilds.com
9209-407	Computer Aided Design for manufacture	Assignment 9209-407 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com
9209-418	Maintenance of engineering systems and equipment	Assignment 9209-418 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com

Unit	Title	Assessment method	Where to obtain assessments
9209-419	Engineering design	Assignment 9209-419 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com
9209-421	Planning and implementing change within businesses	Assignment 9209-421 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com
9209-422	Personal and professional development	Assignment 9209-422 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com
9209-423	Managing information and knowledge	Assignment 9209-423 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com
9209-424	Engineering procurement	Assignment 9209-424 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com
9209-425	Principles of composite materials	Dated entry written exam paper 9209-425	Sample exam papers on www.cityandguilds.com
9209-426	Principles of composites manufacture	Dated entry written exam paper 9209-426	Sample exam papers on www.cityandguilds.com
9209-427	Developing business improvement plans	Assignment 9209-427 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com

Unit	Title	Assessment method	Where to obtain assessments
9209-431	Principles of mechanical component manufacture	Dated entry written exam paper 9209-431	Sample exam papers on www.cityandguilds.com
9209-432	Materials engineering	Dated entry written exam paper 9209-432	Sample exam papers on www.cityandguilds.com
9209-433	Automated machining of materials	Assignment 9209-433 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com
9209-434	Industrial robotics	Assignment 9209-434 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com
9209-435	Statistical process control	Dated entry written exam paper 9209-435	Sample exam papers on www.cityandguilds.com
9209-436	Metal fabrication technology	Assignment 9209-436 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com
9209-437	Welding technology and practice	Assignment 9209-437 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com
9209-438	Quality assurance and testing of welded joints	Assignment 9209-438 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com

Unit assessment overview

Assignments

The following tables are designed to offer a summarised overview of how the tasks in each assignment demonstrate achievement of the assessment criteria in the units.

Some of the assignments in this qualification require that candidates have access to the following industry/international guidelines/standards:

ISO 9000; ISO 14000; BS EN 3834; EN ISO 14731; BS EN ISO 5817:2007

It is indicated in the relevant units when this is the case and which guidelines/standards are required.

Unit 405 Engineering planning and scheduling

Task	Description	Assessment Criteria	Task duration	Grading	Weighting per task
1	Research Task: Explain engineering planning and scheduling processes	1.1, 12, 1.3, 2.1, 2.2, 3.1, 3.2, 4.1, 4.2	20 hours	P / M / D / X	1
2	Produce a plan for an engineering activity	5.1, 5.2	6 hours	P / M / D / X	1

Unit 407 Computer Aided Design for manufacture

Task	Description	Assessment criteria	Task duration	Grading	Weighting per task
1	Drawing task: Computer aided design drawing creation and animation	1.1, 1.2, 4.1, 2.1, 2.2, 2.3, 3.1, 3.2, 1.3, 4.2, 4.3	6 hours	P / M / D / X	1

Unit 418 Maintenance of engineering systems and equipment

Task	Description	Assessment Criteria	Task duration	Grading	Weighting per task
1	Research task: Produce a maintenance operation document incorporating a plan	1.3, 5.2, 1.1, 1.2, 5.1, 5.4, 5.3	10 hours	P / M / D / X	1
2	Carry out a maintenance procedure	6.1, 6.2, 6.3, 6.4	4 hours	P / M / D / X	1
3	Research task: Complete a written report on a mechatronic industrial system specification	2.1, 2.2, 2.3, 2.4, 3.1, 3.2, 3.3, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6	20 hours	P / M / D / X	1

Unit 419 Engineering Design

Task	Description	Assessment Criteria	Task duration	Grading	Weighting per task
1	Defining Design Task & Scope	All	2-3 hours	P / M / D / X	1

Unit 421 Planning and implementing change within businesses

Task	Description	Assessment Criteria	Task duration	Grading	Weighting per task
1	Understand the need for managing and evaluating the change process in organisations	1.1, 1.2, 1.3, 4.1, 4.2, 4.3, 4.4	4 hours	P / M / D / X	1
2	Understand the importance of effective leadership and management of the change process	2.1, 2.2, 3.1, 3.2, 3.3	3 hours	P / M / D / X	1

Unit 422 Personal and professional development

Task	Description	Assessment Criteria	Task duration	Grading	Weighting per task
1	Understand how people learn (learning styles)	2.1, 2.2, 2.3, 2.4	6 hours	P / M / D / X	1
2	Understand how to plan for personal and professional development and create your own personal development plan	1.1, 1.2, 1.3, 3.1, 3.2, 3.3, 3.4	10-20 hours	P / M / D / X	1
3	Be able to make recommendations for personal and professional development	4.1, 4.2, 4.3	5 hours	P / M / D / X	1

Unit 423 Managing information and knowledge

Task	Description	Assessment Criteria	Task duration	Grading	Weighting per task
1	Research Task: Produce a written report for the IT and information requirements for Eco-Bank	All	25 hours	P / M / D / X	1

Unit 424 Engineering procurement

Task	Description	Assessment Criteria	Task duration	Grading	Weighting per task
1	Report: Procurement in the Engineering Industry	1.1, 1.2, 3.3, 4.1, 4.2	4 hours	P / M / D / X	1
2	Research Task: Case Study	2.1, 2.2, 2.3, 3.1, 3.2, 5.1, 5.2	6 hours + research time	P / M / D / X	1

Unit 427 Developing business improvement plans

Task	Description	Assessment Criteria	Task duration	Grading	Weighting per task
1	Research Task: Produce a written Business Improvement Plan for 'London Luxury Contractors'	All	30 hours	P / M / D / X	1

Unit 430 Engineering fluid mechanics and thermodynamics

Task	Description	Assessment Criteria	Task duration	Grading	Weighting per task
1	Practical Task: Laboratory to measure flow rate of fluid in a pipe using an orifice meter	1.3, 1.4, 3.1, 1.1, 1.2, 2.1	Assignment may be shown to candidates up to 30 minutes prior to start of practical. Time allowed 3 hours plus 30 minutes for preparation.	P / M / D / X	1
2	Case Study: A ship anchored in Greece – thermo dynamical and fluid statics considerations	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 3.2	2 days	P / M / D / X	1

Unit 433 Automated machining of materials

Task	Description	Assessment Criteria	Task duration	Grading	Weighting per task
1	Research Task: Produce a written report explaining automated machining systems	1.1, 1.2, 2.1, 3.1, 3.2	10 hours	P / M / D / X	1
2	Research Task: Understand CNC programs	4.3, 4.1, 4.2	3 hours	P / M / D / X	1
3	Practical task: Produce parts on a CNC machine	5.1, 5.2, 5.3, 5.4, 5.5	4 hours	P / M / D / X	1

Unit 434 Industrial robotics

Task	Description	Assessment Criteria	Task duration	Grading	Weighting per task
1	Research Task: The purpose of industrial robots in manufacturing tasks	1.1, 1.2, 4.1, 4.2, 4.3	10 hours	P / M / D / X	1
2	Research Task: Robot arm configurations and classifications	2.1, 2.2, 2.3, 2.4, 2.5, 2.6	6 hours	P / M / D / X	1
3	Produce a working program for an industrial robot	3.1, 3.2, 3.3	4 hours	P / M / D / X	1

Unit 436 Metal fabrication technology

Task	Description	Assessment Criteria	Task duration	Grading	Weighting per task
1	Metal forming processes	1.1, 1.2, 1.3, 1.4	3 hours	P / M / D / X	1
2	Metal joining methods	2.1, 2.2, 2.3, 2.4	3 hours	P / M / D / X	1
3	Metal cutting techniques	3.1, 3.2	3 hours	P / M / D / X	1
4	Choosing metal forming, joining and cutting techniques	4.1, 4.2	3 hours	P / M / D / X	1
5	Choosing metal forming, joining and cutting techniques	5.1, 5.2	3 hours	P / M / D / X	1

Unit 437 Welding technology and practice

Task	Description	Assessment Criteria	Task duration	Grading	Weighting per task
1	Advanced Welding Processes	1.1, 1.2, 1.3	3 hours	P / M / D / X	1
2	Failure modes of welded joints	2.1, 2.2, 2.3	3 hours	P / M / D / X	1
3	Select welding processes	3.1, 3.2, 3.3	3 hours	P / M / D / X	1
4	Specify welding process and design criteria	4.1, 4.2	3 hours	P / M / D / X	1

Unit 438 Quality assurance and testing of welded joints

Task	Description	Assessment Criteria	Task duration	Grading	Weighting per task
1	Quality assurance methods	1.1. 1.2, 1.3, 1.4	3 hours	P / M / D / X	1
2	Weld testing methods	2.1, 2.2	3 hours	P / M / D / X	1
3	Produce quality assurance specifications	3.1, 3.2, 3.3, 3.4, 3.5	3 hours	P / M / D / X	1

Dated entry written exam papers

Test specifications for the dated entry written exam papers are included here.

Test specifications

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

Test: 9209-401 Engineering mathematics

Duration: 3 hours

Grading: Pass/Merit/Distinction

Unit	Outcome		%
401	1.	be able to use algebraic methods to analyse and solve engineering problems	22
	2.	be able to solve engineering problems that require the use of trigonometric methods of analysis	18
	3.	be able to use methods of differential and integral calculus to solve engineering problems	40
	4.	be able to apply complex numbers and complex analysis to solve engineering problems	20
		Total	**100**

Test: 9209-403 Quality assurance and control

Duration: 3 hours

Grading: Pass/Merit/Distinction

Unit	Outcome		%
403	1.	understand the importance of quality assurance and quality control within an organisational culture	16
	2.	understand how total quality management systems operate	20
	3.	understand the implementation process of quality management systems	18
	4.	understand key principles of business excellence models	14
	5.	understand the principles of six sigma project management	14
	6.	understand the techniques and methods applied to the quality control of goods and services	12

Unit	Outcome		%
	7.	understand the use and application of codes of practice, standards and design guides	6
		Total	**100**

Test: 9209-404 Human factors in the workplace

Duration: 3 hours

Grading: Pass/Merit/Distinction

Unit	Outcome		%
404	1.	understand the importance of human factors in the workplace	4
	2.	understand features and limitations of human performance	5
	3.	understand the interrelationship between different roles and responsibilities in the workplace	13
	4.	understand how physical and personal factors of the working environment affect human performance	12
	5.	understand how the execution of different tasks can affect human performance	10
	6.	understand how to communicate effectively in the workplace	15
	7.	understand causes of human error	14
	8.	be able to recommend ways to mitigate risk in the workplace	14
	9.	understand how to apply safety, occupational health and environmental policies within industry	13
		Total	**100**

Test: 9209-406 Statistical analysis for engineers

Duration: 3 hours

Grading: Pass/Merit/Distinction

Unit	Outcome		%
406	1.	understand the causes of variation in industrial processes	13
	2.	understand statistical concepts and functions	19
	3.	be able to calculate unbiased estimates of population parameters	12
	4.	be able to solve industrial problems using statistical analysis of sample data	56
		Total	**100**

Test: 9209-425 Principles of composite materials

Duration: 2.5 hours

Grading: Pass/Merit/Distinction

Unit	Outcome		%
425	1.	understand the principles and structure of composite materials	50
	2.	understand elementary polymer chemistry	24
	3.	understand the materials and techniques used with pre-impregnated (pre-preg) and pre-formed (pre-forms) materials	14
	4.	understand preparation and assembly methods for composite components in the manufacture of composite structures	12
		Total	**100**

Test: 9209-426 Principles of composite manufacture

Duration: 2.5 hours

Grading: Pass/Merit/Distinction

Unit	Outcome		%
426	1.	understand the manufacturing processes used for composite components and structures	34
	2.	understand the implications of manufacturing processes on design for manufacture	18
	3.	understand types and sources of manufacture defects of composite components and structures	20
	4.	understand Non-Destructive Testing (NDT) methods of testing	16
	5.	understand process and quality systems required for composite component and structure manufacture	12
		Total	**100**

Test: 9209-428 Electrical principles for mechanical engineering

Duration: 3 hours

Grading: Pass/Merit/Distinction

Unit	Outcome		%
428	1.	understand the properties of dc circuits	12
	2.	understand electrostatics	14
	3.	understand the properties of ac circuits	14
	4.	understand transformers	20
	5.	understand the principles of dc machines	12
	6.	understand the principles of three-phase induction motors	8
	7.	understand the principles of three-phase synchronous motors	7
	8.	understand the principles of controlling large industrial electric motors	13
		Total	**100**

Test: 9209-429 Principles of mechanical engineering

Duration: 3 hours

Grading: Pass/Merit/Distinction

Unit	Outcome		%
429	1.	understand the application of static theory to structures	31
	2.	understand the effects of loading components under various loads and conditions	32
	3.	understand the principles of kinematics	9
	4.	understand dynamic principles of systems under the action of forces	28
		Total	**100**

Test: 9209-431 Principles of mechanical component manufacture

Duration: 3 hours

Grading: Pass/Merit/Distinction

Unit	Outcome		%
431	1.	understand the modern manufacturing environment	12
	2.	understand manufacturing requirements of mechanical engineering products	12
	3.	understand methods of mechanical engineering manufacture	46
	4.	understand finishing treatments for manufactured parts	20
	5.	understand the requirements for product inspection	10
		Total	**100**

Test: 9209-432 Materials engineering

Duration: 3 hours

Grading: Pass/Merit/Distinction

Unit	Outcome		%
432	1.	be able to determine the properties and selection criteria of materials from tests and data sources	26
	2.	understand the relationships between manufacturing processes and material behaviour	24
	3.	be able to select suitable materials and processing methods for a specific product	24
	4.	understand the in-service causes of failure of engineering materials	26
		Total	**100**

Test: 9209-435 Statistical process control

Duration: 3 hours

Grading: Pass/Merit/Distinction

Unit	Outcome		%
435	1.	understand how Statistical Process Control (SPC) is used as a quality control technique	30
	2.	understand the use of statistical techniques in consumer and producer sampling schemes	18
	3.	be able to apply statistical techniques to sampling plans	22
	4.	understand how to determine manufacturing process capabilities	10
	5.	be able to determine process capabilities	20
		Total	**100**

Question paper resources

The following examination papers will require resource materials as listed below.

Unit no.	Required source material (required on day of exam)	City & Guilds or third party	Cost if third party	How to access
406	9209-406 Statistical tables 9209-406 Statistical formulae sheet	City & Guilds	n/a	**www.cityandguilds.com** Copies will be provided with exam question answer booklets. It is recommended to print a copy from the **9209 webpage** to use throughout the course.
432	9209-432 Material property charts	City & Guilds	n/a	**www.cityandguilds.com** Copies will be provided with exam question answer booklets. It is recommended to print a copy from the **9209 webpage** to use throughout the course.

Time constraints

The following time constraints must be applied to the assessments of this qualification:

- each assignment has specific time constraints; please refer to the individual assignments and to the Assessor Guidance. Centre staff should guide learners to ensure excessive evidence gathering is avoided. Centres finding that assignments are taking longer should contact the Qualification Consultant for guidance
- all assignments must be completed and assessed within the learner's period of registration. Centres should advise learners of any internal timescales for the completion and marking of individual assignments
- all dated entry written exam papers must be sat within the learner's period of registration.

Assessment strategy

City & Guilds provide sample questions for each unit assessed by dated entry written exam paper.

The purpose of these sample questions is to provide examples of the type of question that will be set, giving an indication of the breadth and depth of knowledge that is expected. It should be noted that these are sample questions and **not** a full sample question paper.

Dated entry examinations will take place twice a year, in June / July and November / December, with the first exam series being in November / December 2015.

