QUALIFICATION HANDBOOK

Level 4 Diploma in Electrical and Electronic Engineering (9208-02)

April 2020 Version 1

City & Guilds

Qualification at a glance

Subject area	**Engineering**
City & Guilds number	9208
Age group approved	18+
Entry requirements	To take this qualification, learners should have achieved one of the following: • 2850 Level 3 Diploma in Engineering • 8030 Level 3 Technician Diploma in Electrical and Electronic Engineering • National Diploma in Engineering or a suitable equivalent to any of the above.
Assessment	• Assignments: externally set by City & Guilds, internally marked by centres, externally verified. • Dated entry written exam papers
Fast track	N/A
Support materials	• Qualification handbook
Registration and certification	Consult the Walled Garden/Online Catalogue for last dates

Title and level	**City & Guilds number**	**Accreditation number**
Level 4 Diploma in Electrical and Electronic Engineering	9208-02	N/A

Version and date	Change detail	Section
V1 April 2020	Document created	Throughout

Contents

1 Introduction

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

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: • 9208-12 Level 5 Advanced Technician Diploma in Electrical and Electronic Engineering or other equivalent City & Guilds qualifications.

2 Structure

To achieve the **Level 4 Diploma in Electrical and Electronic Engineering** learners must achieve the **two** mandatory units and a minimum of **nine** optional units.

City & Guilds unit number	Unit title	GLH	NLH
Mandatory			
Unit 401	Engineering mathematics	60	150
Unit 402	Principles of electrical/electronic engineering	70	150
Optional			
Unit 403	Quality assurance and control	42	150
Unit 405	Engineering planning and scheduling	66	150
Unit 407	Computer Aided Design for manufacture	60	150
Unit 408	Data Communication and networks	65	150
Unit 409	Principles and operation of electrical machines	50	150
Unit 410	Using electrical protection techniques for engineering operations	45	150
Unit 411	Electrical services and installation	41	100

City & Guilds unit number	Unit title	GLH	NLH
Unit 412	Electrical supply and distribution	60	100
Unit 413	Testing and measurement of electronic and electrical systems	66	100
Unit 414	Programmable logic controllers	60	100
Unit 415	Principles of analogue circuits	97	150
Unit 416	Sequential and combinational logic circuits	66	100
Unit 417	Microprocessor based systems	60	100
Unit 418	Maintenance of engineering systems and equipment	56	150
Unit 419	Engineering design	60	150
Unit 420	Programming using C	60	150
Unit 421	Planning and implementing change within businesses	30	100
Unit 422	Personal and professional development	25	100
Unit 423	Managing information and knowledge	60	150
Unit 424	Engineering procurement	60	150
Unit 427	Developing business improvement plans	35	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, e.g. 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
- 8030 Level 3 Technician Diploma in Electrical and Electronic 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.

5 Assessment

Units 405, 407, 408, 410, 411, 413, 414, 415, 416, 418, 419, 420, 421, 422, 423, 424 and 427 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 and 402
- **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			
9208-401	Engineering mathematics	Dated entry written exam paper 9208-401	Sample exam papers on www.cityandguilds.com
9208-402	Principles of electrical/electronic engineering	Dated entry written exam paper 9208-402	Sample exam papers on www.cityandguilds.com

Unit	Title	Assessment method	Where to obtain assessments
Optional units			
9208-403	Quality assurance and control	Dated entry written exam paper 9208-403	Sample exam papers on www.cityandguilds.com
9208-405	Engineering planning and scheduling	Assignment 9208-405 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com
9208-407	Computer aided design for manufacture	Assignment 9208-407 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com
9208-408	Data communication and networks	Assignment 9208-408 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com
9208-409	Principles and operation of electrical machines	Dated entry written exam paper 9208-409	Sample exam papers on www.cityandguilds.com
9208-410	Using electrical protection techniques for engineering operations	Assignment 9208-410 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com
9208-411	Electrical services and installation	Assignment 9208-411 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
9208-412	Electrical supply and distribution	Dated entry written exam paper 9208-412	Sample exam papers on www.cityandguilds.com
9208-413	Testing and measurement of electronic and electrical systems	Assignment 9208-413 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com
9208-414	Programmable logic controllers	Assignment 9208-414 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com
9208-415	Principles of analogue circuits	Assignment 9208-415 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com
9208-416	Sequential and combinational logic circuits	Assignment 9208-416 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com
9208-417	Microprocessor based systems	Assignment 9208-417 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
9208-418	Maintenance of engineering systems and equipment	Assignment 9208-418 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com
9208-419	Engineering design	Assignment 9208-419 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com
9208-420	Programming using C	Assignment 9208-420 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com
9208-421	Planning and implementing change within businesses	Assignment 9208-421 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com
9208-422	Personal and professional development	Assignment 9208-422 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com
9208-423	Managing information and knowledge	Assignment 9208-423 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
9208-424	Engineering procurement	Assignment 9208-424 This assignment covers all the learning outcomes in this unit. Assignment set by City & Guilds, internally marked, externally verified	www.cityandguilds.com
9208-427	Developing business improvement plans	Assignment 9208-427 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:

IEEE 1016-2009; IEEE 29148-2011; ISO 9000; ISO 14000; RS232; V24; X21; CCITT; ISO; ANSI; IEEE; EIA; CENELEC; ATEX; IEC; National (BS7671); ANSI/IEE Std 91a-1991; BS EN 60617-12:1999; ASCII.

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 408 Data communications and networks

Task	Description	Assessment criteria	Task duration	Grading	Weighting per task
1	Serial DTE to DTE connection	4.1, 4.2	3 hours with an additional 30 minutes initial preparation time	P / M / D / X	1
2	Communication protocol and configurations.	4.3, 6.5, 6.6, 6.8, 6.9, 7.1, 7.2, 8.2	2 hours and 30 minutes with an additional 30 minutes initial preparation time	P / M / D / X	1

Unit 410 Using electrical protection techniques for engineering operations

Task	Description	Assessment criteria	Task duration	Grading	Weighting per task
1	Prepare a one-line impedance diagram for an electricity supply system.	2.3	2 hours	P / M / D / X	1
2	Protection systems	3.3, 4.2, 4.3	2 hours	P / M / D / X	1
3	Earthing	5.1, 5.2, 5.3	2 hours	P / M / D / X	1
3	Short-answer questions	1.1, 1.2, 1.3, 2.1, 2.2, 3.1, 3.2, 4.1	1 hour	P / M / D / X	1

Unit 411 Electrical services and installation

Task	Description	Assessment criteria	Task duration	Grading	Weighting per task
1	Electrical services and installation project	1.1, 2.1, 2.2, 2.3, 2.4, 2.5, 3.2, 3.3, 4.1, 4.2, 5.3	20 hours	P / M / D / X	1

Unit 413 Testing and measurement of electronic and electrical systems

Task	Description	Assessment criteria	Task duration	Grading	Weighting per task
1	Inspection, Testing and Commissioning	7.1, 7.2, 8.1, 8.2, 8.3	3 hours	P / M / D / X	2
2	Measurements	2.1, 2.2, 2.3	2 hours	P / M / D / X	2

Unit 414 Programmable logic controllers

Task	Description	Assessment criteria	Task duration	Grading	Weighting per task
1	PLC program design and testing.	3.3, 3.4, 4.1, 4.2, 4.3, 5.3, 5.4	3 hours	P / M / D / X	1

Unit 415 Principles of analogue circuits

Task	Description	Assessment criteria	Task duration	Grading	Weighting per task
1	Operation amplifiers (Op-amps)	5.1, 5.2, 5.3	2 hours	P / M / D / X	1
2	Oscillators	6.1, 6.2, 6.3, 6.4	4 hours	P / M / D / X	1
3	Op-amp filters	7.1, 7.2, 7.3, 7.4	3 hours	P / M / D / X	1

Unit 416 Sequential and combinational logic circuits

Task	Description	Assessment criteria	Task duration	Grading	Weighting per task
1	Combinational logic	2.3, 2.4, 2.5	1 hour 30 minutes	P / M / D / X	1
2	Sequential logic	3.6, 3.7	2 hours	P / M / D / X	1

Unit 417 Microprocessor based systems

Task	Description	Assessment criteria	Task duration	Grading	Weighting per task
1	Software development and testing	2.1, 2.2, 2.3, 3.2	2 hours 30 minutes	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 420 Programming using C

Task	Description	Assessment criteria	Task duration	Grading	Weighting per task
1	Research report: Understanding Software development	1.1, 1.2, 1.3, 2.1, 2.2, 2.4, 2.5, 4.6, 5.3	8 hours	P / M / D / X	1
2	Programming Task: Implementation of a design specification in the C language	1.4, 1.5, 1.6, 2.3, 2.6, 3.1, 3.4, 3.5, 4.1, 4.4, 4.5, 5.1, 5.2	32 hours	P / M / D / X	1
3	Short-answer questions	3.2, 3.3, 4.2, 4.3	1 hour	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: 9208-401 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: 9208-402 Principles of electrical and electronic engineering