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 **not** allowed for this qualification.

6 Grade profile

Purpose and use of this qualification grade profile

City & Guilds has taken the decision to grade the individual assessments included in this qualification, and provide a grade associated with each unit. This decision is based on market research with employers and colleges that suggests grading can be of use both as a motivational tool within the learning environment, and also to learners presenting evidence of their skills to prospective employers.

For this reason, the tasks have been developed to extend learners beyond the minimum required for Pass. As a basis for developing the tasks and their related grading criteria, City & Guilds consulted a number of stakeholders to discover what the grades at each level should mean in practice, and how they might be used. The following descriptors are based on that consultation.

The descriptors were used in the development of the task grading criteria and should be used by assessors to understand the intended outcomes of the grading.

They should be referred to during the centre's standardising exercises in addition to the specific grading criteria for the unit to support a consistent understanding of the standard across units, centres and assessors. The grades achieved by a learner would be considered by universities for subsequent entry into the correct year of a degree programme.

Aims

The Level 4 Diplomas in Engineering and 5 Diplomas in Engineering Diplomas in Engineering focus on advanced engineering, with a wide choice of units to provide a flexible route to career success as a professional engineer. The qualifications have been developed closely with both industry and the deliverers of learning in order to ensure fitness for purpose.

Both Level 4 and Level 5 for this qualification are presented here to allow comparison and better understanding of progression.

Levels

Level 4

The Level 4 Diplomas in Engineering focus on advanced engineering. The learners will have the potential to fulfil a role within Engineering that requires a high level of responsibility, for example within first level management, requiring the use of personal initiative and critical judgement.

Holders of these qualifications may also be able to advance into the second year of a selected university engineering degree programme.

Level 5

The Level 5 Advanced Technician Diplomas in Engineering focus on advanced engineering. The learner will have the potential to fulfil a role within Engineering that requires a high level of responsibility, for example leading to middle management and/or project management, requiring the use of personal initiative and critical judgement.

Holders of these qualifications may also be able to advance into the third year of a selected university engineering degree programme.

To take this qualification a learner must first achieve the 9209 Level 4 Diploma in Engineering.

Both levels are also ideal for people wanting to advance as an Engineering technician within the fields of Mechanical Engineering, Electrical and Electronic Engineering, or Civil Engineering.

Delivery of learning

Learning is delivered by approved colleges and training providers in simulated learning environments, not in the workplace. Learners will however have access to real work environments in which to further develop the breadth of their skills and their experience.

Grading

The majority of tasks are graded Pass / Merit / Distinction. Pass reflects the minimum requirements that are expressed in the unit, with Merit and Distinction showing progression in skills and knowledge as well as recognising behaviours important to the industry.

	Pass	Merit	Distinction
Level 4	**Learner:** Capable of making informed decisions, likely to have achieved a grade at Level 3 (Merit / Distinction), starting to have sufficient skills to bring value to the industry, is becoming comfortable with occupational systems and procedures. **Evidence:** Complex tasks may present some challenge, partial attempt at assessment, well defined tasks completed with a	**Learner:** Broader understanding of systems and procedures, can work with minimal guidance, determination to resolve issues, taking ownership and responsibility for own learning, desire to progress. **Evidence:** Full attempt at assessment, well defined tasks completed with minimal guidance, able to follow the required process, higher level skills / knowledge / competence displayed for the industry, can plan, can solve problems more effectively and confidently. Sufficient reflection on the outcomes of the task.	**Learner:** High level of understanding and evaluation of overall systems and procedures, showing potential to achieve a higher level of academic study. Has an ability to carry out tasks without guidance and shows own initiative. **Evidence:** Full achievement of assessment completely independently, within the time given, ie efficient use of time. Detailed / in-depth reflection on the outcomes of the task with recommendations for improvement / alternatives.

	Pass	Merit	Distinction
	level of guidance, able to follow the required process, acceptable skills / knowledge / competence displayed for the industry, can plan, can solve problems. Limited reflection on the outcomes of the task.		
Level 5	**Learner:** Capable of making informed decisions, likely to have achieved a grade at Level 4 (Merit / Distinction), has sufficient skills to bring value to the industry, is fairly comfortable with occupational systems and procedures. **Evidence:** Complex tasks may present some challenge, but most assessments attempted, well defined tasks completed with a level of guidance, able to follow the required process, acceptable skills / knowledge / competence displayed for the industry, can plan, can solve problems. Satisfactory reflection on the outcomes of the task.	**Learner:** Full understanding of systems and procedures, can work with minimal to no guidance, determination to resolve issues, taking ownership and responsibility for own learning, desire to excel. **Evidence:** Full attempt at assessment, well defined tasks completed with minimal guidance, able to follow the required process, higher level skills / knowledge / competence displayed for the industry, can plan, can solve problems more effectively and confidently. Good reflection on the outcomes of the task.	**Learner:** High level of understanding, evaluation and competence in overall systems and procedures, clearly achieving a higher level of academic study. Has an ability to carry out tasks without guidance and shows own initiative. **Evidence:** Full achievement of assessment completely independently, within the time given, ie efficient use of time. Detailed / in-depth reflection on the outcomes of the task with recommendations for improvement / alternatives.

7 Units

Structure of units

These units each have the following:

- City & Guilds reference number
- title
- level
- UAN (Unit Accreditation Number)
- guided learning hours
- unit aim
- assessment method
- learning outcomes which are comprised of a number of assessment criteria.

Unit 401 Engineering mathematics

Level:	4
UAN:	J/506/9243
GLH:	60
NLH:	150
Assessment method:	Dated written paper
Aim:	The purpose of this unit is to enable learners to develop an understanding of a range of mathematical operations and analysis techniques and apply these techniques to solve engineering problems. On completion of this unit, learners will be able to: • apply algebraic methods to analyse and solve engineering problems • apply trigonometric methods of analysis to solve engineering problems • apply differential and integral calculus methods to solve engineering problems • apply complex numbers and complex analysis methods to solve engineering problems

Note

This unit may be supported by the provision of computer-based mathematical software and the learner could have the opportunity to use this software to help reinforce understanding and application of the analysis techniques presented in the unit.

Learning outcome
The learner will: 1. be able to use algebraic methods to analyse and solve engineering problems
Assessment criteria
The learner can: 1.1 evaluate **basic algebraic functions** 1.2 solve engineering problems that are described by **algebraic equations** and **exponential or logarithmic functions**

Range
Basic algebraic functions Algebraic functions (graph of a function, inverse of a function, odd and even functions, linear functions, gradient of a linear function, common engineering functions (polynomial, rational, modulus, unit step, unit impulse)); use of symbols; indices (positive and negative); laws of indices; algebraic formulae (transposition, factorisation, evaluation of algebraic fractions) **Algebraic equations** Linear equations; quadratic equations; polynomial equations; simultaneous equations; solving inequalities; partial fractions **Exponential and logarithmic functions** Laws of logarithms; solving exponential and logarithmic equations

Learning outcome
The learner will: 2. be able to solve engineering problems that require the use of trigonometric methods of analysis
Assessment criteria
The learner can: 2.1 evaluate **basic trigonometric functions** 2.2 evaluate **trigonometric identities** to solve problems involving trigonometric equations.

Range
Basic trigonometric functions Angles; sine; cosine; tangent; secant; cosecant; cotangent of an angle; inverse functions; $\sin^{-1}$; $\cos^{-1}$; $\tan^{-1}$; trigonometric functions and their graphs; amplitude; frequency; phase and period of a sine or cosine function **Trigonometric identities** Compound and double angle formulae for sine and cosine; 'sums to product' and 'product to sums' formulae; solve trigonometric equations; application to resolution and resultant of forces; description of complex wave patterns

Learning outcome
The learner will: 3. be able to use methods of differential and integral calculus to solve engineering problems
Assessment criteria
The learner can: 3.1 evaluate **first and higher order derivatives** of a function involving algebraic and/or trigonometric expressions 3.2 use **differential calculus** to obtain solutions for engineering applications of algebraic and trigonometric equations 3.3 use **methods of integration** to determine indefinite and definite integrals of algebraic and trigonometric functions

3.4 use **integral calculus** to obtain solutions for engineering applications of algebraic and trigonometric equations 3.5 use **integration** to solve engineering applications of differential equations in which the variables are separable.

Range
Differentiation between first and higher order derivatives based on Rate of change of a function; derivative and gradient of a function; table of derivatives for common functions (ax^n, $(ax \pm b)^n$, $\sin^n(ax \pm b)$, $\cos^n(ax \pm b)$, $e^{(ax \pm b)}$, $\ln(ax \pm b)$) and linear combinations of these); higher derivatives **Differential calculus** Product rule; quotient rule; chain rule; implicit and logarithmic differentiation; maximum and minimum values of a function; points of inflection; applications of differentiation to engineering problems **Methods of integration** Integration as the reverse of differentiation; indefinite integrals; table of integrals for common functions (constant, ax^n ($n \neq -1$), $1/x$, $\sin(ax \pm b)$, $\cos(ax \pm b)$, $e^{(ax \pm b)}$), definite integrals; Integration methods: integration by parts; by substitution; using partial fractions; integration of trigonometric functions **Integral calculus** Applications of integration to areas; volumes of revolution; centres of mass; moments of inertia; mean value and root-mean-square (rms) value of an electrical signal **Integration** Apply integration methods for the solution of differential equations in which the variables are separable; general and particular solutions

Learning outcome
The learner will: 4. be able to apply complex numbers and complex analysis to solve engineering problems
Assessment criteria
The learner can: 4.1 evaluate complex equations using rectangular and polar forms of **complex numbers** 4.2 use **complex function analysis** to obtain solutions to engineering problems.

Range
Complex numbers Imaginary number; $j = \sqrt{-1}$; real and imaginary parts of a complex number; complex conjugate; arithmetic of complex numbers; Argand diagram; polar form of complex numbers (modulus and argument); exponential form of complex numbers; Euler's formula; de Moivre's theorem **Complex function analysis** Solve complex equations involving complex variables; find roots of complex numbers; phasors; complex impedances; analyse simple ac electrical circuits and measurement and control systems using complex numbers

Unit 403 Quality assurance and control

Level:	4
UAN:	R/506/9245
GLH:	42
NLH:	150
Assessment method:	Dated written paper
Aim:	The purpose of this unit is to enable learners to develop the skills and knowledge required to assess and evaluate quality management systems in a manufacturing environment.

Learning outcome
The learner will: 1. understand the importance of quality assurance and quality control within an organisational culture
Assessment criteria
The learner can: 1.1 explain the importance of creating an **appropriate organisational culture** 1.2 evaluate the **attributes** of successful organisational management 1.3 evaluate **opportunities to improve or develop** an organisational culture.

Range
Appropriate organisational culture Quality assurance; Quality control **Attributes** Leadership; people management and motivation; process capability; communication; customer focus; decision making **Opportunities to improve or develop** Within appropriate area of responsibility; strategic aims of the business; SWOT and PESTLE analysis

Learning outcome
The learner will: 2. understand how total quality management systems operate
Assessment criteria
The learner can: 2.1 explain the **principles** of total quality management 2.2 evaluate **organisational management structures** 2.3 evaluate **quality policies** of organisations.

Range
Principles Total company commitment to quality oriented leadership and management; zero errors or zero defects; internal and external customer focus; standardisation of procedures / policies to meet customer needs; total employee involvement; a process approach; use of innovation through quality improvement techniques / methodology; quality circles, Kaizen; continuous improvement policy; factual approach to decision making; supplier partnerships **Organisational management structures** Flat; hierarchical; functional; divisional; bureaucratic; matrix; team-based; network-based **Quality policies** Business benefits and outcomes: Customer loyalty, repeat business, reduced costs, competitive advantage, added value, improved effectiveness and efficiency

Learning outcome
The learner will: 3. understand the implementation process of quality management systems
Assessment criteria
The learner can: 3.1 describe **quality management systems** 3.2 identify **key factors** that must be implemented for quality management systems to be successful 3.3 evaluate internal and external quality **audits**.

Range
Quality management systems Quality Assurance; Quality Control **Key factors** Goals of an organisation; mission statement; focus on quality; control of quality achieved through inspection, tools and techniques used; measurement, testing and checking; teamwork; feedback **Audits** Costs of production (fixed, variable, break even); waste; internal failures; external failures; appraisal; prevention costs

Learning outcome
The learner will: 4. understand key principles of business excellence models
Assessment criteria
The learner can: 4.1 explain the nature and **concepts** of business excellence models 4.2 analyse essential components and **interrelationships of business excellence models**.

Range
Concepts EFQM; BEM; Framework; adding value for customers; sustainability; strong, effective management; improvement through creativity and innovation; leading with vision and clear strategic direction; create a culture of empowerment; outstanding results. **Interrelationships of BEMs** Enablers and Results; Leadership; strategic planning; Partnerships and resources; processes, people; creating the appropriate culture; meeting or exceeding needs of customers; products and services; sustainability; soft and hard metrics; fostering innovation and inventiveness.

Learning outcome
The learner will: 5. understand the principles of six sigma project management
Assessment criteria
The learner can: 5.1 explain the **key factors** of six sigma methodology 5.2 evaluate the **application** of six sigma project management.

Range
Key factors Commitment of whole organisation; communication within organisation; involvement of the whole organisation; management of Six Sigma philosophy as a project; setting measurable goals and objectives; education and training of the workforce; cultural change; customer focus; identification of 'champions'. **Application** DMAIC; root cause analysis; use of statistical tools, continuous improvement techniques.

Learning outcome
The learner will: 6. understand the techniques and methods applied to the quality control of goods and services
Assessment criteria
The learner can: 6.1 explain the application of **techniques and methods** used in supply quality control 6.2 explain how **quality control metrics** are used to rate suppliers.

Range
Techniques and methods Use of key performance indicators and the supplier balanced scorecard; TQM; use of 'soft' metrics such as delivery standards, customer satisfaction; use of 'hard' metrics such as checks and tests for mass, weight, length; sampling plans; national and international certification; supplier partnerships; specifications; SLAs. **Quality control metrics** Compliance/non-compliance; supplier audit; corrective action; conformance/non-conformance.

Learning outcome
The learner will: 7. understand the use and application of codes of practice, standards and design guides
Assessment criteria
The learner can: 7.1 describe relevant **codes of practice, standards and design guides** 7.2 evaluate the **application** of codes of practice, standards and design guides.

Range
Codes of practice, standards and design guides Local, national and international (eg ISO 9000). **Application** Local, national and international standards such as ISO 9000/14000, BS, ASME; industry and engineering specific codes of practice; design guides including technical specification, drawings, parts lists, support services.

Unit 404 Human factors in the workplace

Level:	4
UAN:	Y/506/9246
GLH:	60
NLH:	150
Assessment method:	Dated written paper
Aim:	The purpose of this unit is to enable learners to develop an understanding of the principles of human factors in manufacturing environments. Learners will look at the importance and impact of human factors on performance in the workplace, gain an appreciation for workplace company culture, recognise effective methods of communication, know principles of leadership and management, and will be able to carry out risk assessments.

Learning outcome
The learner will: 1. understand the importance of human factors in the workplace
Assessment criteria
The learner can: 1.1 assess the **impact** of human factors on human performance 1.2 describe **categories** of human factors important to staff.

Range
Impact Murphy's law; safety of employees; assets; long-term health of employees; efficiency of organisation **Categories** Working environment; work patterns; social habits; work load; communication; employee health

Learning outcome
The learner will: 2. understand features and limitations of human performance
Assessment criteria
The learner can: 2.1 explain how low and very high light levels affect **visual performance** 2.2 explain how **levels of noise** affect **human performance** 2.3 explain **factors** that affect limitations of the human memory 2.4 assess how working in **challenging environments** increases risks occurrence.

Range
Visual performance Fatigue; visual inspection; residual image; long term sight damage **Levels of noise** Prolonged; intermittent; percussive **Effects on human performance** Communication errors; fatigue **Factors** Attention span; time from exposure to information; fatigue; age; complexity of information; artificial stimulants; depressants; overconfidence; boredom; repetitive work **Challenging environments** Claustrophobia; fear of heights; limited access; confined space; time constraints; poor vision; environmental extremes; peer pressure

Learning outcome
The learner will: 3. understand the interrelationship between different roles and responsibilities in the workplace
Assessment criteria
The learner can: 3.1 explain the principles of workplace **company culture** 3.2 explain areas of **individual and group responsibility** in the workplace 3.3 evaluate the **relationship** between managers, supervisors and operatives 3.4 explain the principles and characteristics of leadership.

Range
Company culture Different types of culture (shift, teams, social); safety culture; individuals; compromise; blame culture; no blame culture **Individual and group responsibility** Roles and responsibilities and the interaction between; groups and teams; individuals; inter group dynamics; shift handovers **Relationship** Differentiate between management and supervisor roles; expectations; organisations

Learning outcome
The learner will: 4. understand how physical and personal factors of the working environment affect human performance
Assessment criteria
The learner can: 4.1 analyse **sources** of stress 4.2 explain the effects of setting **deadlines** on work performance 4.3 analyse the effects of **external environmental factors** on individual performance.

Range
Sources Domestic; work **Deadlines** *Realistic* (improve performance; minimal errors; motivated workforce; improved time management skills; efficiency of resources; staff retention) *Unrealistic* (poor quality of work; increased amount of errors/accidents; decrease in morale; staff turnover) **External environmental factors** Noise; fumes; illumination; climate; motion; working environment

Learning outcome
The learner will: 5. understand how the execution of different tasks can affect human performance
Assessment criteria
The learner can: 5.1 explain the importance of **planning and executing tasks** 5.2 explain how **demanding work** can affect human performance 5.3 analyse the **aspects** of working in complex organisations.

Range
Planning and executing tasks Define the tasks; resources; personal skills and proficiency information; planning of repetitive tasks (complacency; assumption of time) **Impact of demanding work** Health and physical condition; effects of lack of physical fitness against the work standard for the occupation; work environment; physical effort; effects of ageing; visual inspection (importance of good eyesight, knowledge of inspection, illumination, concentration, systematic search) **Aspects** Clear understanding of the purpose of the organisation; pooling of knowledge and skills; comprehensive information and guidance; associated hazards; managing resources; stakeholder management and relationships

Learning outcome
The learner will: 6. understand how to communicate effectively in the workplace
Assessment criteria
The learner can: 6.1 explain the importance of **interpersonal and communication skills** in optimising performance 6.2 evaluate the **effectiveness of feedback** when developing communication skills 6.3 assess **methods of communication** appropriate to different audiences.

Range
Interpersonal and communication skills Writing; verbal; visual; outcomes; key points; intonations; accuracy; urgent; level of importance; adaptation; audience; barriers; achieved purpose; audience; formality; situations **Effectiveness of feedback** Analysis of formal and informal feedback; reflection **Methods of communication** Written; verbal; visual; format; layout; presentation; objectives; discussion; adaptation

Learning outcome
The learner will: 7. understand causes of human error
Assessment criteria
The learner can: 7.1 explain **causes of error** that occur during work 7.2 evaluate **methods of managing and avoiding errors.**

Range
Causes of error Complacency; overconfident; lack of knowledge; poor training; lack of information; lack of interest; inattention; distractions; environmental; violations; communication **Methods of managing and avoiding errors** Self-discipline; safety management system; anonymous and blame-free reporting; review of error logs; formal briefing; coaching; mentoring; training (new and refresher)

Learning outcome
The learner will: 8. be able to recommend ways to mitigate risk in the workplace
Assessment criteria
The learner can: 8.1 explain the **five steps** to risk assessment 8.2 evaluate the risks for workplace hazards 8.3 propose solutions to minimise risk in the workplace.

Range
Five steps Identify hazards; evaluate risks; develop controls; implement controls; review and update

Learning outcome
The learner will: 9. understand how to apply safety, occupational health and environmental policies within industry
Assessment criteria
The learner can: 9.1 analyse **personal legal obligations** of individuals within industry 9.2 evaluate the **impact and implications of legislation** concerning health and safety in the workplace 9.3 evaluate **environmental policies** within industry.

Range
Personal legal obligations Alcohol; drugs; legislation; health and safety **Impact and implications of legislation** Current local; national; international legislation monitored; regulated; controlled **Environmental policy** Material inputs and outputs; waste energy; process efficiency; ISO 14001

Unit 405 Engineering planning and scheduling

Level:	4
UAN:	D/506/9247
GLH:	66
NLH:	150
Assessment method:	Assignment
Aim:	The purpose of this unit is to enable learners to develop an understanding of how maintenance/manufactured products and their associated processes are planned, monitored and controlled. Learners will extend their knowledge to apply both manual and computer-assisted methods and procedures. The unit covers process plans (eg forecasting, network analysis), capacity assessment and scheduling and maintenance strategies. This leads the learner into inventory management with stock control and documentation systems. The last two outcomes require the learner to examine group technology, process plans and production/maintenance scheduling.

Learning outcome
The learner will: 1. understand the use of process planning, capacity assessment and scheduling techniques
Assessment criteria
The learner can: 1.1 assess the uses of different **process planning techniques** 1.2 evaluate the use of **capacity assessment techniques** for different types of engineering process 1.3 evaluate the use of a range of **scheduling techniques**.

Range
Process planning techniques Forecasting; network analysis; critical path method (CPM); project evaluation and review technique (PERT); failure mode and effects analysis (FMEA); material requirement planning (MRP); equipment and tooling; make or buy decisions; computer aided-planning and estimating. **Capacity assessment techniques** Bill of materials; economic batch size; assessment of load and capacity; effects of re-working and scrap; methods of increasing/decreasing capacity; time phased capacity planning. **Scheduling techniques** Lead times; critical path analysis (CPA); supplier and production schedules; Kanban; optimised production technology (OPT) philosophy; influence of scheduling on capacity planning dispatching; material requirement planning (MRP).

Learning outcome
The learner will: 2. understand inventory management documentation
Assessment criteria
The learner can: 2.1 explain the **principles** of inventory management 2.2 assess workplace documentation **systems**.

Range
Principles Types of inventory; dependent and independent demand; role of buffer stock; cost of inventory **Systems** Works orders; routing document; job tickets; recording of finished quantities; re-work and scrap; stock records.

Learning outcome
The learner will: 3. understand the use of shop control systems
Assessment criteria
The learner can: 3.1 explain the **uses of shop control** 3.2 evaluate different **stock control systems**.

Range
Uses of shop control Scheduled release of works orders; progressing; data collection and feedback

Stock control systems
Periodic review; re-order points; two bin system; basic economic order quantities; just in time; Kanban

Learning outcome
The learner will: 4. understand group technology processing
Assessment criteria
The learner can: 4.1 explain **methods** of classifying and coding component parts into family groups 4.2 explain how family groups of components are **sequenced** for processing through grouped facilities.

Range
Methods Sequential; product; production; design; Opitz method; classification of parts into families **Sequence** Layout; product; process; fixed position; group; sequencing of families for groups of facilities

Learning outcome
The learner will: 5. be able to plan engineering activities
Assessment criteria
The learner can: 5.1 produce **process plans** from given data 5.2 produce **schedules** from process plans.

Range
Process plans Forecast to identify timings and completion dates; materials required; equipment and tooling required; methods or processes employed; labour requirements and planning for quality checks; proposal for data logging; use of computers; MRP **Schedule** Developed from the process planning and customer requirements; lead times; using scheduling techniques such as CPA, Gantt charts, software packages (CMMS, CPS, CAM, CAPP, CIM), OPT philosophy, MRP

Unit 406 Statistical analysis for engineers

Level:	4
UAN:	M/506/9270
GLH:	45
NLH:	100
Assessment method:	Dated written paper
Aim:	The purpose of this unit is to enable learners to gain an understanding of statistical concepts and techniques used in analysis and be able to apply these techniques in industrial problems. Learners will understand the need to collect valid and appropriate sample data. They will acquire knowledge of statistical analysis techniques and develop practical analysis skills and apply these to the study of engineering products and processes. Learners will be able to provide unbiased conclusions and recommendations arising from the analysis undertaken.

Note

This unit may be supported by the provision of computer-based statistical analysis software and the learner could have the opportunity to use this software to reinforce understanding and help in the practical application of the analysis techniques presented in the unit.

Learning outcome
The learner will: 1. understand the causes of variation in industrial processes
Assessment criteria
The learner can: 1.1 explain sources of variation due to **assignable causes** in industrial processes 1.2 explain the importance of identifying and removing assignable causes 1.3 explain the **nature of random variation** in industrial processes.

Range
Assignable causes Human factors; mistakes in computation and measurement; disinterest and/or carelessness; systematic error sources (faulty equipment calibration or observer bias) **Nature of random variation** Occur after systematic errors have been accounted for; result from range of uncontrollable effects; ambient/environmental conditions; temperature; humidity; instrument uncertainties

Learning outcome
The learner will: 2. understand statistical concepts and functions
Assessment criteria
The learner can: 2.1 explain the **relationship** between sample data and the total data population 2.2 identify different **distributions** used for sample statistics 2.3 explain the importance of the **normal probability distribution** for sample statistics.

Range
Relationship • Terminology (observational data, variables, attributes, population, sample) • Probability (sets, events, definitions, conditional probability, Bayes theorem) • Random variables (discrete, continuous) • Sampling methods **Distributions** *Probability distributions* (histograms, continuous density, discrete and cumulative functions); *Theoretical distributions* (uniform, exponential, Normal, Weibull, Bernoulli, binomial, Poisson) **Normal probability distribution** Central limit theorem

Learning outcome
The learner will: 3. be able to calculate unbiased estimates of population parameters
Assessment criteria
The learner can: 3.1 explain common statistical techniques for **summarising data** 3.2 use **statistical techniques** to calculate unbiased estimates of population parameters using sample data.

Range
Summarising data Mean; median; mode; variance; standard deviation; proportion **Statistical techniques** Sampling statistics (central limit theorem, standard error of the mean and its distribution); sampling distributions (Normal, Chi-square, Student t, F-distributions); sampling intervals (confidence intervals for mean and difference of two means when variance is or is not known)

Learning outcome
The learner will: 4. be able to solve industrial problems using statistical analysis of sample data
Assessment criteria
The learner can: 4.1 test proposed **statistical hypotheses** about given populations 4.2 use **tests** to identify population distributions 4.3 conduct one-way **analyses of variance** (anova) 4.4 evaluate **correlation coefficients** and perform a linear regression 4.5 evaluate the **reliability** of manufactured engineering products.

Range
Statistical hypotheses Null and alternative hypotheses (type 1 and 2 errors, level of significance, operating characteristic curves); tests for means (one sample and two sample t-tests with known or unknown variance, paired t-tests) **Tests to identify population distributions** Chi-square goodness of fit test; Kolmogorov-Smirnov goodness of fit test **Analysis of variance** Assumptions; single factor (one-way) tests; fixed effects model; random effects model **Correlation coefficients** Coefficient of determination; correlation coefficient; coefficients of linear (one-dimensional) regression **Reliability** Failure rate function (hazard function); reliability modelling and estimation; repairable and non-repairable systems; exponential failure law; mean time to failure (MTTF); mean time between failures (MTBF); reliability of systems comprising components in serial and parallel combinations with active or standby redundancy

Unit 407 Computer Aided Design for manufacture

Level:	4
UAN:	T/506/9271
GLH:	60
NLH:	100
Assessment method:	Assignment
Aim:	The purpose of this unit is to enable learners to gain an understanding of the CAD/CAM systems used in advanced manufacturing and develop practical modelling skills with a CAD system. Learners will understand the benefits of applying both CAD and CAM systems in the workplace and will be able to advise management on the implementation of CAD/CAM in manufacturing processes.

Learning outcome
The learner will: 1. be able to produce 3D Parts using Parametric Modelling
Assessment criteria
The learner can: 1.1 create **2D & 3D Sketches** with the CAD Environment 1.2 create **3D Models** using a range of **Feature Commands** 1.3 Export 3D CAD Models for **CNC, 3D Printing or Laser/Plasma Cutting**.

Range
2D & 3D Sketches Drawing Tools, Constraints, Patterns, Modify **3D Models** Solid Geometry, T-Splines Forms **Feature Commands** Extrude, Revolve, Loft, Fillet, Chamfer, Shell, Sweep, Work Planes, Patterns **CNC, 3D Printing or Laser/Plasma Cutting** DXF, IGES, STL, STEP

Learning outcome
The learner will: 2. be able to produce 3D working assemblies
Assessment criteria
The learner can: 2.1 create **3D Assemblies using Modelled Parts** and **Content Libraries** 2.2 create **3D Functional Assemblies** using correct **constraining procedures** 2.3 create **3D Exploded Assemblies** to demonstrate the **assembly/disassembly process**.

Range
3D Assemblies using Modelled Parts Multiple part models **Content Libraries** Nuts, Bolts, Screws, Washers, Bearings **3D Functional Assemblies** Rotary and Linear Motion **Constraining procedures** Flush, Parallel, Joint **3D Exploded Assemblies** Presentation Files **Assembly/disassembly process** Putting the assembly together or taking apart

Learning outcome
The learner will: 3. be able to create drawings
Assessment criteria
The learner can: 3.1 create**2D drawings of individual parts** for manufacture to **BS8888** 3.2 Create **2D Assembly Drawings** to BS8888.

Range
2D drawings of individual parts DWG files, Orthographic, Sections, Break Outs, Detail **BS8888** Templates, Line Types, Dimensioning, View Layouts, Metric, Surface Finish, GDT, Wiring Diagrams **2D Assembly Drawings** Fully Assembled views, Exploded Assembly Views, BOM

Learning outcome
The learner will: 4. be able to produce rendered images and animations
Assessment criteria
The learner can: 4.1 create **rendered images** of parts and assemblies 4.2 create **animations** of **assembly/disassembly processes** 4.3 create animations of **assembly functionality**.

Range
Rendered Images Photo Realistic, Camera Angle, Lighting, Environment **Animations** MP4, AVI Videos **Assembly/Disassembly Processes** Exploding & Collapsing **Assembly Functionality** Rotary & Linear Motion, Gears, Chains, Sprockets

Unit 407 Computer Aided Design for manufacture

Supporting information

Guidance

The unit will be supported by the provision of computer-based 3-D CAD solid modelling software to enable the learner to develop CAD modelling skills during delivery of the unit and apply these in practical manufacturing situations.

Unit 418 Maintenance of engineering systems and equipment

Level:	4
UAN:	H/506/9301
GLH:	56
NLH:	150
Assessment method:	Assignment
Aim:	The purpose of this unit is to enable learners to develop an understanding of how to plan for and carry out maintenance work on systems and equipment used in manufacturing operations.

Learning outcome
The learner will: 1. understand maintenance planning in engineering
Assessment criteria
The learner can: 1.1 outline **regulations** required to be used for the maintenance of equipment and systems 1.2 evaluate **maintenance strategies** used for different systems and equipment 1.3 assess **factors** in determining maintenance plans.