Duration: 3 hours

Grading: Pass/Merit/Distinction

Unit	Outcome		%
402	1.	understand basic magnetic theory	10
	2.	be able to solve design problems using electromagnetic theory	7
	3.	be able to apply electrical theorems or laws to solve network problems	7
	4.	be able to use complex notation theory in the analysis of single-phase a.c. networks	16
	5.	understand how to analyse RLC circuits	9
	6.	be able to analyse RLC circuits	12

Unit	Outcome		%
	7.	understand how to analyse electrical systems when modelled as two-port networks	8
	8.	be able to analyse electrical systems when modelled as two-port networks	8
	9.	be able to analyse three-phase circuits	14
	10.	be able to solve the transient response of first-order circuits	9
		Total	**100**

Test: 9208-403 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
	7.	understand the use and application of codes of practice, standards and design guides	6
		Total	**100**

Test: 9208-409 Principles and operation of electrical machines

Duration: 3 hours

Grading: Pass/Merit/Distinction

Unit	Outcome		%
409	1.	understand the principles and operation of dc machines	17
	2.	understand the principles and operation of three-phase induction motors	24
	3.	understand the principles and operation of synchronous machines	18
	4.	understand the principles and operation of power transformers	41
		Total	**100**

Test: 9208-412 Electrical supply and distribution

Duration: 3 hours

Grading: Pass/Merit/Distinction

Unit	Outcome		%
412	1.	understand principles, components and economic factors of electrical transmission and distribution systems	12
	2.	be able to analyse the characteristics of three-phase power transformers in parallel operation	15
	3.	be able to apply short transmission line theory for electrical supply configurations	14
	4.	understand operating characteristics of three-phase generators on infinite busbars	18
	5.	be able to solve fault levels on electrical supply system configurations	25
	6.	understand protection systems used in electrical supply systems	16
		Total	**100**

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.

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 and 5 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 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 9208 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 level of guidance, able to follow the	**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
	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
- guided learning hours
- notional Learning hours
- unit aim
- assessment method
- learning outcomes which are comprised of a number of assessment criteria
- notes for guidance.

Unit 401 Engineering mathematics

Level:	4
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 that are required 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 402 Principles of electrical/electronic engineering

Level:	4
GLH:	70
NLH:	150
Assessment method:	Dated written paper
Aim:	The purpose of this unit is to enable learners to develop an understanding of the fundamental principles of electrical and electronic engineering.

Learning outcome
The learner will: 1. understand basic magnetic theory
Assessment criteria
The learner can: 1.1 explain the relationship between common electromagnetic **units of measurement** 1.2 explain the occurrence of **properties** in relation to the behaviour of magnetic materials undergoing cyclic magnetisation 1.3 explain the relationship between the shapes of hysteresis loops of **materials** and their application in magnetic and electromagnetic circuits 1.4 explain electromagnetic behaviour **laws**.

Range
Units of measurement Magnetomotive force (m.m.f); Magnetic field strength; flux density; total flux; reluctance **Properties** Coercivity; remanence; saturation; permeability **Materials** Magnetically soft and magnetically hard **Laws** Faraday's law; Lenz's law; Flemings rule

Learning outcome
The learner will: 2. be able to solve design problems using electromagnetic theory
Assessment criteria
The learner can: 2.1 assess the reluctance of magnetic materials 2.2 calculate the inductance of magnetic circuits using applied **variables** 2.3 solve **values** relating to magnetic circuit operation.

Range
Variables m.m.f, circuit dimensions and permeability **Values** Magnetic field strength; flux density; total flux; magnetomotive force (m.m.f)

Learning outcome
The learner will: 3. be able to apply electrical theorems or laws to solve network problems
Assessment criteria
The learner can: 3.1 explain methods of resolving network problems using electrical **theorems or laws** 3.2 use electrical **theorems or laws** to solve problems involving networks.

Range
Theorems and laws Ohm's law; Kirchhoff's current and voltage laws; Thévenin's theorem; Norton's theorem; Maximum power transfer theorem; Superposition theorem

Learning outcome
The learner will: 4. be able to use complex notation theory in the analysis of single-phase a.c. networks
Assessment criteria
The learner can: 4.1 explain the **properties** of R, L and C circuits 4.2 explain the **representation** of series R, L and C circuits 4.3 evaluate complex variables in **operations** 4.4 convert electrical values between polar and rectangular form 4.5 calculate **power** using **relationships**.

Range
Properties Voltage, Current, Phase Angle, Frequency, Resistance, Reactance and Impedance **(R, X_L, X_C, Z)** **Representation** By complex impedance and complex admittance **Operations** Addition; subtraction; multiplication; division **Power** Real; Reactive; Apparent; Power Factor **Relationships** P=Re[VI*] and Q=Im[VI*]

Learning outcome
The learner will: 5. understand how to analyse RLC circuits
Assessment criteria
The learner can: 5.1 represent differing **types** of R, L and C circuits using phasor diagrams 5.2 explain the conditions of resonance for **RLC circuits** 5.3 explain power factor **relationships** using diagrams.

Range
Types Series; parallel **RLC circuits** Series; parallel **Relationships** Real power; Reactive power; Apparent power

Learning outcome
The learner will: 6. be able to analyse RLC circuits
Assessment criteria
The learner can: 6.1 produce plots of the frequency responses of tuned **RLC circuits** 6.2 solve problems of **resonance** in **RLC circuits** 6.3 solve problems relating to power-factor improvement.

Range
Resonance Quality factor; bandwidth; impedance; reactance; capacitance **RLC circuits** Series; parallel

Learning outcome
The learner will: 7. understand how to analyse electrical systems when modelled as two-port networks
Assessment criteria
The learner can: 7.1 explain the **parameters** used in two-port models 7.2 explain the deriving of input and output equations for **parameter** models.

Range
Parameters Z (impedance model); Y (admittance model); h (hybrid model); g (inverse hybrid model)

Learning outcome
The learner will: 8. be able to analyse electrical systems when modelled as two-port networks
Assessment criteria
The learner can: 8.1 convert circuit values using **parameters** from different models 8.2 solve problems involving **gain** of two-port model networks.

Range
Parameters Z (impedance model); Y (admittance model);h (hybrid model); g (inverse hybrid model) **Gain** Low frequency; mid-band; high frequency

Learning outcome
The learner will: 9. be able to analyse three-phase circuits
Assessment criteria
The learner can: 9.1 illustrate three-phase systems using phasor diagrams 9.2 solve **problems** in balanced three-phase loads 9.3 evaluate methods of three-phase power measurement for different **systems**.

Range
Problems Involving line values (voltage and current); phase values (voltage and current); power and power-factor; Star connection and Delta connection **Systems** Balanced; unbalanced; star (three-wire, four-wire); delta

Learning outcome
The learner will: 10. be able to solve the transient response of first-order circuits
Assessment criteria
The learner can: 10.1 produce graphs of growth and decay of transient **components** in **circuits** 10.2 solve problems relating to **time** and steady state values of **circuits**

Range
Components Voltages and currents **Circuits** RL and RC **Time** Time constant; rise-time and fall-time **Circuits** RL and RC

Unit 403 Quality assurance and control

Level:	4
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 405 Engineering planning and scheduling

Level:	4
GLH:	66
NLH:	100
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 407 Computer Aided Design for manufacture

Level:	4
GLH:	60
NLH:	150
Assessment method:	Assignment
Aim:	The purpose of this unit is to enable learners to develop an understanding of CAD/CAM systems used in advanced manufacturing. Learners will understand the benefits of using both systems, their application in the workplace and will be able to recommend 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, 3D Models Drawing Tools, Constraints, Solid Geometry **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 3**D 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 Orthographic, Sections, Break Outs, Detail **BS8888** Templates, Line Types, Dimensioning, View Layouts, Metric units, Surface Finish, GDT **2D Assembly Drawings** General Assembly view, Exploded Assembly view, 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, Lighting, Environment **Animations** e.g. MP4, avi files **Assembly/Disassembly Processes** Exploding & Reassembling **Assembly Functionality** Rotary & Linear Motion, Gears, Chains, Sprockets

Unit 408 Data communication and networks

Level:	4
GLH:	65
NLH:	150
Assessment method:	Assignment
Aim:	The purpose of this unit is to enable learners to develop an understanding of data communication and networks used for electrical and electronic engineering operations. The unit also enables learners to practically apply skills and knowledge to given communication/network applications

Learning outcome
The learner will: 1. understand data communication media, connectors and methods of data transmission
Assessment criteria
The learner can: 1.1 explain different **types** of data transmission media 1.2 explain attenuation and interference with different transmission media 1.3 explain the applications of different **cable connectors** 1.4 compare analogue and digital signals for data transmission 1.5 explain the **effects** of bandwidth limitations for data transmission 1.6 describe **modulation techniques** used for data transmission 1.7 explain simplex, duplex and half-duplex communications 1.8 assess different **methods** and **techniques** of data transmission 1.9 explain how data channels may be shared using different **methods** of multiplexing.