Range
Regulations UK current or international equivalents of: (statutory and non-statutory including Codes of Practice) - Electricity at Work Regulations (1989), BS7671, GS 38 or international equivalents, Health & Safety Act (1974), Building Regulations (2000), Management of Health & Safety at Work Regulations, Reporting of Injuries, Diseases & Dangerous Occurrences Regulations, Provision & Use of Work Equipment Regulations, Manual Handling Operations Regulations, Personal Protective Equipment at Work Regulations, Work at Height Regulations, Control of Substances Hazardous to Health Regulations, Control of Asbestos at Work Regulations **Maintenance strategies** Breakdown; preventative; periodic; predictive; corrective Maintenance Prevention – as part of Total Productive Maintenance (TPM) **Factors** System functions; system failures; failure consequences; failure processes

Learning outcome
The learner will: 2. understand mechatronics in industrial systems
Assessment criteria
The learner can: 2.1 explain **key components** of industrial systems 2.2 outline the **architecture** of various types of industrial systems 2.3 evaluate the **features** of conventional and mechatronic systems 2.4 evaluate the **use of fieldbus networks** in industrial network systems.

Range
Key components Input devices; prime movers; gearing; controllers; output devices **Architecture** Controller; correction element; process; outputs; logical sequence of events; construct block diagrams **Features** Centralised control or distributed control; hard wiring or networks; sequence control or intelligent individual control; relay logic *or* software programming; plant maintenance or predictive maintenance **Use of fieldbus networks** Requirement for multiple devices in a process control system to communicate with each other without conflict; cost, complexity, competing fieldbus standards – compatibility between components (eg sensors and actuators); Ethernet based systems

Learning outcome
The learner will: 3. understand the principles of sensors in mechatronics
Assessment criteria
The learner can: 3.1 evaluate the operation and application of **sensors** in control systems 3.2 evaluate the operation of **signal conditioning systems** for use in mechatronics 3.3 explain the **terms** applied to sensors used in mechatronics.

Range
Sensors *Contact*: micro switch, snap action limit switch, wobble stick, pressure mat, positively guided safety switch, level switch *Non-contact*: inductive proximity, capacitive proximity, optical proximity, light curtain, thermocouple, strain gauge, differential pressure, impeller flow, encoder (incremental and absolute), resolver, vibration transducer, motion sensor **Signal conditioning systems**

Purpose; isolation; amplification; excitation; monitoring; conversion (voltage to current, current to voltage, pressure to voltage, pressure to current, analogue to digital, digital to analogue, frequency to voltage, frequency to current, sink to source, source to sink)

Terms (characteristics)

Sensitivity; repeatability; resolution; dead band; alignment; compatibility; cross talk; grounding; calibration; noise; discrimination; linearity; dynamic error

Learning outcome
The learner will: 4. understand the principles of actuation systems
Assessment criteria
The learner can: 4.1 evaluate the use of **control and actuation systems** in mechatronics 4.2 assess the operation of **pneumatic power systems** and their **components** 4.3 assess the operation of **hydraulic power systems** and their **components** 4.4 assess the operation of **electrical actuation systems** and their **components** 4.5 assess the operation of **mechanical systems** 4.6 describe the **symbols** used in actuation **systems**.

Range
Control and actuation systems Pneumatic; hydraulic; electrical, mechanical **Pneumatic power systems** Prime mover (ie motor); compressor (ie two stage reciprocating); silencer; filter; pressure relief valve; cooler; filter and water trap; air receiver; pipe work distribution system, air motors and actuators **Components** *Valves* (directional control valves (DCV) – spool, 3/2, 4/2, 5/2, directly operated, pilot operated, solenoid operated, poppet) *Directional valves* (one way, one way restrictor return) *Pressure control valves* (pressure regulating, pressure limiting, pressure sequence) *Proportional process control valves* (pneumatic diaphragm actuator, linear contoured, equal) *Actuators* (Linear actuators – single acting, double acting, fluid muscle, tandem, multi position, stick slip phenomenon; Rotary actuators – use of linear actuator to produce rotation, vane-type semi-rotary, vane motor) **Hydraulic power system** Prime mover (ie motor); pump; non return valve; pressure relief valve; accumulator (ie bladder-type); sump; hydraulic oil; pipe work distribution system and return **Components**

Valves (directional control valves (DCV) – spool, 3/2, 4/2, 5/2, directly operated, pilot operated, solenoid operated, poppet)

Directional valves (one way, one way restrictor return)
Pressure control valves (pressure regulating, pressure limiting, pressure sequence, proportional)
Electrical actuation systems:
Switching devices (push buttons, relays, thyristor, TRIAC, solid state relay, solenoid devices)

Motors (series dc, shunt dc, separately excited dc, stepper, servo, single phase induction, three-phase induction)

Motor control (basic dc. motor speed control (ie, inverter drive), basic induction motor speed control (ie, inverter drive), basic stepper motor controllers, basic servo motor controllers)
Components
Benefits over hard wired systems; communications interface to control system; basic requirements of wiring medium (ie CAT 5, screening, grounding); types of distributed input /output modules (ie digital, analogue) terminations (insulation displacement connection (IDC), RJ-45, DIN, BNC)

Mechanical system
Comprising of: prismatic motion; revolute motion; sliding joints; revolving joints; force amplification (ie levers); change of speed (ie gears); transfer of rotation (ie belts and chains); types of motion (ie quick return mechanism); cams and cam followers; change of direction (ie bevel and worm gear); linear to revolute / revolute to linear (ie rack and pinion); bearings (ie plain roller needle and ball)
Symbols
Flow path; flow shut-off; initial connections; push button operation; lever operation; roller operation; plunger operation; spring operation; solenoid operation; pedal operation; pilot operation; 2/2 valve; 3/2 valve; 4/2 valve; 5/2 valve; non return valve; pressure limiting valve; regulator; pressure source; exhaust; filter; single acting cylinder; double acting cylinder; rotary actuator
Systems
Pneumatic; hydraulic; electrical

Learning outcome
The learner will: 5. be able to plan for maintenance operations
Assessment criteria
The learner can: 5.1 evaluate the **safety factors** affecting maintenance operations 5.2 evaluate **sources of information** used to facilitate maintenance of systems and equipment 5.3 produce operational maintenance **documentation** 5.4 assess **physical and human resources** required to carry out maintenance of systems and equipment.

Range
Safety factors Area; safety requirements; equipment; barriers and enclosures; safe isolation procedures; selection of safe isolation methods for: electrical systems and pressurised systems (ie hydraulic; compressed air; water; gas); notification of personnel and other workers; Personal Protective Equipment (PPE); switchgear requirements; Environmental considerations; provision for safe storage of tools; equipment and materials; arrangements for working at height and in confined spaces **Sources of information** Component data; availability of materials; e-diagnostics; drawings; diagrams (circuit and wiring); maintenance schedules/specifications; data charts; manufacturer's manuals; servicing records/running logs; flow charts; standard maintenance time records **Documentation:** Risk assessments; method statements; maintenance reports ; safe isolation procedures; Permits to work; work plan (including definition of tasks, planned shut downs/isolations, safety precautions (provision for release of stored and latent energy), communication with relevant stakeholders, time/cost effectiveness, work over-run notification procedures) **Physical and human resources** *Physical*: tools and equipment (power tools, hand tools, lighting, power supplies, diagnostic equipment, temporary services, access equipment, safety equipment (fall-arrest gear, gas tester, breathing apparatus), mechanical handling equipment); works orders; requisitions; contracts; tendering *Human*: company-based maintenance staff; sub-contractor involvement; skills and competence of involved personnel; training needs; licence / authority to work

Learning outcome
The learner will: 6. be able to carry out maintenance procedures on systems and equipment
Assessment criteria
The learner can: 6.1 assess the **safety** of **systems** prior to undertaking maintenance operations 6.2 apply **maintenance procedures** to **systems** and **equipment** 6.3 evaluate the **performance** of maintained systems and equipment 6.4 apply **re-commissioning** processes on completion of maintenance activities.

Range
Safety Safe isolation procedures in accordance with regulatory requirements for systems and equipment; the Health and Safety of personnel within the work location **Systems** Mechanical; electrical; pneumatic; hydraulic

Maintenance

Planned preventative (periodic, predictive); breakdown/corrective (including fault diagnosis/rectification)

Procedures

Complying with manufacturer's instructions, industry approved practices, maintenance schedules and specifications

Electrical, Hydraulic and pneumatic: loss of supply; overload; short circuit and earth fault; transient voltage; loss of phase/line; incorrect phase rotation; high resistance joints

Mechanical: component; accessory or equipment faults)

Systems

Pneumatic radial, Pneumatic ring, Hydraulic, components and accessories

Electrical: Three-line four wire distribution systems; ELV and LV single and multiphase circuits; lighting systems heating and ventilating systems; air conditioning and refrigeration systems; drive systems, security systems; earthing systems and data communication systems

Equipment

Electrical plant; components and accessories; motors and starters; switchgear and distribution panels; control systems and components; contactors; power transmission mechanisms; luminaires and lamps

Performance

Using suitable test methods

Re-commissioning

Safety before re-energising; check all systems in place and re-set; carry out re-instatement procedures; electrical; mechanical and pneumatic/hydraulic checks.

Dispose of hazardous substances: oils; greases; cleaning agents; solvents; insulation; adhesives; fillers; packing; lagging.

Complete reports: maintenance schedules; clear permits to work and sign off; diaries; materials used; record likely future requirements; update maintenance schedule; complete hand over

Unit 419 Engineering design

Level:	4
UAN:	M/506/9334
GLH:	60
NLH:	150
Assessment method:	Assignment
Aim:	The purpose of this unit is to enable learners to understand the principles and processes involved in engineering design and develop the computer-based skills that are needed to produce industry standard engineering drawings. It is recommended a basic level of competency in CAD is attained before beginning this unit, in order to be able to meet all the learning outcomes. On completion of this unit, learners will be able to • use computer software to develop design drawings or schemes • develop design specifications to meet customer requirements.

Learning outcome
The learner will: 1. understand how to select and justify design solutions required to meet given specifications
Assessment criteria
The learner can: 1.1 analyse possible design solutions 1.2 evaluate **conceptual designs** 1.3 justify selected design solution 1.4 assess **compliance** of design solution.

Range
Compliance Health and safety; ethics; sustainability; product end-of-life disposal. **Conceptual designs** SWOT, weighted matrix of design parameters

Learning outcome
The learner will: 2. be able to use computer software to develop design drawings or schemes to meet design specifications
Assessment criteria
The learner can: 2.1 explain the key features of **computer software** in the design for manufacture process 2.2 use computer software to produce design drawings or schemes 2.3 review available computer software that can assist the design process

Range
Computer software CAD; CAM

Learning outcome
The learner will: 3. understand how to justify selected product designs for economic manufacture
Assessment criteria
The learner can: 3.1 explain the advantages and disadvantages of **standardisation** 3.2 describe the **elements** involved in the total cost of manufacture 3.3 review manufacturing **processes** and material **requirements** for components.

Range
Standardisation Product; components; manufacturing process **Elements** eg materials; labour; overheads; compliance fees; development and testing; marketing **Processes** Forming; forging; casting; moulding; machining; fabrication **Requirements** Strength; material type eg ferrous, non-ferrous, metallic, composites

Learning outcome
The learner will: 4. be able to develop design specifications to meet customer requirements
Assessment criteria
The learner can: 4.1 research customer requirements including **design parameters** 4.2 use design information from appropriate **sources** to prepare design specifications 4.3 assess customer requirements against **design limitations**.

Range
Design parameters eg off the shelf solution; safety standards; national, international industry standards (eg BSI, CE); compatibility with existing/emerging technologies, size of product, function of product, material, expected shelf life, numbers of products required, cost, end user **Sources** eg client; designer; stress engineer; production designer; procurement; marketing; regulatory authorities; legal/patent team; business case **Design limitations** eg cost; practicality; available technology; materials; production process; reliability of product; manufacturing type (mass, batch, bespoke)

Unit 419 Engineering design

Supporting information

Guidance

This unit will be supported by the provision of computer-based 2-D CAD drawing software to enable the learner to develop practical CAD drawing skills during delivery of the unit.

Unit 421 Planning and implementing change within businesses

Level:	4
UAN:	T/506/9304
GLH:	30
NLH:	100
Assessment method:	Assignment
Aim:	The purpose of this unit is to enable learners to develop an understanding of the need to plan, manage and implement organisational change in a positive way to ensure that the organisation and its employees benefit from the change. Learners will also gain an understanding of how to evaluate the change process and how to use various tools and techniques for evaluation.

Learning outcome
The learner will: 1. understand the need for managing organisational change
Assessment criteria
The learner can: 1.1 describe the **internal and external factors** that contribute to the need for change in organisations 1.2 analyse different **types** of organisational change 1.3 explain the **benefits** of planning organisational change.

Range
Internal factors Strategic; organisational; sector led objectives; resources eg human; financial; physical; technological **External factors** Environmental; political; legal; economic; technological, PESTLE **Types** Strategic; structural; process orientated; people centred **Benefits** Change is planned and managed; reduces stress levels on individuals; maximise efficiency of existing resources; more opportunities for development; increased skills.

Learning outcome
The learner will: 2. understand the change process within business environments
Assessment criteria
The learner can: 2.1 explain **processes** for managing change 2.2 explain why **organisational culture** has a **role** in the management of change.

Range
Processes Learners should be encouraged to refer to current theories and processes eg Kotter's 8 Steps, Dunphy and Stace, Kurt Lewin (unfreeze change freeze), Burke-Litwin **Organisational culture** Learners should be encouraged to refer to specific theories on organisational culture eg Thomas Handy, Johnson and Scholes Cultural Web, Hofstede's Cultural Dimensions **Role** In terms of ensuring clear communication, committed managers, modelling cultures through actions, recognition, change in physical environment

Learning outcome
The learner will: 3. understand the importance of effective leadership and management in the change process
Assessment criteria
The learner can: 3.1 explain the **skills** needed to manage people through organisational change 3.2 describe **reasons** for individuals to resist change 3.3 explain how leaders and managers can **overcome** resistance to change.

Range
Skills Use of effective communication; giving feedback; understanding behaviours/styles; managing performance; team working **Reasons** Disbelief/anxiety; failure to understand problem; mistrust; demotivation; frustration **Overcome** Resistance to change eg how organisations encourage participation, empathy, feedback, trust, be open to revision of plans. Learners must refer to the Change Transition Curve, and a leadership model eg; Tannenbaum and Schmidt, Situational Leadership, John Adair, Transformational Leadership

Learning outcome
The learner will: 4. be able to evaluate the change process in organisations
Assessment criteria
The learner can: 4.1 describe how to **monitor** the implementation of change 4.2 explain the importance of **evaluating** the efficiency and effectiveness of the implementation process 4.3 use **techniques** to evaluate the change process 4.4 recommend **procedures** by which the change process can be continually improved.

Range
Monitor Use of planning tools (eg GANTT charts, critical path analysis, cost benefit analysis, PDCA Cycle) to monitor cost, quality, adherence to change programme, timescales eg how it can be used for continuous improvement **Evaluating** Identifying strengths and weaknesses of change, making comparisons of benefits and limitations, the use of KPI's **Techniques** Learners should be given an understanding of the following techniques before applying them: • identifying the benefits of change through SWOT analysis • force field analysis • measuring against standards, eg KPIs/targets **Procedures** Data analysis techniques, critical success factors, best practice, importance of evaluation

Unit 422 Personal and professional development

Level:	4
UAN:	A/506/9305
GLH:	25
NLH:	100
Assessment method:	Assignment
Aim:	The purpose of this unit is to enable learners to develop an understanding of the different methods and resources available to them for planning their personal and professional development. They will learn how to identify factors that may affect targets or goals, prioritise actions and how feedback from others can be utilised to aid their development and career progression. They will be able to develop a plan which can either be used during progress of a course of study or as a tool for their future or current career path.

Learning outcome
The learner will: 1. understand how to plan for personal and professional development
Assessment criteria
The learner can: 1.1 describe the **benefits** of personal and professional development 1.2 identify **development opportunities** for career and personal progression 1.3 analyse development opportunities that may support career and personal progression.

Range
Benefits personal - update skills, gain new skills, increase motivation, confidence professional - career progression, meeting organisation goals, how role fits into organisation **Development opportunities** • internal and external • skills: interpersonal, enterprise, self-management and leadership

- knowledge: qualifications

Learning outcome
The learner will: 2. understand how people learn
Assessment criteria
The learner can: 2.1 explain the **principles** of how people learn 2.2 describe different **learning styles** 2.3 evaluate **learning resources** to support development 2.4 analyse the use of different **learning strategies**.

Range
Principles relevant theories, methodologies, pedagogies, codes of ethics **Learning styles** General: visual, aural, physical, logical, social, solitary Applications: awareness of personal style eg Kolb, Honey and Mumford theories **Learning resources** libraries; organisation's resources, IT, internet, progress files, portfolio development **Learning strategies** interactions with others, taking responsibility for own development, effective time management, structured reflection, self-directed learning

Learning outcome
The learner will: 3. be able to produce personal and professional development plans
Assessment criteria
The learner can: 3.1 carry out **self-audit** of skills and experience 3.2 identify **targets** for personal and professional development 3.3 use **methods** to track personal development 3.4 create a personal and professional development plan.

Range
Self-audit personal reflections, 360 feedback, skills scan, personal SWOT **Targets** SMART target setting, responding to feedback, realigning targets, addressing strengths and weaknesses **Methods** task manager, blog, project management tools, diaries, performance review/plan, objectives, monitoring, reflecting and planning

Learning outcome
The learner will: 4. be able to make recommendations for personal and professional development
Assessment criteria
The learner can: 4.1 explain the **benefits** of reflective practice 4.2 evaluate **progress** against development plan 4.3 recommend opportunities for further development.

Range
Benefits extent to which targets have been met/not met, recognise any changes in expectations; suggest further support required, identify barriers to progress **Progress** the learner should regularly identify progress against original plan and refine plan accordingly

Unit 423 Managing information and knowledge

Level:	4
UAN:	F/506/9306
GLH:	60
NLH:	150
Assessment method:	Assignment
Aim:	The purpose of this unit is to enable learners to develop an understanding of the relationship between data, information and knowledge, and the contribution, information and knowledge management makes to the success of organisations.

Learning outcome
The learner will: 1. understand the need to manage information and knowledge within organisations
Assessment criteria
The learner can: 1.1 outline the main **features of information management** 1.2 explain the **relationship between data, information and knowledge** 1.3 analyse the concept of **knowledge management** 1.4 analyse the **benefits** information and knowledge management brings to organisations.

Range
Features of information management Database management; compiling reports; success/security **Relationship between data, information and knowledge** Definitions and attributes of data and information, eg Types of data (qualitive and quantative) Data: one off event Information: when data is added to data Knowledge: the ability to use the information **Knowledge Management** Gather; organise; share; analyse **Benefits** Efficient processing of data; positive impact on organisation goals; improved productivity; improved customer service.

Learning outcome
The learner will: 2. understand the role of ICT in managing information and knowledge
Assessment criteria
The learner can: 2.1 outline the **types** and nature of organisational information systems 2.2 explain how information and communication technology (ICT) affects **organisational communication** 2.3 evaluate how ICT can be used to **disseminate knowledge** throughout the organisation.

Range
Types Accounting; financial; human resources; marketing; operational **Organisational communication** Formal and informal, Computer Misuse Act **Disseminate knowledge** Through written reports, networks, intranet, emails, to a wide audience

Learning outcome
The learner will: 3. understand the links between knowledge management strategy and competitive advantage
Assessment criteria
The learner can: 3.1 explain the **role** and importance of knowledge for organisations 3.2 justify the **need for maintaining a learning culture** in a changing environment 3.3 demonstrate how **knowledge management strategies** and processes support and facilitate organisational learning 3.4 evaluate the relationship between **organisational learning** and **competitive advantage**.

Range
Role Organisational culture; organisational knowledge; individual knowledge; wider cultural context **Need for maintaining a learning culture** Improved performance; increased customer satisfaction; committed workforce; ability to deal with change **Knowledge management strategies** In relation to culture; internal/external networks; support/change structures; monitoring **Organisational learning** Peter Senge model of organisational learning

Competitive advantage
Increases profits; less resistance to change

Unit 424 Engineering Procurement

Level:	4
UAN:	T/506/9335
GLH:	60
NLH:	150
Assessment method:	Assignment
Aim:	The purpose of this unit is to enable learners to develop an understanding of procurement for engineering operations.

Learning outcome
The learner will: 1. understand the principles of resource management and its application to an engineering operation
Assessment criteria
The learner can: 1.1 assess the **methods** available for managing materials 1.2 explain the **principles** involved when procuring equipment and the ongoing requirements over the life of that equipment

Range
Methods Selection; acquisition; maintenance; replacement criteria; storage; handling logistics **Principles** Procurement strategy; specification; supplier identification; selection criteria; working with specialist suppliers; stock control; maintenance strategy

Learning outcome
The learner will: 2. understand how the procurement strategy contributes to the achievement of an engineering operation's objectives
Assessment criteria
The learner can: 2.1 recommend procurement **systems and processes** with related performance indicators and benchmarking for an engineering operation 2.2 analyse the **risks** involved in a procurement strategy 2.3 examine the role of the procurement officer within an engineering operation.

Range
Systems and processes Standard specification; tendering; estimating/quoting; methods of procurement (centralised, contract, lease) Pareto analysis; 'just in time' (JIT); services; terms and conditions; risk register **Risks** Financial; physical; task duplication; direct and indirect costs; effect on the internal and external customer (quality assurance and control, legal implications); effect on process and outcome activities of organisations; assessing operational needs; selecting suppliers; timing; company policies; budgetary restrictions (discounts, receipt and control of purchases, wastage factors)

Learning outcome
The learner will: 3. understand the importance of the procurement contract and its application to engineering operations
Assessment criteria
The learner can: 3.1 explain the importance of a procurement contract 3.2 evaluate the **sourcing issues** for a procurement situation using a range of suppliers 3.3 review the **management techniques** used to appraise and evaluate the suppliers of an engineering management operation.

Range
Sourcing issues Method of supply (buying products/services, tendering, subcontracting/ outsourcing); value for money; hygiene factors; choice; service guarantee; legal and contractual compliance; trace origin data; methods of payment; credit and price; volume of product; negotiating skills **Management techniques include review of** Communication; attitude to customers; compliance with procurement specification (cost, size, quantity); sample testing and defect elimination; delivery

Learning outcome
The learner will: 4. understand procurement pricing and management strategies within an engineering organisation
Assessment criteria
The learner can: 4.1 explain the **management strategies** that can be used to maximise the purchasing power of the procurement officer 4.2 compare **pricing management techniques** used in an engineering procurement situation.

Range
Management strategies Competition between suppliers; developing profit margins to increase financial returns; releasing cash and capital by minimising stock; negotiating extended credit; determining the right quality for the right application; negotiating and developing delivery schedules **Pricing management techniques** Negotiating price reductions; controlling or resisting price increases; quantity discounts; prompt payment discounts

Learning outcome
The learner will: 5. be able to review and evaluate procurement strategies within an engineering organisation
Assessment criteria
The learner can: 5.1 plan a **review** and **evaluation** to measure the success of a company's procurement strategy 5.2 conduct a **review** and **evaluation** for a procurement scenario in an engineering operation.

Range
Review Standard specifications; terms and conditions; monitoring; redeveloping strategy; contemporary developments; comparing and contrasting purchasing options **Evaluation** Cost models (return on investment); productivity gain; human resource benefits; value added analysis

Unit 425 Principles of composite materials

Level:	4
UAN:	J/506/9307
GLH:	75
NLH:	150
Assessment method:	Dated written paper
Aim:	The purpose of this unit is to enable learners to develop an understanding of the principles of composite materials. Learners will understand the different structures of composite materials, the fundamentals of polymer chemistry and will look in detail at the materials and techniques used with pre-preg, pre-form materials and in dry fibre moulding. Learners will also gain an understanding of the preparation and assembly methods used for composite components in the manufacture of composite structures.

Learning outcome
The learner will: 1. understand the principles and structure of composite materials
Assessment criteria
The learner can: 1.1 explain different **types** and applications of composite materials 1.2 explain the concept of **reinforcement** embedded within a **matrix** and evaluate the resultant global properties 1.3 describe properties of **reinforcement** 1.4 explain reinforcement **types** and their selection for particular applications 1.5 explain the purpose and concept of **core materials** and their selection for particular applications 1.6 describe the **composition** of commonly used composite matrix materials 1.7 analyse **mechanical properties** of composite materials 1.8 explain the concept and **principles** of laminate characteristics 1.9 describe the **application** of composites 1.10 review the **advantages and disadvantages** of composites 1.11 describe health and safety **requirements** for handling and using composite materials.

Range
Types PMC; MMC; CMC **Reinforcement** Stiffness; strength; materials **Matrix** Mechanical, chemical and adhesive properties **Reinforcement** Glass; carbon; aramid; thermoplastic fibres; ceramic; metal; natural fibres **Types** Uni-directional; Multi-directional; bonded; particulate; stitched; braids; roving; woven **Core materials** Honeycombs; woods; foams; inserts **Composition** Thermosetting polymers; thermoplastic polymer; metal; ceramic; bio-resins **Mechanical properties** Load transfer; rule of mixtures; axial and transverse stiffness; long and short fibres; anisotropic and isotropic strength; creep; wear; toughness; thermal stability; composite classification **Principles** Ply direction; direction of stiffness; rule of mixtures; use of cores **Application** Sector-specific (eg aircraft, automotive, marine, power generation, construction, civil engineering, rail) **Advantages and disadvantages** Material performance; weight; embedded defects; cost; lifespan; degradation; repair; assembly; bespoke properties **Requirements** Bulk storage; ventilation and temperature control of work areas; protection of respiratory system; skin; fire protection; long- and short-term exposure to fibres; solvents and matrix materials

Learning outcome
The learner will: 2. understand elementary polymer chemistry
Assessment criteria
The learner can: 2.1 describe the chemistry of the **main classes of resin systems** 2.2 compare the **properties** of thermoplastics and thermosets 2.3 analyse the **performance** of resin systems in different applications 2.4 evaluate the use of **additive materials** in resin systems 2.5 assess the curing cycle for different resin systems 2.6 explain how composites are recycled or disposed of.

Range
Main classes of resin systems Thermoplastics; thermosets **Properties** Physical; chemical **Performance** eg strength; corrosion resistance; UV resistance; toughness **Additive 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-forms) materials
Assessment criteria
The learner can: 3.1 explain the **benefits** of pre-combined materials 3.2 describe **pre-preg materials** and their use 3.3 describe **pre-form materials** and their use 3.4 explain **storage requirements** for **pre-preg materials** 3.5 explain laminate **preparation** and efficient use of consumables 3.6 explain **techniques** for manufacturing components from **pre-preg materials**.

Range
Benefits Quality control; productivity; cost effective **Pre-preg materials** Woven; uni-directional; B-stage material; filler **Pre-form materials** eg 3D; cloths **Storage requirements** Refrigeration; humidity control **Preparation** Nesting; cutting; knitting; bagging materials; release films **Techniques** Manual (use of heat and pressure; autoclave, out of autoclave; vacuum bag); automated (automatic tape laying)

Learning outcome
The learner will: 4. understand preparation and assembly methods for composite components in the manufacture of composite structures
Assessment criteria
The learner can: 4.1 describe **adhesive and bonding agents** and their application in composite structures 4.2 describe **mechanical fastening methods and fittings** used for composite structures 4.3 evaluate the effectiveness of mechanical and chemical techniques in composite structures for different **applications** 4.4 explain the importance of correct surface preparation, sealing and curing.

Range
Adhesive and bonding agents Jigs; fixtures **Mechanical fastening methods and fittings** Shims; bolts **Application** Sector-specific (eg aircraft, automotive, marine, power generation, construction, civil engineering, rail)

Unit 426 Principles of composites manufacture

Level:	4
UAN:	L/506/9308
GLH:	60
NLH:	150
Assessment method:	Dated written paper
Aim:	The purpose of this unit is to enable learners to develop an understanding of the principles of composites manufacture. Learners will understand the different manufacturing processes used for thermoplastics and thermosets, implications of manufacturing processes on design for manufacture, types and sources of defects, different applications of NDT methods and the process and quality systems required for composite component and structure manufacture.

Learning outcome
The learner will: 1. understand the manufacturing processes used for composite components and structures
Assessment criteria
The learner can: 1.1 describe the **range of processes** used in the manufacture of thermoset composite materials 1.2 describe the **range of processes** used in the manufacture of thermoplastic composite materials 1.3 research the **selection criteria** for use of manufacturing processes.

Range
Range of processes used to manufacture thermoset composite materials Hand layup; resin infusion systems; resin transfer; filament winding; pultrusion; automated tape and fibre placement; hot press **Range of processes used to manufacture thermoplastic composite materials** Hot pressing; RTM; compression moulding; pultrusion; auto-clave; rotational moulding

Selection criteria
Cost; application; raw materials required; skill of labour force; quality assurance; defect tolerance; repeatability

Learning outcome
The learner will: 2. understand the implications of manufacturing processes on design for manufacture
Assessment criteria
The learner can: 2.1 investigate how manufacturing processes influence the **design for manufacture** of composite components and structures

Range
Design for manufacture Shape; thickness; process sequence; assembly; bonding; surface finish; material selection; quality control

Learning outcome
The learner will: 3. understand types and sources of manufacture defects of composite components and structures
Assessment criteria
The learner can: 3.1 identify different **types** of manufacturing defects 3.2 explain **sources** of manufacture defects 3.3 analyse the **effects** of different types of manufacturing defects on component and structures fitness for purpose.

Range
Types eg cavities/voids; wrinkling; porosity; de-lamination; bridging; debonds; pre-release **Sources** eg contamination and cleanliness; incorrect process control; environmental; equipment failure; manufacturing damage **Effects** eg unsatisfactory properties; cost; rework; delivery; service life; premature failure

Learning outcome
The learner will: 4. understand Non-Destructive Testing (NDT) methods of testing
Assessment criteria
The learner can: 4.1 explain the principles of **NDT methods** 4.2 review **types**, functions and limitations of NDT systems 4.3 review the **selection criteria** of NDT type to suit manufacture processes and materials.

Range
NDT methods Visual; physical; penetrative **Types** Tap test; visual surface; dye penetrant; thermography; x-ray; ultrasonic **Selection criteria** eg costs; accuracy; repeatability; skill level available; effectiveness

Learning outcome
The learner will: 5. understand process and quality systems required for composite component and structure manufacture
Assessment criteria
The learner can: 5.1 analyse the need for materials' **life control and correct storage** of raw materials and finished product 5.2 analyse the need for **environmental controls** in composite manufacture and storage 5.3 explain the process of defect management and concessions (lower tolerance) for composite materials.

Range
Life control and correct storage Refrigeration, Material Safety Data Sheets; shelf life of materials; inhibitors **Environmental controls** Room ventilation; push-pull ventilation; on-tool air extraction; personal protective equipment

Unit 427 Developing business improvement plans

Level:	4
UAN:	K/506/9333
GLH:	35
NLH:	100
Assessment method:	Assignment
Aim:	The purpose of this unit is to provide learners with the knowledge and understanding to be able to develop business plans to implement improvements in the workplace and communicate it appropriately to others.