Range
Types Coaxial cable; twisted pair (shielded and unshielded); optical fibre; radio waves; Microwave; infra-red **Cable connectors** BNC (plugs, sockets, 'T' connectors, terminators); RJ45 connectors; D-Type; USB **Effects** Interference and data rates **Modulation techniques**

Amplitude; frequency; phase

Methods

Serial; parallel; baseband and broadband

Techniques

Asynchronous and synchronous

Methods

Time Division Multiplexing (TDM); Frequency Division Multiplexing (FDM)

Learning outcome
The learner will: 2. understand basic network theory and applications
Assessment criteria
The learner can: 2.1 explain the operation of **network models** 2.2 describe network **applications and services**.

Range
Network models ISO/OSI; TCP/IP **Applications and services** Electronic mail (e-mail) for electronic communication, browser for access to internet and Worldwide Wide Web (WWW), scheduling for group meetings and appointments, File Transfer Protocol (FTP) for the transfer of files, Hypertext Transfer Protocol (http) for retrieval of world wide web pages (WWW)

Learning outcome
The learner will: 3. understand how to make direct connections between devices
Assessment criteria
The learner can: 3.1 explain different **codes** used for data transmission 3.2 describe standard **character sets** for data representation 3.3 describe **standards** used for data transmission 3.4 explain **connection formats** 3.5 explain the **protocols** used between **connections** 3.6 explain the function of modems used in **connections**.

Range
Codes Character; control signal **Character sets** ASCII; EBCDIC **Standards** RS232; V24; X21 **Connection formats**

RS232 (9-way and 25-way D type); USB

Protocols

XON; XOFF; CTS; RTS

Connections

DTE to DTE; DTE to DCTE

Connections

DTE to DTE; DTE to PSTN

Learning outcome
The learner will: 4. be able to safely establish connections between similar devices for data transfer
Assessment criteria
The learner can: 4.1 use **safe working practices** on mains-powered equipment 4.2 use **cables and connectors** to provide a serial port direction **connection** 4.3 apply **communication software protocol** to allow file transfer.

Range
Safe working practices Safe isolation methods; appropriate to national standards; use of anti-static equipment **Cables and connectors** Construction and testing of serial port interfaces and connections **Connection** DTE to DTE; USB, **Communication software protocol** Number of data bits; parity; number of start bits; number of stop bits; baud rate

Learning outcome
The learner will: 5. understand communication network concepts and components
Assessment criteria
The learner can: 5.1 explain the **advantages and disadvantages** of networking devices 5.2 evaluate attributes of local area networks (LAN) and wide area networks (WAN) 5.3 explain the purpose and **types of servers** available on a network 5.4 evaluate types of **network topologies** 5.5 explain **methods** used for accessing a data transmission network 5.6 explain **types** of data error detection methods 5.7 describe the operational principles of **main hardware** components in networks 5.8 explain the functions of **network components** 5.9 evaluate different **protocols** used in networks

5.10 explain the relevance of using **international standards** for data transmission

5.11 describe **communication network technologies**.

Range
Advantages and Disadvantages Shared devices; cost; item failure; accessibility; security; management **Types or servers** File; web; mail; database; media; application **Network topologies** Bus; ring; mesh; star **Methods** Token passing; CSMA/CD data control flow; TDMA; CDMA **Types** Parity checking; checksum; CRC **Main hardware** Server; PCs; terminals; peripherals **Network components** Hubs; repeaters; regenerators; bridges; routers; switches including typical features **Protocols** TCP/IP; UDP; ARP; ICMP; IPv6 **International standards** CCITT; ISO; ANSI; IEEE; EIA **Communication network technologies** ISDN; ASDL; HDSL; VDSL; SDSL including typical data rates

Learning outcome
The learner will: 6. be able to install a functioning data network interface card in local area networks (LAN)
Assessment criteria
The learner can: 6.1 describe the operation of LANs 6.2 explain the purpose of different types of network interface cards (NIC) 6.3 describe security issues of externally connected networks 6.4 explain **problems** that may prevent networks from operating correctly 6.5 install appropriate network interface card 6.6 use software and **hardware resources** to connect devices 6.7 explain the purpose of **software resources** for network hardware operation 6.8 install network **software resources** using appropriate operating systems 6.9 create **user access** rights to resources on devices.

Range
Problems Loose socket connection; break in cable; incompatible protocols installed **Installation** IRQ; port address; memory address **Hardware resources** Cables; cable connectors; components **Software resources** Drivers; protocols; services **User access** Client logon and directory/folder facilities

Learning outcome
The learner will: 7. be able to commission local area network (LAN) operation
Assessment criteria
The learner can: 7.1 produce **network implementation documents** 7.2 **Test network installation and configuration** 7.3 evaluate network **installation and configuration**.

Range
Network implementation documents Configuration; protocol(s) used; type of network interface cards used; whether passwords are required for shared resources and specification of which resources are shared **Installation and configuration** Testing of functionality; benefit to users; security of data; speed of data transfer for files and printed output and any problems which may have occurred

Learning outcome
The learner will: 8. understand data network services maintenance and management
Assessment criteria
The learner can: 8.1 explain **tasks** involved in the management of networks 8.2 explain the process for **managing** individual and group accounts on networks 8.3 evaluate **network security techniques** to prevent unauthorised access to data 8.4 assess the importance of **security software**.

Range
Tasks System configuration; management of users; management of workstations; activity log reporting; error log reporting; traffic analysis; performance analysis; regular backup of data **Managing** Creating; disabling; deleting **Network security techniques** Physical access; user identification code; password; access rights; proxy server; encryption **Security software** Antivirus; firewall; antispyware; desktop; network.

Unit 409 Principles and operation of electrical machines

Level:	4
GLH:	50
NLH:	150
Assessment method:	Dated written paper
Aim:	The purpose of this unit is to enable learners to develop an understanding of the principles and operations of electrical machines in engineering operations.

Learning outcome
The learner will: 1. understand the principles and operation of dc machines
Assessment criteria
The learner can: 1.1 describe components of dc machines 1.2 explain the **operating principles** of dc machines 1.3 describe **types** of winding arrangements and their **effects** on operation 1.4 solve problems involving dc machine **parameters**.

Range
Operating principles Torque, speed and rotation for shunt, series and compound wound machines **Types** Shunt; series; compound **Effects** Armature reaction (effects and minimisation) **Parameters** Voltage, current, power/horse-power, speed, starting torque

Learning outcome
The learner will: 2. understand the principles and operation of three-phase induction motors
Assessment criteria
The learner can: 2.1 evaluate features of different **types of motors** 2.2 outline parameters of induction motors 2.3 describe the load characteristic of three-phase induction motors 2.4 illustrate the equivalent circuit of three phase induction motors 2.5 assess **types of induction motor starter systems** 2.6 solve problems involving induction motor parameters.

Range
Types of motors Wound rotor and squirrel cage induction **Types of induction motor starter systems** Direct on-line; Star-delta; Auto-transformer; Rotor resistance

Learning outcome
The learner will: 3. understand the principles and operation of synchronous machines
Assessment criteria
The learner can: 3.1 describe the operating principles of synchronous **machines** 3.2 analyse the operation of synchronous machines for different rotor **types** 3.3 describe the wound rotor synchronous induction motor 3.4 illustrate the equivalent circuit of a synchronous motor 3.5 solve problems involving synchronous induction motor **parameters**.

Range
Machines Motors; generators **Types** Salient pole; cylindrical **Parameters** Power input; power output; efficiency and power factor correction

Learning outcome
The learner will: 4. understand the principles and operation of power transformers
Assessment criteria
The learner can: 4.1 explain the operating **principles** of a power transformer 4.2 assess the suitability of three phase transformers for different **applications** 4.3 outline **standards** for power transformer terminal **markings** 4.4 assess the functions of transformer winding vector **groups** 4.5 evaluate transformer types according to **properties** 4.6 analyse the consequences of **incompatible** transformers connected in parallel 4.7 explain faults that can occur with power transformers 4.8 solve problems involving transformer parameters.

Range
Principles Ratios for voltage, current and turns; regulation and efficiency **Applications** Transmission systems; distribution systems **Standards** Current BS, EN or ISO equivalent **Markings** HV; LV; potential; phase shift and winding method **Groups** Including phasor diagrams (Star-star; delta-delta; star-delta; delta-star) **Properties** Winding type; low voltage displacement; high voltage displacement and methods of cooling **Incompatible** Polarity; phase sequence; phase difference; voltage ratio; per-unit impedance

Unit 410 Using electrical protection techniques for engineering operations

Level:	4
GLH:	45
NLH:	150
Assessment method:	Assignment
Aim:	The purpose of this unit is to enable learners to develop an understanding of how to use electrical protection techniques for engineering operations.

Learning outcome
The learner will: 1. be able to solve cable fault location problems using the bridge method
Assessment criteria
The learner can: 1.1 explain the bridge method of cable fault location 1.2 use algebraic expressions for cable fault location 1.3 solve cable fault location problems.

Learning outcome
The learner will: 2. understand how to simplify power systems into one-line impedance circuits
Assessment criteria
The learner can: 2.1 explain fault level, base MVA and per unit impedance 2.2 explain the construction of supply system one-line impedance diagrams 2.3 evaluate electrical supply system **parameters** to simplify electrical supply system networks to one-line impedance diagrams.

Range
Parameters Sbase; Vbase; Zbase

Learning outcome
The learner will: 3. understand current transformer application in electrical system protection
Assessment criteria
The learner can: 3.1 explain current transformer principles of operation 3.2 evaluate current transformer **parameters** 3.3 evaluate classes of current transformer for particular applications.

Range
Parameters Magnetic field strength; flux density; total flux; reluctance

Learning outcome
The learner will: 4. be able to specify electrical protection relays for electrical systems
Assessment criteria
The learner can: 4.1 describe relay **time** relationships 4.2 evaluate advantages and disadvantages of unit differential protection 4.3 solve relay **problems**.

Range
Time Desired operating time; time setting multiplier and the British Standard IDMT characteristic time for full travel **Problems** IDMT relay setting from maximum load current for different system voltages; fault current as a multiple of relay setting; time for full travel of an IDMT relay from the BS characteristic (ISO equivalent); desired operating time of an IDMT relay; TMS of an IDMT relay and setting times of graded relays; fault clearance time

Learning outcome
The learner will: 5. understand the principles of earthing and circuit protection of electrical plant
Assessment criteria
The learner can: 5.1 explain earthing system **arrangements** 5.2 evaluate earth fault current in electrical circuits 5.3 describe circuit **protection** against various fault types.

Range
Arrangements TN; TT; IT; TN-C-S, TN-S **Protection** Overload; short-circuit; earth fault

Unit 411 Electrical services and installation

Level:	4
GLH:	41
NLH:	100
Assessment method:	Assignment
Aim:	The purpose of this unit is to enable learners to develop an understanding of electrical services and installation. Learners will look at regulations that apply, materials and equipment used and types of earthing systems and circuits. The unit also enables learners to practically apply skills and knowledge to design aspects of low voltage electrical installations.

Learning outcome
The learner will: 1. understand the regulations applicable to electrical installations and services
Assessment criteria
The learner can: 1.1 outline **regulations** for safe electrical installation practice and equipment 1.2 interpret International Code of Protection ratings for electrical equipment 1.3 explain **international standards** for the use of electrical equipment in hazardous areas.

Range
Regulations National (BS7671); European and international (IEC) **International standards** CENELEC; ATEX; IEC

Learning outcome
The learner will: 2. understand materials and equipment used in electrical services and installations
Assessment criteria
The learner can: 2.1 define types of **wiring systems** by their **properties** 2.2 evaluate types of **electrical equipment** according to installation method and location 2.3 evaluate types of **wiring enclosure** according to installation method and location 2.4 evaluate electrical switchgear in respect of **purpose** and operation. 2.5 evaluate **circuit protective devices** according to the type of fault protection required.

Range
Wiring systems Thermosetting insulated cables including flexes; single and multicore thermoplastic (PVC) and thermosetting insulated cables; PVC/PVC flat profile cable; MICC (with and without PVC sheath); SWA cables (PILC, XLPE, PVC); armoured/braided flexible cables and cords; data cables; fibre optic cables and fire resistant cables **Properties** Type of construction; voltage rating; material of construction; size and compatibility for installation method/location **Electrical equipment** Isolators and switches; socket-outlets; distribution-boards; consumer units; earthing fault and over current protective devices; luminaries; control equipment; data socket outlets; auxiliary equipment (eg heating/water system components) **Wiring enclosure** Conduit (PVC and metallic); trunking (PVC and metallic); cable tray; cable basket; ladder systems; ducting; modular wiring systems and Busbar systems/Powertrack **Purpose** Protection; isolation; switching **Circuit protective devices** MCB; RCBO; RCD; Fuses (BS1361, BS3036 and BS88 or national equivalent)

Learning outcome
The learner will: 3. understand earthing systems and circuits
Assessment criteria
The learner can: 3.1 define types of permitted **earthing systems** 3.2 analyse electrical circuit earth fault loop **parameters** 3.3 explain the operation of residual current devices (RCDs) 3.4 analyse earth electrode resistance and soil resistivity using **standard** techniques 3.5 evaluate earthing installation testing methods according to **standards**.

Range
Earthing systems TN-C; TN-S; TN-C-S; TT; IT **Parameters** Earth fault loop impedance; external loop impedance; fault current; protective conductor size; circuit protective devices **Standard** IET GN3 methodology (or international equivalent) **Standards** National (BS7671); International

Learning outcome
The learner will: 4. understand the requirements of special electrical installations or locations
Assessment criteria
The learner can: 4.1 outline prescribed **locations** or **installations** with particular electrical installation requirements 4.2 analyse electrical installation requirements in relation to special **locations** or **installations**.

Range
Locations or installations As per BS7671 – Part 7 definition; or international equivalent

Learning outcome
The learner will: 5. understand the requirements of electrical equipment for protection against other hazards
Assessment criteria
The learner can: 5.1 describe hazards associated with static charge 5.2 evaluate methods of minimising hazards associated with high resistivity hydrocarbons and other inflammable sources 5.3 evaluate the use of Zener diode barrier circuits 5.4 assess the suitability of different types of fire system installations 5.5 evaluate electrical equipment for use in hazardous areas according to regulations 5.6 evaluate international regulations to establish equivalence to national classifications and equipment classes 5.7 assess types of hazardous area electrical equipment appropriate to various industrial and commercial locations 5.8 analyse certification authority requirements for electrical equipment for use in hazardous areas.

Learning outcome
The learner will: 6. be able to design aspects of low voltage electrical installations
Assessment criteria
The learner can: 6.1 explain the relationship between electrical installation design and **statutory/non-statutory regulations** 6.2 describe considerations for designing **final circuits** 6.3 explain the **requirements** for the assessment of general characteristics of electrical installations 6.4 use design calculations relevant to electrical installation design **parameters** 6.5 assess how the use of **associated protective systems** affects the design of electrical installations.

Range
Statutory/non-statutory regulations BS 7671; IET Guidance Notes; Electricity at Work Regulations; Electricity Safety Quality and Continuity Regulations; The Building Regulations (England & Wales) (Scotland) and Construction (Design Management) Regulations; international equivalence **Final circuits** Ring final; radial; powertrack and bus bar trunking; circuit loading. **Requirements** Purpose of supplies and structure; maximum demand and diversity; arrangements of live conductors and earthing arrangements; supplies; division of installation; compatibility; maintainability and continuity of service

Parameters

Cable sizes; protective device ratings; cable grouping; input power; line and phase current loads; earth fault loop impedance; diversity; prospective fault current

Associated protective systems

Lightning protection systems using zones of protection; lightning protection systems component parts; methods of protection against corrosion and erosion; manual fire detection systems; automatic fire detection systems; standby lighting systems; self-contained emergency lighting systems; centrally supplied emergency lighting systems; generator systems for alternative supplies; UPS systems for alternative supplies

Unit 412 Electrical supply and distribution

Level:	4
GLH:	60
NLH:	100
Assessment method:	Dated written paper
Aim:	The purpose of this unit is to enable learners to develop an understanding of electrical supply and distribution.

Learning outcome
The learner will: 1. understand principles, components and economic factors of electrical transmission and distribution systems
Assessment criteria
The learner can: 1.1 explain the principles of ac **power generation** 1.2 explain the methods of ac power generation 1.3 explain the principles of ac **power transmission** 1.4 explain the functions of local distribution system **components** 1.5 evaluate advantages and disadvantages of **network systems** for use in engineering supply connections 1.6 analyse **costs** involved with electricity supply systems for selection of use.