Learning outcome
The learner will: 1. understand the need for business improvement within organisations
Assessment criteria
The learner can: 1.1 explain the application of **performance measures** used in business analysis 1.2 explain the application of **processing measures** used in organisations 1.3 explain types of **tools** used to improve business performance 1.4 explain how to **apply diagnostic tools** 1.5 explain the **benefits** of lean programmes to organisations.

Range
Performance measures Cost; OEE; manning; material savings; balanced scorecard **Processing measures** Flow; takt time; pitch time **Tools** Kaizen; 5S/5C analysis; visual management; VSM; TPM; SMED; SOPs; six sigma; line balancing; lead time analysis; process flow analysis **Apply diagnostic tools** Manual; electronic; verbal **Benefits** Cost; quality; productivity; efficiency; effectiveness

Learning outcome
The learner will: 2. be able to create training plans to identify work place requirements prior to the implementation of the improvement plan
Assessment criteria
The learner can: 2.1 outline improvement plan **objectives** 2.2 explain the **terms of reference** of improvement plans 2.3 explain individual **roles** that will be responsible for improvement activities 2.4 assess **skill and knowledge gaps** in individuals who will be responsible for improvement activities 2.5 produce training plans to address skill gaps of individuals responsible for improvement activities.

Range
Objectives Short term; medium term; long term **Terms of reference** Scope; requirements; constraints **Roles** Colleagues; subordinates; line manager; department heads; managing director; chief executive **Skill and knowledge gaps** Skills matrix; diagnostics; skill scans, consultation with affected people

Learning outcome
The learner will: 3. be able to produce business improvement plans
Assessment criteria
The learner can: 3.1 identify **resources** required for improvement activities 3.2 predict **time scales** for completion of improvement activities 3.3 **communicate** role responsibilities for improvement activities including required actions 3.4 evaluate the impact of improvement activities on organisational performance 3.5 identify **performance measures** to be used 3.6 state review dates for improvement activities.

Range
Resources Physical; HR; financial **Time scales** Short-term; medium term; long term **Communicate** eg verbal; non-verbal; formal; informal; electronic, importance of consultation process **Performance measures**

Vision; objectives; stakeholders; financial and quality; cost benefit analysis

Learning outcome
The learner will: 4. be able to communicate business improvement plans to stakeholders
Assessment criteria
The learner can: 4.1 explain who should be involved/consulted with at each stage of the plan 4.2 communicate potential changes to focus areas 4.3 explain how improvement and training plans will be communicated to the organisation 4.4 present results of planning activities to business stakeholders

Unit 428 Electrical principles for mechanical engineering

Level:	4
UAN:	Y/506/9313
GLH:	108
NLH:	150
Assessment method:	Dated written paper
Aim:	The purpose of this unit is to enable mechanical engineering learners to understand the principles of electrical engineering that are most commonly required by mechanical engineers. Through this unit, learners will develop their understanding of the theory of electrical machines and associated control methods. Learners will apply the understanding they develop to solve related engineering problems.

Learning outcome
the learner will: 1. understand the properties of dc circuits.
assessment criteria
the learner can: 1.1 explain the relationship between basic electrical **units** in dc circuits 1.2 calculate the values of units in dc circuits using Ohm's law 1.3 explain overall values of series and parallel resistance 1.4 calculate the values of potential differences and currents in circuits with various **connections of resistance**. 1.5 explain the relationship of power to voltage, current and resistance in dc circuits 1.6 calculate the value of power in a dc circuit 1.7 explain the relationship between power and energy in dc circuits. 1.8 calculate running **costs**.

Range
Units Voltage, current, resistance. **Connections of resistance** Series, parallel, series and parallel **Costs** £ per kWh

Learning outcome
the learner will: 2. understand electrostatics
assessment criteria
the learner can: 2.1 describe the construction of **types** of capacitor 2.2 explain **terms** associated with electrostatics 2.3 calculate electric flux, electric flux density and electric field strength 2.4 explain the effects of connecting capacitors in different **combinations** 2.5 carry out calculations involving capacitors connected in parallel and series **combinations**.

Range
Types Air dielectric, mica dielectric, paper dielectric, ceramic dielectric, plastic dielectric, aluminium oxide and tantalum oxide. **Terms** Electric field, electric flux, electric flux density, electric field strength, permittivity (relative and absolute) **Combinations** Series, parallel, series-parallel

Learning outcome
the learner will: 3. understand the properties of ac circuits
assessment criteria
the learner can: 3.1 explain how resistance, capacitance and inductance changes the **relationships** of voltage and current in ac circuits 3.2 explain the term power factor in ac circuits 3.3 explain the **effects** of a low power factor in an ac circuit 3.4 explain the relationship between kW, kVa, kVAr and power factor in ac circuits 3.5 calculate power factor in ac circuits 3.6 explain **methods** of improving power factor 3.7 calculate the rating of a capacitor required to improve a lagging power factor.

Range
Relationships In phase, leading current, lagging current **Effects** Increase in current, increase in power losses, poor voltage regulation, lower transmission efficiency, increased transmission costs **Methods** Capacitors, synchronous motors

Learning outcome
The learner will: 4. understand transformers
Assessment criteria
The learner can: 4.1 explain the relationship between common electromagnetic **units of measurement** 4.2 explain the changes in **magnetic properties** of a soft iron core undergoing cyclic magnetisation 4.3 explain the operation of a single phase transformer 4.4 explain the relationships between **ratios** in a transformer 4.5 explain where the principal **losses** occur within power transformers 4.6 explain how the losses in a power transformer can be minimized 4.7 describe the construction of a five limb core three-phase power transformer 4.8 explain the principle and operation of **tap changers** 4.9 calculate the efficiency of a transformer 4.10 calculate the no load power factor of a transformer.

Range
Units of measurement Magnetomotive force (m.m.f); Magnetic field strength; flux density; total flux; reluctance **Magnetic properties** Coercivity; remanence; saturation; permeability **Ratios** Turns ratio, voltage ratio, current ratio **Losses** Iron losses, copper losses, heating effect of a current, hysteresis losses, eddy currents, leakage flux **Tap changers** On load, off load

Learning outcome
The learner will: 5. understand the principles of dc machines
Assessment criteria
The learner can: 5.1 explain the function of **components** in dc motors 5.2 explain the effects of armature reaction 5.3 explain how the **winding arrangement** affects the applications of a dc motor 5.4 represent the **characteristic curves** of the different **types of dc motors** in a diagram 5.5 evaluate the **relative characteristics** of different types of dc motors 5.6 calculate the performance of dc motor from parameters.

Range
Components Stator, fan, armature, commutator, stator windings, laminated pole pieces, brush holders, brushes, terminals **Winding arrangement** Lap, wave **Characteristic curves** Speed, torque **Types of dc motors** Shunt, series, compound **Relative characteristics** Starting torque, speed, speed control

Learning outcome
The learner will: 6. understand the principles of three-phase induction motors
Assessment criteria
The learner can: 6.1 evaluate the **relative characteristics** of different **types of three-phase motors** 6.2 explain the relationship between torque and slip of three-phase induction motors 6.3 explain the ability of the three-phase induction motor to be self starting 6.4 explain how a change of rotational direction of a three-phase induction motor is achieved 6.5 explain **terms** associated with machine **ratings** 6.6 calculate the rating of a motor for intermittent operation 6.7 calculate speed, slip and torque of motors.

Range
Characteristics Compactness, robustness, simplicity, cost **Types of three-phase motors** Squirrel cage, wound rotor **Terms and ratings** Continuous rating, intermittent rating

Learning outcome
The learner will: 7. understand the principles of three-phase synchronous motors
Assessment criteria
The learner can: 7.1 explain the operating principles of three-phase synchronous induction motors for different rotor types 7.2 explain how torque is produced in three-phase synchronous induction motors 7.3 explain the function of **components** of three-phase wound rotor synchronous induction motors 7.4 explain the **construction** and **operation** of three-phase synchronous induction motors

Range
Components Slip rings, brushes, start resistance **Construction** Embedded squirrel-cage winding. **Operation** Starting, running

Learning outcome
The learner will: 8. understand the principles of controlling large industrial electric motors
Assessment criteria
The learner can: 8.1 assess **attributes** of different types of **motor starters** for three-phase squirrel cage induction motors 8.2 explain the operating principle of the Silicon Controlled Rectifier (SCR) 8.3 explain how precise speed control of a dc motor can be achieved using an SCR and a suitable feedback signal 8.4 explain how speed control of a three-phase induction motor can be achieved using a variable frequency drive 8.5 explain **effects** of solid state speed control systems on different **types of motors**

Range
Motor starters Direct online, star delta, auto-transformer, rotor resistance, **Attributes** Reliability, robustness, cost, starting current, simplicity **Effects** Energy consumption, reliability, maintenance costs, accuracy of speed control **Types of motors** dc, ac

Unit 428 Electrical principles for mechanical engineering

Supporting information

Guidance

The learner will need the following underpinning knowledge:
Lenz's Law, Faradays Laws, Fleming's rules, mutual induction, self induction, frequency, sine waves, amplitude, root mean square values, peak-to-peak values, basic semiconductor theory of a pn junction.

Unit 429 Principles of mechanical engineering

Level:	4
UAN:	R/506/9312
GLH:	58
NLH:	100
Assessment method:	Dated written paper
Aim:	The unit enables learners to understand the effects of loads and forces acting in or on various components. Learners will be able to acquire knowledge of the effects of stress and strain on beams, shafts and other systems and how these are contained. Learners will need an appreciation of mathematics at level 3 to benefit from this unit.

Note

This unit may be supported by the provision of laboratory equipment to enable learners to conduct experiments to explore the effects of tension, torsion and bending when applied to mechanical components.

Learning outcome
The learner will: 1. understand the application of static theory to structures
Assessment criteria
The learner can: 1.1 explain the general **conditions** of static equilibrium 1.2 construct free body diagrams of components in equilibrium 1.3 evaluate the forces required to keep a **body** in equilibrium 1.4 use Bow's notation to determine the forces in **loaded** pin jointed **frameworks** 1.5 **calculate** the forces in selected members of a framework 1.6 determine **loading** at various points on a **beam** 1.7 calculate the second moment of area for **beam cross sections** 1.8 use bending theory to find solutions to **problems** relating to beams.

Range
Conditions $\sum F_v = 0, \sum F_H = 0,$ $\sum M = 0$ **Body** Two dimensional, three dimensional **Loaded** Vertical, horizontal, inclined, point, uniformly distributed, combination of point and uniformly distributed **Frameworks** Simply supported, cantilever **Calculate** Using the method of sections **Loading** Shear force, bending moments **Beam** Simply supported, cantilever **Beam cross sections** Rectangular, I simple and complex, T, circular **Problems** Maximum stress, maximum load, beam dimensions, radius of curvature

Learning outcome
The learner will: 2. understand the effects of loading components under various loads and conditions
Assessment criteria
The learner can: 2.1 calculate stress and strain in components under various **conditions** 2.2 calculate **stresses** in **pressure vessels** 2.3 explain the effect of different **factors** on the thickness of materials required for pressure vessel design 2.4 explain the application of strain energy to **loading** 2.5 solve problems involving the stress produced by **loading** 2.6 calculate the polar moment of inertia of **shafts** 2.7 use the torsion equation to solve **problems**.

Range
Conditions Different diameters, materials, compound bars, thermal strain **Stresses** Hoop, axial, tangential **Pressure vessels** Thin walled cylindrical, spherical

Factors
Joint efficiency, factor of safety, type of fluids and gases, application of pressure vessel standards
Loading
Impact, suddenly applied
Shafts
Solid, hollow
Problems
Transmission of power, sizing of shafts

Learning outcome
The learner will: 3. understand the principles of kinematics
Assessment criteria
The learner can: 3.1 explain **kinematic motions** 3.2 solve **problems** using velocity diagrams.

Range
Kinematic motions Translation; rotation; general motion; relative motion **Problems** Involving the relative velocities of two unconnected bodies, involving mechanisms (slider and crank, four bar link)

Learning outcome
The learner will: 4. understand dynamic principles of systems under the action of forces
Assessment criteria
The learner can: 4.1 explain the application of the conservation of momentum to **collisions** 4.2 solve problems of **dynamics** of **simple systems** 4.3 evaluate the moment of inertia of a body about an axis of rotation 4.4 solve **problems** of rotation 4.5 apply the angle of friction to motion on **inclined planes** 4.6 solve problems involving motion on **inclined planes**.

Range
Collisions Elastic, inelastic **Dynamics** Momentum, impulse, Newton's laws of motion, acceleration **Simple systems** Vehicles, material handling equipment, pile drivers

Problems
Involving driving and frictional torque, angular momentum, rotational energy
Inclined planes
Screw jacks and similar devices operated by a square thread, moving loads on a plane

Unit 430 Engineering fluid mechanics and thermodynamics

Level:	4
UAN:	D/506/9314
GLH:	43
NLH:	100
Assessment method:	Assignment
Aim:	The unit presents the engineering science topics of fluid mechanics and thermodynamics. It aims to develop knowledge and skills in these topics to support the analysis of problems in fluid flow and energy transfer systems. On successful completion learners will be able to: • apply principles of fluid mechanics to solve engineering problems • apply the laws of thermodynamics to solve engineering problems • solve practical steady-state engineering problems

Learning outcome
The learner will: 1. understand the principles of fluid mechanics
Assessment criteria
The learner can: 1.1 evaluate **hydrostatic forces** in a stationary fluid 1.2 evaluate the stability of floating bodies under **different conditions** 1.3 evaluate the steady flow of an ideal fluid 1.4 evaluate the **effects** of fluid viscosity on the steady flow of a fluid.

Range
Hydrostatic forces Hydrostatic pressure; pressure measurement; hydrostatic forces on submerged surfaces; centre of pressure **Different conditions** Density of fluid, density of the body, shape of the body

Effects
Viscous forces; laminar and turbulent flows; Reynolds number; flow-rate, temperature
Learning outcome
The learner will: 2. understand the use of thermodynamics laws in engineering applications
Assessment criteria
The learner can: 2.1 explain the **thermodynamic concepts** 2.2 evaluate **energy transfers** in engineering systems 2.3 evaluate **applications** of the first law of thermodynamics to engineering systems 2.4 evaluate the thermodynamic properties of a pure substance 2.5 evaluate **thermodynamic processes** involving pure substances 2.6 explain the importance of the second law of thermodynamics in engineering process analysis 2.7 evaluate changes of entropy in reversible and irreversible **thermodynamic processes**.

Range
Thermodynamic concepts system; control volume; states; reversible and irreversible processes; cycles; temperature equilibrium, conservation of energy **Energy transfers** work transfer; work done at a moving boundary; work done in a cycle of processes; heat transfer **Applications** a thermodynamic cycle; a closed system in a non-cyclic process; a control volume in a steady-state steady-flow process **Thermodynamic processes** constant pressure; constant volume; isothermal; adiabatic; polytropic.

Learning outcome
The learner will: 3. be able to solve practical, steady-state engineering problems
Assessment criteria
The learner can: 3.1 apply fluid mechanics to the solution of **steady-state flow processes** 3.2 apply the laws of thermodynamics to practical **steady state thermodynamic processes**.