Range
Power generation 3-phase generators; frequency; phase displacement; voltage **Methods** Fossil fuel; nuclear; renewable **Power transmission** Transmission voltages; National grid; sub-stations; transformers **Components** Isolating switches; contactors; fuses and circuit breakers, switch-fuses and fuse-switches; oil switches **Network systems** Radial; parallel and open and closed ring; feeder **Costs** Fixed and variable (tariffs – using system values: load, demand, maximum demand, diversity factor, load factor and power factor)

Learning outcome
The learner will: 2. be able to analyse the characteristics of three-phase power transformers in parallel operation
Assessment criteria
The learner can: 2.1 explain the conditions for transformers to successfully and safely operate in parallel 2.2 explain the operation of voltage control of transmission lines using tap changing transformers 2.3 assess the kVA **load** of transformers operating in parallel using impedance based schematics 2.4 assess transformer impedances connected in parallel referred to primary or secondary windings 2.5 assess the **properties** of **system configurations** of transformers connected in parallel.

Range
Load Product of total load being shared and the ratio of transformer impedances **Properties** Load distribution; current circulation; phase regulation; in groupings; (using phasor diagrams where appropriate) **System configurations** Involving different complex impedances; supplying different loads over short transmission lines and connected in various configurations

Learning outcome
The learner will: 3. be able to apply short transmission line theory for electrical supply configurations
Assessment criteria
The learner can: 3.1 assess the configuration of **supply systems** using equivalent circuits 3.2 assess the configuration of **systems** using schematic diagrams and complex reactances 3.3 illustrate series **equivalent circuits** representing transmission lines 3.4 evaluate the **performance** of short line receiving end line systems 3.5 assess short line system **parameters** using complex notation from given data.

Range
Supply systems Consisting of generators; transformers; motors; lines; loads **Systems** Radial supply; parallel; ring **Equivalent circuits** (in the form of phasor diagrams) Using load current as a reference and using the receiving end voltage as the reference **Performance** For different power factors, from given data, for control of real and reactive power by transmission angle and sending voltage and for demonstrating the effects of variation in real power and power factor on the sending end voltage **Parameters** The sending end voltage; line voltage drop; load angle

Learning outcome
The learner will: 4. understand operating characteristics of three-phase generators on infinite busbars
Assessment criteria
The learner can: 4.1 explain the relationships between generator **parameters** 4.2 assess the operation of synchronous machines using equivalent circuits 4.3 assess the relationship between generator **parameters** 4.4 illustrate generator load diagrams using **given data** 4.5 evaluate generator load diagrams to measure operational performance and **limits** 4.6 assess generator performance limitations with respect to **operating characteristics**.

Range
Parameters Stator phase voltage; stator phase current; generated voltage and synchronous reactance and impedance **Parameters** Stator phase voltage; stator phase current; generated voltage; load angle; stator voltage drop; power factor; constant power; constant VAR control mode; terminal voltage **Given data** Stator phase current; power; reactive power; load angle; power factor; active power lines; rotor current limit; unity power factor line; areas of lagging and leading power factor; power output limit; generated voltage; terminal voltage **Limits** Prime mover limit (MW or turbine power limit); theoretical and practical stability limits; excitation; stator heat limits

Operating characteristics

Real power output; reactive power output; the p.u. excitation; operating power factor and apparent power output; short circuit ratio (SCR)

Learning outcome

The learner will:

5. be able to solve fault levels on electrical supply system configurations

Assessment criteria

The learner can:

5.1 explain **terms** used in electrical supply system configurations

5.2 illustrate **supply systems** using one-line diagrams

5.3 describe **principles** used in high voltage circuit breakers

5.4 assess the construction and operation of **high voltage protection devices** for use in different applications

5.5 assess the operation of circuit breakers using equivalent circuits

5.6 evaluate **techniques** for reducing fault levels to specified values

5.7 assess the magnitude of fault levels at various points using system **parameters**

5.8 evaluate the effects of system switching transients on electrical supply system operation

5.9 solve system fault level problems involving star/delta circuit transformations.

Range

Terms

Fault level; per unit impedance; grid in-feed; source fault VA

Supply systems

Appropriate symbols for generators, transformers and lines, units represented as voltages

Principles

Arc suppression; control; interruption and closing of circuits

High voltage protection devices

Bulk and minimum oil circuit breakers; air blast circuit breakers; vacuum interrupters; sulphur hexafluoride circuit breakers; HRC, liquid and expulsion fuses; high voltage fuses; switch fuses and fuse switches

Techniques

In accordance to industry standards (UK and International)

Parameters

Circuit p.u. impedance; base VA and impedance circuit reduction

Learning outcome
The learner will: 6. understand protection systems used in electrical supply systems
Assessment criteria
The learner can: 6.1 explain elements used in overcurrent protection systems 6.2 explain the operation of overcurrent protection equipment on contactors and circuit breakers 6.3 explain the operation of overcurrent and differential **protection systems** 6.4 explain over-voltage protection **methods** 6.5 evaluate circuit breaker operations relative to fault positions 6.6 assess advantages of IDMT relays, Directional Overcurrent relays and unit protection for use in supply systems 6.7 assess the operation of time setting multipliers and plug setting multipliers for **IDMT relays** in electrical supply systems.

Range
Protection systems Inverse definite minimum time (IDMT) relays; supply system unit circulating current differential protection schemes (as applied to a large generator and to protect a star/delta transformer) **Methods** Overhead earth wires on EHV lines; surge diverters; non-linear surge diverters **IDMT relays** With reference to BS142 (BS EN 60255) IDMT characteristic curve and to give the required discrimination in radial feeder circuits with various load take off points

Unit 413 Testing and measurement of electronic and electrical systems

Level:	4
GLH:	66
NLH:	100
Assessment method:	Assignment
Aim:	The purpose of this unit is to enable learners to develop an understanding of testing and measurements of electrical and electronic systems. The unit also enables learners to practically apply skills and knowledge to given testing and measurement applications.

Learning outcome
The learner will: 1. understand the selection of equipment used to measure electrical and electronic values
Assessment criteria
The learner can: 1.1 explain the operation of **test equipment** 1.2 describe types of signal **transmission systems** used for measurement 1.3 evaluate the **selection** of test equipment used to measure differing **values**.

Range
Test equipment Explain with the aid of block diagrams as appropriate: oscilloscopes; meters; signal generators; counters; logic analysers; spectrum analysers; low resistance ohmmeters; insulation resistance testers; voltage indicating devices; earth fault loop impendence testers; prospective fault current testers; RCD testers; earth electrode testers and phase rotation meters **Transmission systems** Coaxial; twisted pair; flat cable; single cable; clamp; fibre-optic; attenuation; phase change and frequency response; noise and noise reduction where appropriate; accounting for; response of the systems; transfer function; impulse response; frequency response and dynamic range **Selection** The correct equipment to measure signals based on; signal characteristics (continuous signals, discrete signals, frequency and

period, peak, average; effective value, phase shift, amplitude, attenuated. Magnitude, peak to peak, time domain, frequency Domain, Fourier series of signals), actual or emulated, transmission system, environment, cost, availability, accuracy and required outcome.

Values

Electronic and low voltage electrical

Learning outcome
The learner will: 2. be able to apply the principles and techniques employed in electrical and electronic measurement
Assessment criteria
The learner can: 2.1 measure differing **signal characteristics** 2.2 assess measured values for **appropriateness of use** 2.3 use **methods** and **techniques** to interpret measurements taken.

Range
Signal characteristics Continuous signals; discrete signals; frequency and period; peak; average; effective value; phase shift; amplitude; peak to peak; time domain; frequency domain; Fourier series of signals **Appropriateness of use** Errors; accuracy; significant digits; rounding numbers; statistical analysis; error rates. Including potential solutions to problems relating to values measured **Methods** Graphs (linear, polar and logarithmic – including line of best fit), tables and use of spreadsheets **Techniques** Graphical analytical techniques to illustrate outcomes including: system/component performance, fault diagnosis, compliance to design/operational parameters

Learning outcome
The learner will: 3. be able to apply the principles and techniques used in data acquisition systems
Assessment criteria
The learner can: 3.1 explain the **internal architecture** and operation of typical data acquisition systems 3.2 measure the performance of items under test using data acquisition systems 3.3 assess the performance of items under **test** using data acquisition systems.

Range

Internal architecture
Using block diagrams as appropriate: input section (eg transducers), signal conditioning and multiplexer, sampling methods, output filtering and corrections (sin x/x), errors, A/D conversion, CPU and I/O devices, data recording methods (eg graphic and magnetic), operation of bus structures and control of data lines.
Test
As appropriate to range included within 3.1

Learning outcome
The learner will: 4. understand procedures for the inspection of electrical systems
Assessment criteria
The learner can: 4.1 outline the **regulatory requirements** for inspection, testing and commissioning of **electrical systems** 4.2 outline the **procedures** to prepare for inspection of electrical systems 4.3 explain how **human senses** could be used during the **inspection** process 4.4 assess items that would form part of inspection checklists for **electrical systems**.