Range
Steady-state flow processes fluid flow measurement; pipe and duct flows; simple fluid-pumping systems; oil-spill containment; flood control; stabilisation of floating vessels

Steady state thermodynamic processes

simple steam and gas power processes, heating and cooling of gases and vapours in closed vessels, measurement of compressible fluid flows

Guidance

This unit will be supported by the provision of laboratory equipment to enable learners to evaluate steady incompressible flow in a pipe and steady compressible flow in a nozzle to verify theoretical predictions.

LO1: ensure learners understand the principles of fluids.

Candidates need to learn the underlying principles and concepts in order to meet the assessment criteria using sources from thermodynamic property tables, properties of a perfect gas.

Unit 431 Principles of mechanical component manufacture

Level:	4
UAN:	K/506/9316
GLH:	52
NLH:	150
Assessment method:	Dated written paper
Aim:	The purpose of this unit is to enable learners to develop an understanding of a wide range of manufacturing methods for metallic and non-metallic mechanical components. Learners will be able to analyse the manufacturing requirements of mechanical components, compare and select from different manufacturing methods, determine suitable finishing processes for varying component specifications, and identify the requirements for, and methods of, component inspection.

Learning outcome
The learner will: 1. understand the modern manufacturing environment
Assessment criteria
The learner can: 1.1 explain **factors** that have influenced the development of modern manufacturing systems 1.2 evaluate the different ways of organising the **manufacturing process for discrete mechanical products**

Range
Factors Increased product diversity; greatly reduced product life cycles; changing balance of costs for materials; labour and overheads; availability of increasing range of manufacturing technologies; demands for flexibility of manufacturing systems **Process organisation for discrete manufacturing** Job shop production; batch production; mass production; characteristics of process organisation (production volumes, required labour skills, specialised/customised equipment and tooling)

Learning outcome
The learner will: 2. understand manufacturing requirements of mechanical engineering products
Assessment criteria
The learner can: 2.1 describe **sources of data used** to **interpret** the specification details for mechanical engineering products 2.2 evaluate the **manufacturing requirements** for products.

Range
Sources of data Product representation in a CAD system; graphical; drawing; geometric and product model data **Interpretation of data using:** Engineering drawings; bill of materials; reference sources of information on materials; dimensional standards (wire and sheet metal gauges, screw threads, bolt and nut sizes, tubes and fitting sizes); technical safety standards; quality standards (Industry/National specific) **Manufacturing requirements** Parts required; materials; overall dimensions; accuracy requirements; types of surface finish required and other treatments; need for special jigs and/or fixtures; quantities to be manufactured; manufacturing methods available; manufacturing lead times; decisions to make or buy particular parts; estimate of the cost of manufacture; in-house/external

Learning outcome
The learner will: 3. understand methods of mechanical engineering manufacture
Assessment criteria
The learner can: 3.1 describe manufacturing **processing methods** for metal and plastic parts 3.2 evaluate **methods of casting** mechanical components 3.3 evaluate **methods of forming** mechanical components 3.4 assess **latest developments** of mechanical engineering manufacture 3.5 evaluate **methods of moulding** plastic components 3.6 evaluate **machining processes** for mechanical components 3.7 evaluate **specialty machining processes** available for mechanical component manufacture 3.8 evaluate **methods for joining** mechanical components.

Range
Processing methods Casting; extrusion; forming; moulding; cutting and joining **Methods of casting** Die casting (both low and high pressure); investment casting (lost wax process); centrifugal casting; sand casting (sand bonded with chemicals or clay and water or oil); shell casting; spin casting **Methods of forming** Cold sizing; extrusion; drawing (including deep drawing); forging; hydroforming; roll forming; powder metallurgy **Latest developments** Rapid prototyping; 3-D printing **Methods of moulding polymers** Polymerisation; thermoplastic and thermosetting polymers; injection moulding; extrusion moulding; compression moulding; roto-moulding **Machining processes** Turning; milling; drilling; grinding; broaching; use of cutting fluid or coolant, CNC machining **Specialty machining processes** Ultrasonic machining; high pressure water jet cutting; abrasive water jet cutting and abrasive jet machining; spark erosion; laser **Methods for joining** Welding (oxy-fuel, MIG/MAG, TIG/TAG, MMA); brazing; soldering and adhesive bonding

Learning outcome
The learner will: 4. understand finishing treatments for manufactured parts
Assessment criteria
The learner can: 4.1 explain how **heat treatment processes** improve mechanical performance 4.2 evaluate **processes** required to produce smooth regular surfaces 4.3 explain **surface treatment processes** used to improve resistance to wear 4.4 explain **surface treatment processes** used to improve resistance to corrosion

Range
Heat treatment processes Annealing; precipitation strengthening; hardening/quenching, and tempering; normalising **Processes** Grinding; lapping; honing; super finishing **Surface treatment processes to improve resistance to wear** Nitriding; case hardening; hard chrome finish **Surface treatment processes to improve resistance to corrosion** Galvanising; anodising; tin plating; sherardizing; electroplating

Learning outcome
The learner will: 5. understand the requirements for product inspection
Assessment criteria
The learner can: 5.1 outline the purpose of inspecting mechanical products 5.2 explain **methods** available for inspecting mechanical products

Range
Methods Select suitable inspection equipment and methods (manual or computer-controlled measuring systems); determine the need for any special test or inspection equipment (gauges, test rigs); ensure that all inspection equipment has been properly calibrated; establish conditions and procedures for either re-working or rejecting products that do not meet the design specification

Unit 432 Materials Engineering

Level:	4
UAN:	M/506/9317
GLH:	60
NLH:	150
Assessment method:	Dated written paper
Aim:	The purpose of this unit is to enable learners to develop an understanding of the properties, selection criteria, relationships between processes and behaviour, and causes of failure of engineering materials.

Learning outcome
The learner will: 1. be able to determine the properties and selection criteria of materials from tests and data sources
Assessment criteria
The learner can: 1.1 detail the appropriate properties and **criteria for the selection** of a metallic, ceramic, polymer and composite material 1.2 explain the particular characteristics related to the microstructure and macroscopic behaviour of the four **categories of engineering materials** 1.3 generate and process **test data** to assess material properties for two categories of material 1.4 investigate and assess the quality of suitable data from three different **sources**.

Range
Criteria for selection Characteristics (mechanical and physical properties, stress-strain charts, load-extension charts) **Categories of engineering materials** Metals; ceramics; polymers; composites **Test data** Electrical conductivity/resistivity; magnetic susceptibility; mechanical strength; hardness; toughness; fatigue and creep resistance; corrosion and reactivity; wear resistance; optical and thermal properties; formability; appropriate statistical methods; processing of test data

Sources

British Standards; ISO; product data sheets; IT sources; manufacturers' literature; job-specific information (specifications, test data and engineering drawings)

Learning outcome

The learner will:

2. understand the relationships between manufacturing processes and material behaviour

Assessment criteria

The learner can:

2.1 explain how one **heat treatment process** and two **other treatment processes** effect the structure properties and behaviour of the parent material

2.2 explain how one **liquid processing** method and two **mechanical processing** methods affect the structure, properties and behaviour of the parent material

2.3 investigate how the **composition and structure** of metal alloys, polymers and polymer matrix composites, influences the properties of the parent material.

Range

Heat treatment processes

Heat treatments (quench and precipitation hardening processes); complex heat treatments (conjoint mechanical/thermal treatments, glass transitions)

Other treatment processes

Coated materials; chip technology; surface treatments/surface engineering; polymer treatments; composites/powder produced materials; matrix / reinforcement relationships; dispersion strengthening

Liquid processing

Metal casting and injection moulding/extrusion of polymers

Mechanical processing

Mechanical working of metals; powder processing of metals and ceramics; extrusion and forming of polymer sheet; welding; use of adhesives

Composition and structure

Alloying; co-polymerisation; additives; cross-linking; crystallinity; lattice structure; slip planes

Learning outcome
The learner will: 3. be able to select suitable materials and processing methods for a specific product
Assessment criteria
The learner can: 3.1 analyse the function/s of a product in terms of the materials' **constraints** on its **design** 3.2 identify the required **properties** for the product and select the most appropriate materials and processing methods 3.3 identify and explain the possible **limitations** on the product imposed by the processing and by the need to safeguard the environment and minimise costs.

Range
Design constraints Working conditions; environment; electrical/magnetic requirements; shape; form and function of the product **Properties** Merit index/index of suitability; ability to be recycled **Processing limitations** Effects of the manufacturing processing capabilities on the structure of materials; preventing or facilitating product design; effect on environment (sustainability, emissions, energy conservation, disposal)

Learning outcome
The learner will: 4. understand the in-service causes of failure of engineering materials
Assessment criteria
The learner can: 4.1 explain the common **causes of in-service failure** for products or structures produced from each or a combination of the four categories of engineering materials 4.2 for one product or material structure, identify and explain the in-service conditions that may contribute to **early failure** 4.3 explain the **methods** for investigating materials failure and for estimating product service life, when a product is subject to creep and fatigue loading 4.4 determine and make recommendations for remedial/preventive measures for a given product or materials structure, that will help **improve** its **service life**.

Range
Causes of in-service failure Creep; fatigue; impact; overstressing; corrosion; temperature; thermal cycling; residual stresses; stress relaxation; degradation (composition change, aging); radiation; electrical; breakdown **Methods** Simulation; experimentation; research data **Early failure** Inappropriate maintenance; inappropriate use; faults in manufacture; material selection and design faults; changes in service conditions such as environment; loading and temperature **Improving service life** Changes to material; product design; protective systems for corrosion and degradation; adjustment loading and working temperature; preventative maintenance

Unit 433 Automated machining of materials

Level:	4
UAN:	A/506/9319
GLH:	40
NLH:	100
Assessment method:	Assignment
Aim:	The purpose of this unit is to enable learners to develop an understanding of modern machining systems, the importance of information links between CAD product data and manufacturing data, the role of process planning in manufacturing and the types of process planning available. On successful completion of this unit, learners will be able to prepare part-programs for a CNC machine, set up a CNC machine to safely machine a part, test and prove a new part-program and, if necessary, edit the program, and produce the part on a CNC machine.

Learning outcome
The learner will: 1. understand the use of automation in modern machining systems
Assessment criteria
The learner can: 1.1 explain the **development of modern machining** systems from stand-alone machines to flexible manufacturing systems 1.2 evaluate the **principal features** of flexible manufacturing systems

Range
Development of modern machining systems The influence of customer demands for quality and variability of products on manufacturing requirements; types of manufacturing facility (NC/CNC stand-alone machine; machining centre; manufacturing cell; flexible manufacturing system (FMS); batch flow line; transfer line; flexibility; productivity and quality control in the different types of facility) **Principal features** Flow line production principle; unique identification of parts and tools; automation of material transportation and handling; limitation on

number of manufacturing tools through standardisation of pallets; fixtures and cutting tools/cutters; clear division of work between machine stations; automatic testing/inspection after each manufacturing process. Flexibility is achieved through being able to accommodate short product life cycles, fast response to changing markets and efficient manufacture of small batch sizes

Learning outcome
The learner will: 2. understand the information links between CAD and manufacturing systems
Assessment criteria
The learner can: 2.1 explain the **relationships** between CAD product data and manufacturing data.

Range
Relationship The importance of having a single source of product data; representation in a CAD system of products to be manufactured; the product database; (graphical data, drawing data, geometric data, product model data), product design and analysis; 3-D product models; rapid prototyping of components; engineering part drawings; detailed engineering drawings; bill of materials

Learning outcome
The learner will: 3. understand process planning for manufacture
Assessment criteria
The learner can: 3.1 explain the **role of process planning** in part manufacture 3.2 evaluate the different **types** of manufacturing process planning.

Range
Process planning Aims to produce finished parts that meet the product design requirements in terms of functionality, surface finish, quality, tolerances, hardness, life expectancy and processing costs. Planning requires selection of part material; processing machine(s); routing between machines; machining operations and their sequencing; selection of cutting tools/cutters; determining setup requirements; calculation of cutting parameters; tool path planning; generation of CNC part programs; design of jigs/fixtures **Types** Experienced; manual planners or by computer-aided process planning (CAPP) software

Learning outcome
The learner will: 4. know how to produce CNC part-programs
Assessment criteria
The learner can: 4.1 describe **program terminology** used to produce CNC part-programs 4.2 explain the **preparation** and **content** of typical CNC part-programs 4.3 explain the **issues** that need to be addressed when creating CNC part-programs.

Range
Program terminology Character; word; block; modal and non-modal functions; types of program format; fixed sequence/block; word address; storage and retrieval of prepared programs; canned cycles; program loops; macros and subroutines **Preparation** Processed by a computer to produce machine-independent cutter location data; then by a post-processor that adapts this data for the particular machine controller to be used **Content** Sequence of instructions for machining a part that contains header data; geometric and technical definitions; operation execution instructions and a program end statement **Issues** Assembly of part-program data (identification of datum position, geometric and technical data from engineering part drawings); programming codes (G and M codes, sequence of operations, cutting tool specifications, spindle speeds and feed rates, coolant control, cutter diameter compensation, tool length offset values, canned cycles); program specification (choice of safe tool paths to ensure operator safety and avoid collisions, safe tool changing positions, tool path simulation, cutter diameter compensation for milling operations, assigned canned cycles, user-defined canned cycles, translation and transformation commands for mirror imaging, rotation, scaling and datum offset); choice of speeds and feeds (spindle speed, use of manufacturers feed rate data allowing for type of cutting operation, surface finish requirements, cutting tool geometry, part/tool material combinations, delicacy of part and part clamping method)

Learning outcome
The learner will: 5. be able to produce parts using CNC machines
Assessment criteria
The learner can: 5.1 describe essential **safety features** needed when setting and operating CNC machines 5.2 describe the **main steps** to take when testing/proving part-programs 5.3 describe **tooling systems** used in CNC machining 5.4 produce **simple CNC part-programs** 5.5 explain the functions and features available in **part-holding and setting devices** used with CNC machines.

Range
Essential features Identify precautions that need to be taken to prevent accidents when setting and operating CNC machines; be familiar with the location and function of emergency stop and program stop controls; check that guards; interlocking devices and fail safe mechanisms are operating correctly **Main steps** Set work datum and tool length offset values; perform a trial run of the part-program to identify unwanted rapid tool movements; reduce unnecessary tool movements; make adjustments to speeds and feeds or compensate for errors; look for potential hazards; tool collisions; swarf/chips problems; rapid movement of machine parts and tooling; entrapment; avoidance using machine over-ride controls; edit the part-program if changes are required during the trial run **Tooling systems** Preset; qualified and semi-qualified tools; tool libraries; tool identification; geometry; offset values; speed; feed and tool life data; devices for monitoring tool life and cutting conditions; tool breakage detection; tool offset measurements **Simple CNC program** Use programming codes and sequence of operations to define a program; test the program with tool path simulation; implement on a CNC machine; run program; evaluate performance **Part-holding and setting devices** Conventional part-holding devices modified to suit CNC operation; positioning part datum relative to machine datum; the need for zero shift controls and how they are used; use of air and hydraulic part-holding devices for gripping delicate components; methods for accurately setting part-holding devices relative to machine slide movements

Unit 433 Automated machining of materials

Supporting information

Guidance

This unit requires that candidates are given access to a CNC machining centre to support the practical application of CNC programming and enable learners to develop, edit and implement a CNC program for automated production of a part.

Unit 434 Industrial robotics

Level:	4
UAN:	M/506/9320
GLH:	35
NLH:	100
Assessment method:	Assignment
Aim:	The purpose of this unit is to enable learners to develop an understanding of the reasons for using robots in manufacturing and gain knowledge of the many application areas in which robots are already used. They will have knowledge of the classification and geometrical and kinematic configurations of robot arms, their accuracy and repeatability and the types of computer-based control systems used. Also, they will gain knowledge of the tooling (robot end effectors) needed for robots to carry out manufacturing tasks. Robot programming methods will be introduced in the unit and learners will have the opportunity to create and test their robot programs.