Range
Regulatory requirements UK current or international equivalents of: IET wiring regulations and IET Guidance Note 3 Electricity at Work Regulations 1989 **Electrical systems** Low voltage - new, existing, three phase, single phase **Procedures** Contact with client; arrange isolation timings; range and limitations of inspection; gather information (client, test results, certificates); risk assessment; prepare method statements **Human senses** Sight, touch, hearing, smell **Inspection** Initial installation, periodic review, minor works **Electrical systems** Low voltage - new, existing, three phase, single phase

Learning outcome
The learner will: 5. understand procedures used for testing of electrical systems
Assessment criteria
The learner can: 5.1 explain the purpose and procedures for conducting **regulatory tests** on **electrical systems** 5.2 explain the **preparation requirements** for testing 5.3 explain the **implications** of test values that are non-compliant with regulatory standards

5.4 explain the requirements for the safe and correct **use** of **instruments** to be utilised for testing.

Range
Regulatory tests Verify continuity of conductors (circuit protective, earthing, bonding, ring final); insulation resistance; polarity; earth electrode resistance; earth fault loop impedance; prospective fault current; correct operation of RCDs; functional testing; phase rotation (to include explanation of sequence of tests) **Electrical systems** Low voltage - new, existing, three phase, single phase **Preparation requirements** Risk assessment; safe system of work; precautions to be taken when carrying out tests; safe isolation; instrumentation fit for purpose; communication with clients; range and limitations **Implications** Shock; fire; burns; injury **Use** Correct scale/settings of the instrument; safety checks; functioning correctly; calibrated in accordance with regulatory requirements **Instruments** In accordance with UK current or international equivalents of: HSE guidance document GS 38; low resistance ohmmeter; insulation resistance tester; voltage and current indicating devices; earth fault loop impendence tester; prospective fault current tester; RCD tester; earth electrode tester; phase rotation meter

Learning outcome
The learner will: 6. understand the requirements for documenting installed electrical systems
Assessment criteria
The learner can: 6.1 explain the purpose of **certification** documentation 6.2 explain the responsibilities of **personnel** involved in the completion of certification **documentation** 6.3 explain the **regulatory requirements** for documenting electrical systems.

Range
Certification Electrical installation certificate; electrical installation condition report; minor works certificate; schedule of inspections; schedule of test results **Personnel** Designer; installer; tester **Documentation** Regulatory requirements; UK current or international equivalents of: IET wiring regulations; IET Guidance Note 3; recording; retention **Regulatory requirements** UK current or international equivalents of: IET wiring regulations; IET Guidance Note 3; recording; retention

Learning outcome
The learner will: 7. be able to inspect electrical wiring systems
Assessment criteria
The learner can: 7.1 use **safe systems** of work for inspection of electrical systems 7.2 carry out electrical system **inspections**.

Range
Safe systems Design; apply; document; safe isolation **Inspection** UK current or international equivalents of: IET Wiring Regulations, IET Guidance Note 3, specifications

Learning outcome
The learner will: 8. be able to test the safety of electrical systems
Assessment criteria
The learner can: 8.1 use **safe systems** of work for testing electrical systems 8.2 carry out **regulatory tests** of electrical systems 8.3 carry out **commissioning** of electrical systems.

Range
Safe systems Design; apply; document; safe isolation **Regulatory tests** Verify continuity of conductors (circuit protective, earthing, bonding, ring final); insulation resistance; polarity; earth electrode resistance; earth fault loop impedance; prospective fault current; correct operation of RCDs; functional testing; phase rotation (to include explanation of sequence of tests) **Commissioning** Functionality; fitness for purpose; safety in accordance with the installation specification and complete documentation (electrical installation certificates, schedules of inspections, schedules of test results)

Unit 414 Programmable logic controllers

Level:	4
GLH:	60
Assessment method:	Assignment
NLH:	100
Aim:	The purpose of this unit is to enable learners to develop an understanding of programmable controller systems. Learners will understand features, PLC information and communication techniques, programming methods and methods of diagnosing faults in programmable controlled environments. The unit also enables learners to practically apply skills and knowledge to create operational programs to drive PLCs in industrial related tasks.

Learning outcome
The learner will: 1. understand features of programmable controller systems
Assessment criteria
The learner can: 1.1 explain the advantages of processor controlled logic systems over relay logic systems 1.2 explain the **internal architecture** of Programmable Logic Controllers (PLCs) 1.3 explain the **operational characteristics** of PLCs 1.4 explain the operational requirements for input and output **devices** used by PLCs 1.5 evaluate **types** of communication link used in programmable logic control systems and controllers.

Range
Internal architecture Input and output units; storage devices; memory; central processing unit (CPU); address bus; data bus; control bus; arithmetic logic unit (ALU); opto-isolators; flags; shift; registers. **Operational characteristics** Scanning; performing logic operations; continuous updating; mass input/output (I/O) copying. **Devices** Mechanical switches; non-mechanical digital sources; transducers; relays. **Types** Twisted pair; coaxial; fibre-optic; networks

Learning outcome
The learner will: 2. understand PLC information and communication techniques
Assessment criteria
The learner can: 2.1 describe the **forms** of signal interface used by PLCs 2.2 explain the significance of digital **resolution** 2.3 calculate the resolution of analogue-to–digital converters 2.4 assess the uses of **number systems** in PLCs 2.5 evaluate **network topologies** used by PLCs 2.6 explain the use of logic functions in PLC programming 2.7 explain how to write ladder logic programs using **logic functions**.

Range
Forms Analogue (0-10 v dc, 4-20mA); digital **Resolution** 9-bit; 10-bit; 12-bit **Number systems** Decimal; binary; octal; hexadecimal; Binary-Coded Decimal (BCD) **Network topologies** Master to slave; peer to peer; ISO; IEE; MAP **Logic functions** AND; OR; EXCLUSIVE OR; NAND; NOR.

Learning outcome
The learner will: 3. understand PLC programming methods
Assessment criteria
The learner can: 3.1 explain the relationship between source codes and object codes 3.2 identify **methods** of using text in PLCs 3.3 assess the operation of PLC software **functions** 3.4 explain the application of different **PLC programming methods** 3.5 evaluate PLC **advanced functions**.

Range
Methods of using text in PLCs Contact labels; rung labels; programming lists; cross-referencing. **Functions** Contacts; coils; timers; counters; override facilities; flip-flops; shift registers; sequencers. **PLC programming methods** Ladder and logic diagrams; flow charts: statement lists; Boolean algebra; function diagrams; graphical programming languages. **Advanced functions** Less than; greater than; binary to BCD conversion; proportional feedback control.

Learning outcome
The learner will: 4. be able to create operational programs to drive PLCs in industrial related tasks
Assessment criteria
The learner can: 4.1 design operational PLC programs 4.2 **produce** operational PLC programs 4.3 **test - debug** PLC programs.

Range
Produce Enter suitable PLC programs **Test – Debug** **Run program and test for correct operation.** Forcing inputs, forcing outputs; changing data; comparing files (tapes, EPROM, disc); displayed error analysis.

Learning outcome
The learner will: 5. understand how to diagnose faults in programmable controller environments
Assessment criteria
The learner can: 5.1 describe **methods** of communicating symptoms of faults 5.2 evaluate **types** of fault finding techniques 5.3 assess the relationship between cause and effects of faults 5.4 recommend remedial action for the correction of system faults.

Range
Methods Verbal; written (job sheets, fault reports, production rejects) **Types** Safety; software (built in fault analysis, watchdog, disaster recovery); physical (power/battery, system indicators, half-split)

Unit 415 Principles of analogue circuits

Level:	4
GLH:	97
NLH:	150
Assessment method:	Assignment
Aim:	The purpose of this unit is to enable learners to develop an understanding of the principles and simple design of analogue circuits. Learners will understand the properties and applications of semiconductor diodes; characteristics, operation and applications of transistors; principles of gain and loss, related to the function of amplifiers in analogue circuits; feedback on amplifier performance. On completion of this unit, learners will be able to design simple linear and non-linear operational amplifier circuits; and design, and simulate oscillators and filters using the operational-amplifier.

Learning outcome
The learner will: 1. understand the properties, principles and applications of semiconductor diodes
Assessment criteria
The learner can: 1.1 explain the principles of **semiconductor** operation 1.2 evaluate the characteristics of diode **types** 1.3 calculate diode **resistance** using the diode equation 1.4 evaluate the use of diodes for different **applications**.

Range
Semiconductor Materials (Silicon, Germanium); P and N-type doping; PN junction; forward and reverse bias characteristics. **Types** Schottky; Zener; tunnel **Resistance** Static; dynamic **Applications** Power rectification; voltage reference; signal processing; light emitting; photosensitive diodes; variable capacitance; high voltage.

Learning outcome
The learner will: 2. understand the characteristics, operation and applications of transistors
Assessment criteria
The learner can: 2.1 analyse the operation of bipolar junction transistors in terms of their construction 2.2 explain the operation of a common emitter amplifier using **hybrid parameters** 2.3 analyse Common Emitter transistor amplifier **characteristics** 2.4 analyse the quiescent conditions of transistor amplifiers using different **methods** 2.5 analyse the operation of **field effect transistors** (FET) in terms of their construction 2.6 evaluate the application of transistor amplifier **biasing** against **parameters** 2.7 compare actual FET **output transfer characteristics** against manufactures data to assess component fidelity.

Range
Hybrid parameters hfe; hie; hoe; hre. **Characteristics** Static; dynamic resistance; gain **Methods** Load-line; algebraic **Field effect transistors** JFETs; IGFETs; MOSFET; NOMFET; CNTFET **Biasing** Common emitter; emitter follower; common source; **Parameters** Input impedance; output impedance; gain; stability. **Output transfer characteristics** Static (VDS; VGS; IG; ID; saturation, pinch-off; ohmic region)Dynamic (quiescent values and voltage gain)

Learning outcome
The learner will: 3. understand the operational properties, related to the function of amplifiers in analogue circuits
Assessment criteria
The learner can: 3.1 explain the use of the decibel (dB) 3.2 explain the **operating properties** of an amplifier 3.3 assess the principles of **noise** affecting components and circuits 3.4 evaluate the application of different **classes** of transistor amplifiers.
Range

Operating properties
Gain; attenuation; input impedance; output impedance
Noise
Thermal; cross-talk; Avalanche; burst noise; shot; calculation of signal-to noise ratio
Classes
A; B; AB; C

Learning outcome
The learner will: 4. understand the effects of feedback on amplifier performance
Assessment criteria
The learner can: 4.1 explain **types** of feedback applied to amplifiers 4.2 explain the **terms** associated with amplifier feedback 4.3 analyse the effect of loop gain on **amplifiers** 4.4 explain the effects of **feedback variables** on amplifiers 4.5 assess the relationship between gain and bandwidth on amplifier performance 4.6 solve loop gain using different **measures**.

Range
Types Positive; negative; voltage; current **Terms** Open loop; closed loop; stability; distortion; bandwidth. **Amplifiers** When under gain conditions G >>1; G<<1; using classic amplifier feedback equation **Feedback variables** Input and output impedances; series; shunt fed; voltage and current derived; frequency and phase; noise and distortion. **Measures** Decibels, power, voltage, current

Learning outcome
The learner will: 5. be able to design simple linear and non-linear operational amplifier circuits
Assessment criteria
The learner can: 5.1 explain the **operation** of an ideal operational amplifier 5.2 calculate the transfer functions in feedback circuit under different **conditions** 5.3 carry out **circuit** design calculations, including simulation for specified **applications**.

Range
Operation Including 'virtual earth' concept **Conditions** Linear; non-linear **Circuit** Linear (summing, difference, inverting and non-inverting amplifier circuits); non-linear (precision rectifier, precision voltage regulator). **Application** Level shifter; current-to-voltage converter; voltage-to-current converter

Learning outcome
The learner will: 6. be able to design and simulate oscillators using the operational-amplifier
Assessment criteria
The learner can: 6.1 state the feedback conditions required for an amplifier to give sustained oscillations 6.2 evaluate the operation of different **oscillator** circuits 6.3 carry out oscillator circuit design calculations at given frequencies 6.4 simulate the **design parameters** for oscillator operation.

Range
Oscillator R/C oscillator; phase-shift oscillator; Wien bridge oscillator **Design parameters** At given operating frequency

Learning outcome
The learner will: 7. be able to design and simulate simple filters using operational-amplifiers
Assessment criteria
The learner can: 7.1 explain the **parameters** of first and second order filters 7.2 use transfer functions to calculate mid-band gain and Q-factor 7.3 carry out filter design calculations 7.4 simulate the design parameters for **filter** operation.

Range
Parameters Transfer function (from first principles); asymptotic gain-frequency response **Filter** Low-pass, Sallen Key

Learning outcome
The learner will: 8. understand properties of data converters
Assessment criteria
The learner can: 8.1 explain **terms** associated with data conversion 8.2 explain the operational properties of analogue /digital **(converters)**.

Range
Terms Conversion time; conversion rate; conversion code; resolution; settling time; quantization error; nominal full-scale output; missing code; aliasing; oversampling **converters** 'R-2R' ladder; slope; successive approximation and flash

Unit 416 Sequential and combinational logic circuits

Level:	4
GLH:	66
NLH:	100
Assessment method:	Assignment
Aim:	The purpose of this unit is to enable learners to develop an understanding of designing simple sequential and combinational logic circuits. Learners will understand the function and features of logic device circuits. The unit also enables learners to practically apply skills and knowledge to design sequential and combinational logic circuits.

Learning outcome
The learner will: 1. understand the function and features of logic device circuits
Assessment criteria
The learner can: 1.1 evaluate the **function** of **logic gates** 1.2 evaluate the **principal characteristics** of different logic **families**.

Range
Function Symbols; truth tables; logic gate equivalence. **Logic gates** AND; OR; NOT; EXOR; NAND; NOR **Principal characteristics** Speed; power; cost; interface requirements (propagation delay). **Families** Complementary metal oxide – semiconductor (CMOS); transistor-transistor logic (TTL); ECL; BiCMOS

Learning outcome
The learner will: 2. be able to design simple combinational logic circuits
Assessment criteria
The learner can: 2.1 explain the **operation** of combinational **logic circuits** 2.2 produce minimised Boolean expressions using the **laws** of Boolean algebra 2.3 use **methods** to simplify Boolean functions 2.4 illustrate minimised Boolean expressions using **universal gates** 2.5 design minimised circuits using simulation to test against specifications.

Range
Operation Using Boolean expressions; truth tables **Logic circuits** Half adder; full adders; multiplexers and demultiplexers; code converters; comparators, decoders and encoders, parity checkers. **Laws** Commutative; associative; distributive; duality; de Morgan **Methods** Algebraic methods; graphical methods (Karnaugh Mapping) **Universal gates** NAND; NOR - Illustrate using logic diagrams; or other

Learning outcome
The learner will: 3. be able to design simple sequential logic circuits
Assessment criteria
The learner can: 3.1 assess **types** of sequential logic circuit 3.2 outline **standards** of graphical symbols for binary logic elements 3.3 describe the function of sequential **logic devices** 3.4 explain the operation of sequential circuits using **state diagrams** 3.5 produce state-transition and output tables from **state** diagrams 3.6 evaluate the minimum number of binary elements required to implement a sequential circuit from the number of internal system states 3.7 design minimised circuits using simulation to test against specifications.

Range
Types Synchronous; Asynchronous working **Standards** ANSI/IEE Std 91a-1991; BS EN 60617-12:1999; dependency notation; international equivalent **Logic devices** S-R; J-K; T-type and D-Type bistables (element in terms of a truth table, steering table, Karnaugh map; timing diagram); data latch; counter; shift register **State diagrams** Mealy or Moore model **State** Previous; next

Unit 417 Microprocessor based systems

Level:	4
GLH:	60
NLH:	100
Assessment method:	Assignment
Aim:	The purpose of this unit is to enable learners to develop an understanding of microprocessor based systems. Learners will understand the structure of microprocessor based systems. The unit also enables learners to practically apply skills and knowledge to • develop software for microprocessor-based systems • develop simple control software for programmable interface devices.

Learning outcome
The learner will: 1. understand the structure of microprocessor based systems
Assessment criteria
The learner can: 1.1 analyse **characteristics** of microprocessor based families 1.2 describe the **features** commonly found in a Centre Processing Unit (CPU) 1.3 describe the properties of **memory** components 1.4 explain common **applications** of embedded microprocessor based systems.

Range
Characteristics Speed; cost; input/output (I/O) facilities; instruction set; physical size; bus structure (address, data and control); word size **Features** Program Counter; Stack pointer; Status Register; General Purpose Registers; Arithmetic and Logic Unit (ALU); Instruction Set **Memory** SRAM; DRAM; flash memory **Applications**

- *Control systems*: Engine management systems (EMU); robotics; distributed control systems; coin-operated machines; printers
- *Instrumentation systems*: data acquisition systems; data logging systems; indicator display systems; 'intelligent' panel instruments; test equipment
- *Communication systems*: modems; radio transmitters; radar systems
- *Commercial systems*: electronic funds transfer at point of sale systems (EFTPOS); electronic bank teller machines; hand-held stock loggers

Learning outcome
The learner will: 2. be able to develop software for microprocessor-based systems
Assessment criteria
The learner can: 2.1 design software to given specifications using software design **techniques** 2.2 use computer **language** to develop programs for simple **operations** 2.3 use **software debugging tools** to **test** software against specifications.