Learning outcome
The learner will: 1. understand the developing trends for using robots in engineering manufacture
Assessment criteria
The learner can: 1.1 explain the **advantages** of using robots for manufacturing tasks 1.2 describe common **application areas** for robots

Range
Advantages Remove humans from hazardous areas; repetitive; boring tasks; lifting heavy loads; decrease labour costs; increase precision and productivity; provide more flexibility than specialised machines; consistency of performance **Application areas** Materials handling (palletising); machine loading and unloading; welding (spot and MIG welding); spray painting; assembly

Learning outcome
The learner will: 2. understand robot arm configurations and their classifications
Assessment criteria
The learner can: 2.1 explain the **principal features** of robot arms 2.2 explain the **accuracy and the repeatability** of robot arms 2.3 evaluate the **kinematics** of arm configurations 2.4 evaluate the **dynamics of robots** 2.5 evaluate the **types of control** of robots 2.6 describe **types** and **characteristics** of robot end effectors.

Range
Principal features Number of arm axes (degrees of freedom); number of wrist axes(yaw, pitch, roll); working envelope; joint types (revolute R, prismatic P); arm configurations (articulated-RRR, spherical-RRP, SCARA-RRP, cylindrical-RPP, Cartesian-PPP); payload; power sources (hydraulic, electric motors, pneumatic) **Accuracy and the repeatability** As specified in ISO 9283 **Kinematics** Forward and inverse kinematic calculations on a two-link plan arm mechanism to illustrate arm position and velocity control calculations; singularities **Dynamics of robots** Characteristics of robot arms; sensors and sensor interfaces for communication with other machines **Types of control** Non-servo (open loop) with mechanical stops; servo point-to-point (discrete position control); continuous path control (motion and orientation along path is controlled) **Types** Gripper (for material transfer); electromechanical or pneumatic; vacuum Operation; welding gun (MIG-welder, spot-welder); paint spray gun; grinding and de- burring tools **Characteristics** Tools may have sensors fitted to aid locating, handling and positioning Components

Learning outcome
The learner will: 3. be able to produce working robot programs
Assessment criteria
The learner can: 3.1 explain the **steps required** to program robot arms 3.2 describe robot programming **methods** 3.3 produce **working** simple robot programs.

Range
Steps required Use of program flow charts to define the program steps and sequential logic; implement the program; evaluate program performance **Methods** Teach pendant programming; lead-through programming (for paint spraying); offline programming (based on computer model of the robot and its environment) **Working** creation; evaluation; implementation

Learning outcome
The learner will: 4. understand robot cell design
Assessment criteria
The learner can: 4.1 explain the **safety aspects** needed in robot cells 4.2 describe **operator supervision and control features** in robot cells 4.3 evaluate the **design** of robot-controlled work cells.

Range
Safety aspects Emergency stop controls; safety interlock systems; cell fencing (including light curtains); integration with other cell component systems **Operator supervision and control features** Switch between programs; make program adjustments; set and reset peripheral devices in the cell including component feeders; conveyor systems; machine vision systems; cell PLC or computer controller **Design evaluation** Examine cell designs for common robot application areas in manufacture (machine loading/unloading, welding, spray painting, assembly)

Unit 434 Industrial robotics

Supporting information

Guidance

This unit requires that candidates are given access to an industrial robot to support the practical application of robot programming and enable learners to develop, edit and implement a robot program for automated handling of a part.

Unit 435 Statistical process control

Level:	4
UAN:	A/506/9322
GLH:	52
NLH:	100
Assessment method:	Dated written paper
Aim:	The purpose of this unit is to enable learners to develop an understanding of Statistical Process Control and the industrial application of statistical tools and methodology to achieve process control, the acceptability of product quality and determine process capability. The unit will extend the learner's knowledge and understanding in an area closely related to Quality Assurance and Quality Control and give the opportunity to apply and develop previously acquired knowledge of mathematical statistics.

Note

The unit may be supported by the provision of computer-based statistical analysis software containing a statistical process control capability. The learner could have the opportunity to use this software to reinforce understanding and to help the practical application of the statistical process control techniques presented in the unit.

Learning outcome
The learner will: 1. understand how Statistical Process Control (SPC) is used as a quality control technique
Assessment criteria
The learner can: 1.1 explain the **principles** of continuous improvement 1.2 explain the key **features** of normal distribution curves 1.3 describe the use of normal distribution curves for six sigma applications 1.4 explain the difference between **types of data** used in control charts 1.5 identify control chart **datum values** 1.6 explain how to **interpret control charts** to monitor production process.

Range
Principles Adding value to products; waste management (Toyota's 7 Wastes); effects of quality on real costs of production **Features** Mean; standard deviation **Types of data** Attribute; variable **Control charts** c charts; p charts; u charts **Datum values** Upper warning or control limits (UCL); lower warning or control limit (LCL); the centre line (actual nominal size); the upper and lower action limits **Interpretation of control charts** Causes of variation (tool wear, vibration, coolant, environmental changes, human error), special and common causes

Learning outcome
The learner will: 2. understand the use of statistical techniques in consumer and producer sampling schemes
Assessment criteria
The learner can: 2.1 explain the principles of **acceptance sampling** 2.2 justify the **application** of acceptance sampling 2.3 evaluate different **types** of sampling plans.

Range
Acceptance sampling Producer's risk quality (PRQ); Consumer's risk quality (CRQ) **Application** Testing is destructive; cost of 100% inspection is prohibitive; 100% inspection is too time consuming **Types** Single sampling; double sampling; multiple sampling; sequential sampling

Learning outcome
The learner will: 3. be able to apply statistical techniques to sampling plans
Assessment criteria
The learner can: 3.1 justify the use of **sampling** schemes to ensure levels of quality are achieved 3.2 calculate **metrics** used for sampling plans 3.3 explain the significance of **lot sizes** in sampling plans.

Range
Sampling Single sampling; double sampling; multiple sampling; sequential sampling, representative and random sampling, attribute and variable **Metrics** Acceptable Quality Level (AQL); Lot Tolerance Percent Defective (LTPD); Type 1 Error (Producer's Risk) and Type 2 Error (Consumer's Risk); Average Outgoing Quality (AOQ); Average Total Inspection (ATI) **Lot sizes** Large lot; small sample size (non-replaced)

Learning outcome
The learner will: 4. understand how to determine manufacturing process capabilities
Assessment criteria
The learner can: 4.1 explain **statistical capability indices** used to determine process capabilities 4.2 explain the application of **statistical capability indices**.

Range
Statistical capability indices LSL, USL, T, Cp, Cpk, and Cpm

Learning outcome
The learner will: 5. be able to determine process capabilities
Assessment criteria
The learner can: 5.1 **calculate statistical capability indices** 5.2 evaluate the process capability of manufacturing cases where data is normally distributed.

Range
Calculation of statistical capability indices $Cp = (USL—LSL)/6\sigma$ (where σ is the standard deviation) $Cpk = \min [(USL-\mu)/3\sigma)(\mu-LSL)/ 3\sigma]$ (where μ is the mean) $Cpm= (USL-LSL)/ 6 \sqrt{(\sigma^2 + (\mu-T)^2)}$

Unit 436 Metal fabrication technology

Level:	4
UAN:	F/506/9323
GLH:	75
NLH:	150
Assessment method:	Assignment
Aim:	The purpose of this unit is to enable learners to develop an understanding of a broad range of processes used within the fabrication and welding sector including forming, cutting and joining. This knowledge will allow candidates to assess the suitability of various methods and techniques to suit practical situations in the workplace. A range of welding and cutting processes are also considered to inform production decisions.

Learning outcome
The learner will: 1. understand metal forming processes
Assessment criteria
The learner can: 1.1 explain the **principles** of metal forming 1.2 explain the **principles** of press braking processes 1.3 explain **axisymmetric forming** methods 1.4 explain **die forming applications**.

Range
Principles Effect of metal properties; metal thickness; hot/cold forming **Principles** Types of press brakes and tooling; inspection and testing of press brakes (National – (UK:PUWER; International standards); calculation of vee die openings and punch force; application of CNC control to press braking **Axisymmetric forming** Spinning; flow forming **Die forming applications** Principles of die forming; equipment; calculations of blank size, clearance and tonnage requirements; lubrication

Learning outcome
The learner will: 2. understand metal joining methods
Assessment criteria
The learner can: 2.1 explain **bolting procedures** 2.2 explain **sheet metal jointing** 2.3 explain structural steelwork joining **methods** 2.4 explain **principles** of different **types** of welding processes

Range
Bolting procedures Joint, bolt and gasket preparation; application of torque or tension; procedure documentation; jigs and fixtures **Sheet metal jointing** Clinch joints; riveting including aero applications; resistance welding; jigs and fixtures **Methods** Stanchion splices; web cleats; roof trusses; lattice girders; web stiffeners; jigs and fixtures **Types and Principles of processes** • *Manual Metal Arc Welding* Safety; applications; equipment; consumables; jigs and fixtures • *Tungsten Arc Gas Welding* Safety; applications; equipment; consumables; jigs and fixtures • *Metal Arc Gas Welding* Safety; applications; equipment; synergic control; consumables; jigs and fixtures • *Flux Cored Metal Arc Gas Welding* Safety; applications; equipment; synergic control; consumables; jigs and fixtures

Learning outcome
The learner will: 3. understand metal cutting methods
Assessment criteria
The learner can: 3.1 explain metal fabrication **cutting methods and equipment** 3.2 explain **mechanical cutting methods and equipment**.

Range
Cutting methods and equipment used • *Oxy-fuel* Safety; equipment; gases; procedures; mechanisation. • *Air Plasma* Safety; plasma theory; equipment; procedures, mechanisation/CNC control • *Water Jet cutting* Safety; abrasives; applications **Mechanical cutting methods and equipment** • *Cutting by shear processes* Shear theory; guillotines; punching; blanking; calculation of punching force; tool clearance calculations • *Chip forming cutting processes* Chip theory; reciprocating saws; band saws; circular saws; drilling machines and drill nomenclature; coolants.

Learning outcome
The learner will: 4. understand surface protection methods
Assessment criteria
The learner can: 4.1 explain **preparation methods** for surface protection 4.2 explain **methods** of surface protection of fabrications.

Range
Preparation methods Shot blasting; sand blasting; pickling; dry ice blasting; degreasing **Methods** Painting; powder-coating; galvanising; phosphating; anodising; plating; plastic coating

Learning outcome
The learner will: 5. be able to specify processes for fabricated products
Assessment criteria
The learner can: 5.1 select appropriate fabrication manufacturing processes including cutting, forming, jigs and fixtures, joining and finishing 5.2 produce fabrication process specifications.

Unit 437 Welding technology and practice

Level:	4
UAN:	J/506/9324
GLH:	35
NLH:	100
Assessment method:	Assignment
Aim:	The purpose of this unit is to enable learners to develop an understanding of a broad range of welding processes. This knowledge will allow candidates to be able to identify a preferred welding process for various production situations. It will also highlight a variety of defects that could be attributable to incorrect welding process, joint design or material properties. In addition, candidates will develop skills and understanding that will allow them to consider the cost implication of each process and the benefits of the mechanisation of each process when applicable.

Learning outcome
The learner will: 1. understand advanced welding processes
Assessment criteria
The learner can: 1.1 explain the **TIG/TAG** welding process 1.2 explain the **MIG/MAG** welding process 1.3 describe **specialised** welding processes.

Range
TIG/TAG Electrical parameters; gas selection; pulsed applications; hot wire process; mechanised applications **MIG/MAG** Electrical parameters; gas selection; modes of transfer; pulsed applications; flux cored electrodes; mechanised applications **Specialised** Laser; electron beam; plasma arc; friction stir

Learning outcome
The learner will: 2. understand failure modes of welded joints
Assessment criteria
The learner can: 2.1 explain **aspects** that affect notch toughness 2.2 explain **principles** of fatigue and creep failure 2.3 explain **design considerations** to prevent weld joint failure.

Range
Aspects Material properties; corrosion; environmental conditions; testing **Principles** Stress concentrations; S-N curves; prevention of failure **Design considerations** Access; hydrogen control; restraint; weld preparation; welding process

Learning outcome
The learner will: 3. understand how to select appropriate welding processes
Assessment criteria
The learner can: 3.1 identify **mechanical factors** that affect the selection of welding processes 3.2 identify **cost factors** that affect the selection of welding process 3.3 explain the **mechanisation** of the welding process.

Range
Mechanical factors Material type; material thickness; joint design; application; corrosion resistance; aesthetics **Cost factors** Initial set up costs; electrical efficiency; consumable costs; deposition rates, skill requirements **Mechanisation** Synergic parameter control; mechanisation techniques including robotics and orbital welding

Learning outcome
The learner will: 4. be able to specify welding processes and design criteria for products
Assessment criteria
The learner can: 4.1 identify joint geometry and materials from design specifications 4.2 produce welding process specifications.

Unit 438 Quality assurance and testing of welded joints

Level:	4
UAN:	R/506/9326
GLH:	43
NLH:	100
Assessment method:	Assignment
Aim:	The purpose of this unit is to enable learners to develop an understanding of the requirements of quality and assurance systems in the welding and fabrication sector. This unit covers welder certification, weld testing and the identification and maintenance of relevant documentation to ensure welding quality is assured.

Learning outcome
The learner will: 1. know quality assurance methods used in welding
Assessment criteria
The learner can: 1.1 identify **quality requirements** for fusion welded metallic joints 1.2 outline the **competence required** for the welding co-ordinator 1.3 describe different **elements** of quality specifications 1.4 explain **quality levels** of imperfections or defects in welded joints.

Range
Quality requirements As defined in BS EN 3834 (or national equivalent); traceability **Competence required** As defined in EN ISO 14731 (or national equivalent) **Elements** Welding procedure qualification and specification as defined in ISO 15614 (or national equivalent); weld maps; certification of welder competence as defined within appropriate national standards **Quality levels** Levels B, C and D as identified in BS EN ISO 5817:2007 (or national equivalent)

Learning outcome
The learner will: 2. understand weld testing methods
Assessment criteria
The learner can: 2.1 explain **non-destructive** testing techniques 2.2 explain **destructive** testing techniques.

Range
Non-destructive Visual; penetrant testing; magnetic particle; ultrasonic; radiographic **Destructive** Macro/micro; nick break; bend testing; tensile testing; CTOD; weld coupons

Learning outcome
The learner will: 3. be able to produce quality assurance specifications
Assessment criteria
The learner can: 3.1 identify **quality levels** of imperfections relevant to welded components 3.2 produce welding specification sheets 3.3 recommend the appropriate level of welder certification 3.4 specify testing techniques for welded components 3.5 produce weld maps.

Range
Quality levels Levels B, C and D as identified in BS EN ISO 5817:2007 (or national equivalent)

Appendix 1 Sources of general information

The following documents contain essential information for centres delivering City & Guilds qualifications. They should be referred to in conjunction with this handbook. To download the documents and to find other useful documents, go to the **Centres and Training Providers homepage** on **www.cityandguilds.com**.

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.

Useful contacts

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Walled Garden Re-issue of password or username, Technical problems, Entries, Results, e-assessment, Navigation, User/menu option, Problems	T: +44 (0)844 543 0000 F: +44 (0)20 7294 2413 E: **walledgarden@cityandguilds.com**
Employer Employer solutions, Mapping, Accreditation, Development Skills, Consultancy	T: +44 (0)121 503 8993 E: **business@cityandguilds.com**
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