Range
Techniques Algorithms in the form of a structure chart showing actions and conditions; pseudo code **Language** Assemblers; high-level language compilers (C++, Visual BASIC, Java, Pascal (Delphi)) **Operations** Interface to external devices: lights; switches; motors; heaters; keypads; liquid crystal displays (LCD); light emitting diode (LED) displays; printers; analogue to digital converters (ADC); digital to analogue converters (DAC) **Software debugging tools** Integrated Development Environment (IDE); In-Circuit Emulation (ICE); simulators **Test** Data (inputs and expected outputs) should be prepared prior to running programs and results of the tests should be documented

Learning outcome
The learner will: 3. be able to develop simple control software for programmable **interface** devices
Assessment criteria
The learner can: 3.1 evaluate programmable interface devices in terms of **functionality** 3.2 develop simple control software against given **specifications**.

Range
Interfaces Universal asynchronous receiver transmitter (UART); programmable peripheral interface (PPI); I/O mapped devices, memory-mapped devices **Functionality** Control signals; interrupts; polling; handshaking; port current rating; (interfaces can be in parallel or serial form in terms of performance or distance respectively). Programmable/configurable features **Specifications** Testing; control; monitoring

Unit 418 Maintenance of engineering systems and equipment

Level:	4
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
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
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
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; prescribed start up 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
GLH:	60
NLH:	150
Assessment method:	Assignment
Aim:	The purpose of this unit is to enable learners to develop an understanding of the principles and processes involved in engineering design. 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.

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

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 **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 420 Programming using C

Level:	4
GLH:	60
NLH:	150
Assessment method:	Assignment
Aim:	The purpose of this unit is to enable learners to develop problem solving and software programming skills to build C programs for specific engineering problems using appropriate abstractions to represent problems, requirements, algorithms and data structures; and to understand the role of documentation for improving software design, usability and maintenance.

Learning outcome
The learner will: 1. be able to apply knowledge of the software development life cycle and tools to build programs
Assessment criteria
The learner can: 1.1 explain characteristics of popular software development **models** 1.2 explain the purpose and the outcome of the **stages** in the Waterfall software development model 1.3 explain the purpose and usage of software development **tools** 1.4 use software development tools to edit, compile, and execute programs 1.5 construct pre-processor **directives** to manage compilation of programs 1.6 apply a program debugger to step through a program and to inspect values of program variables at different stages of execution

Range
Models Waterfall; Spiral; Iterative and incremental development; Agile programming; Rapid application development **Stages** System requirements; Software requirements; Analysis; Program design; Implementation; Testing; Operation and maintenance **Tools**

Editor; Pre-processor; Compiler; Linker; Debugger; Integrated Development Environment (IDE)

Directives

#include; #define; #ifdef/#ifndef

Learning outcome
The learner will: 2. understand software requirements, designs and quality metrics
Assessment criteria
The learner can: 2.1 explain **processes** for requirements identification and **methods** for requirements specification 2.2 distinguish between different **types** of software requirements 2.3 produce use cases and requirements lists for a given engineering problem 2.4 explain commonly used software quality **characteristics** and relationships between those characteristics and measurable software attributes 2.5 compare quality characteristics of programs based on measurable software attributes 2.6 produce requirements specification and software design documents according to the relevant documentation **standards**

Range
Processes Stakeholder identification; Stakeholder interviews; Facilitation and joint sessions **Methods** Contract-style lists; Use cases; Measurable goals **Types** Structural; Behavioural; Functional; Non-functional **Characteristics** Reliability, Security, Efficiency, Maintainability, Size **Standards** IEEE 1016-2009; IEEE 29148-2011

Learning outcome
The learner will: 3. be able to use problem solving to develop software programs which reflect considerations for usability and hardware portability
Assessment criteria
The learner can: 3.1 identify and select appropriate **data types** to represent information pertaining to a given engineering problem 3.2 explain representation of symbolic (character) and logical (Boolean) values using appropriate **encoding standards** 3.3 explain encoding of numeric data in different **hardware architectures** and analyse how this may affect software portability

3.4 use appropriate C language **expressions**, **control structures**, and **functions** to construct a program to solve a given engineering problem

3.5 apply the best practice in **coding conventions** and facilitate re-use of frequently used code, ease of maintenance, and collaborative development

Range

Data types

Void; Integer (char, short, int, long); Floating point (float, double, long double)

Encoding standards

ASCII

Hardware architectures

Big-endian; Little-endian

Expressions

Algebraic; Boolean

Control structures

Decision; selection; iteration (for, do/while, while)

Functions

Input/output (scanf(), printf()); user defined

Coding conventions

Code indentation; comments; naming

Learning outcome

The learner will:

4. be able to apply data structures and algorithms for software

Assessment criteria

The learner can:

4.1 declare and use appropriate **data structures** to represent information pertaining to a given engineering problem

4.2 distinguish between common **types** of algorithms

4.3 explain the concept of recursion and its theoretical and practical benefits

4.4 produce representations of algorithms with commonly used abstract **methods**

4.5 select and implement suitable **algorithms** to solve a given engineering problem

4.6 compare performance **characteristics** of different algorithms

Range

Data structures

Arrays; records (struct)

Types

Deterministic; Heuristic; Recursive

Methods

Flow charts; Pseudo code

Algorithms

Iterative; recursive; sorting; search

Characteristics

Time; memory

Learning outcome
The learner will: 5. be able to use information provided with software development tools and libraries
Assessment criteria
The learner can: 5.1 use built-in help sub-systems within software development **tools** 5.2 interpret information provided in reference manuals for software libraries to determine the purpose and **usage** for library functions 5.3 investigate online sources, including the use of Web search engines, to locate information about specific software development **topics**

Range
Tools Compiler; Linker; Debugger; Integrated Development Environment **Usage** Acceptable input parameter ranges; meaning of output values **Topics** Tools; functions; algorithms

Unit 421 Planning and implementing change within businesses

Level:	4
GLH:	30
NLH:	150
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. **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. **Organisational culture** Learners should be encouraged to refer to specific theories on organisational culture eg Thomas Handy: power culture, role culture, task culture, person culture. **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 should refer to specific theories such as Tannenbaum and Schmidt.

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 to monitor cost, quality, adherence to change programme, timescales eg how it can be used for continuous improvement. **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.

Unit 422 Personal and professional development

Level:	4
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: inter-personal, 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, feedback from others; skills scan; revisiting job role **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
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
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 427 Developing business improvement plans

Level:	4
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.

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

UK learners **General qualification information**	**T: +44 (0)844 543 0033** **E: learnersupport@cityandguilds.com**
International learners General qualification information	T: +44 (0)844 543 0033 F: +44 (0)20 7294 2413 E: **intcg@cityandguilds.com**
Centres Exam entries, Certificates, Registrations/enrolment, Invoices, Missing or late exam materials, Nominal roll reports, Results	T: +44 (0)844 543 0000 F: +44 (0)20 7294 2413 E: **centresupport@cityandguilds.com**
Single subject qualifications Exam entries, Results, Certification, Missing or late exam materials, Incorrect exam papers, Forms request (BB, results entry), Exam date and time change	T: +44 (0)844 543 0000 F: +44 (0)20 7294 2413 F: +44 (0)20 7294 2404 (BB forms) E: **singlesubjects@cityandguilds.com**
International awards Results, Entries, Enrolments, Invoices, Missing or late exam materials, Nominal roll reports	T: +44 (0)844 543 0000 F: +44 (0)20 7294 2413 E: **intops@cityandguilds.com**
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**
Publications Logbooks, Centre documents, Forms, Free literature	T: +44 (0)844 543 0000 F: +44 (0)20 7294 2413

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As the UK's leading vocational education organisation, City & Guilds is leading the talent revolution by inspiring people to unlock their potential and develop their skills. We offer over 500 qualifications across 28 industries through 8500 centres worldwide and award around two million certificates every year. City & Guilds is recognised and respected by employers across the world as a sign of quality and exceptional training.

City & Guilds Group

The City & Guilds Group operates from three major hubs: London (servicing Europe, the Caribbean and Americas), Johannesburg (servicing Africa), and Singapore (servicing Asia, Australia and New Zealand). The Group also includes the Institute of Leadership & Management (management and leadership qualifications), City & Guilds Licence to Practice (land-based qualifications), the Centre for Skills Development (CSD works to improve the policy and practice of vocational education and training worldwide) and Learning Assistant (an online e-portfolio).

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