QUALIFICATION HANDBOOK

Level 4 Diploma in Advanced Manufacturing Engineering (2875-40)

March 2017 Version 2.1

City & Guilds

Qualification at a glance

Subject area	**Engineering**
City & Guilds number	2875
Age group approved	19+
Entry requirements	N/A
Assessment	• Centre set and marked assignments • Externally set, internally marked assignments
Fast track	N/A
Support materials	• Centre handbook • Assessment pack • Exemplar assignments • Centre devised assignment writing guidance • Recording forms • Online tutor and learner support material
Registration and certification	Consult the Walled Garden/Online Catalogue for last dates

Title and level	City & Guilds number	Accreditation number
Level 4 Diploma in Mechanical Manufacturing Engineering	2875-40	600/6874/7
Level 4 Diploma in Electrical and Electronic Engineering	2875-40	600/6955/7
Level 4 Diploma in Aeronautical Engineering	2875-40	600/9042/X

Contents

1 Introduction

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

Area	Description
Who are the qualifications for?	These qualifications allow candidates to learn, develop and practise the skills required for employment and/or career progression in Advanced Manufacturing Engineering. They also serve as Technical Certificates in the Advanced Manufacturing Engineering Level 4 apprenticeship framework.
What do the qualifications cover?	They allow candidates to learn, develop and practise the skills required for employment and/or career progression in the manufacturing sector.
Are the qualifications part of a framework or initiative?	These qualifications serve as technical certificates in the Level 4 Advanced Manufacturing Apprenticeship framework.
What opportunities for progression are there?	They allow candidates to progress into employment or to the following qualifications: • ILM Level 4 or Level 5 Qualifications in Management • City & Guilds Professional Recognition Awards. • Foundation Degree or other Higher Education qualifications These qualifications may also provide preparation towards professional registration as an Engineering Technician and progression to Incorporated Engineer registration.

Structure

To achieve the **Level 4 Diploma in Mechanical Manufacturing Engineering**, learners must achieve **70** credits from the mandatory units and a minimum of **50** credits from the optional units available.

Unit accreditation number	City & Guilds unit number	Unit title	Credit value
Mandatory			
D/504/4011	Unit 401	Quality assurance and control	15
K/504/4030	Unit 402	Human factors in the workplace	15
M/504/4014	Unit 403	Engineering planning and scheduling	15
F/504/4017	Unit 404	Statistical analysis for Engineers	10
R/504/4023	Unit 405	Principles of mechanical component manufacture	15
Optional B1 – Learners must take a minimum of 30 credits from this group			
F/601/1626	Unit 406	Materials engineering	15
Y/504/4024	Unit 407	Automated machining of materials	10
D/504/4025	Unit 408	Introducing CAD/CAM systems in advanced manufacturing	10
H/504/4026	Unit 409	Engineering mathematics	15
K/504/4027	Unit 410	Industrial robotics	10
T/504/4029	Unit 411	Statistical process control	10
M/504/4031	Unit 412	Metal fabrication technology	15
L/504/4036	Unit 413	Welding technology and practice	10
F/504/4034	Unit 414	Quality assurance and testing of welded joints	10
Y/504/4041	Unit 415	Maintenance of engineering systems and equipment	15
J/601/1417	Unit 416	Instrumentation and control principles	15
R/504/9626	Unit 418	Engineering design	15

D/504/9631	Unit 445	Principles of composite materials	15
J/504/9638	Unit 446	Principles of composites manufacture	15

Optional B2 – Learners must take a minimum of 20 credits

F/601/1500	Unit 417	Engineering procurement	15
H/504/2910	Unit 420	Planning and implementing change within businesses	10
K/504/1449	Unit 421	Personal and professional development	10
T/504/1129	Unit 422	Project Management	15
F/602/1797	Unit 423	Managing information and knowledge	15
H/504/9713	Unit 450	Developing business improvement plans	10
H/504/4043	Unit 501	Work based project	20

To achieve the **Level 4 Diploma in Electrical and Electronic Engineering**, learners must achieve **70** credits from the mandatory units and a minimum of **50** credits from the optional units available.

Unit accreditation number	City & Guilds unit number	Unit title	Credit value
Mandatory			
D/504/4011	Unit 401	Quality assurance and control	15
K/504/4030	Unit 402	Human factors in the workplace	15
M/504/4014	Unit 403	Engineering planning and scheduling	15
F/504/4017	Unit 404	Statistical analysis for Engineers	10
K/504/4450	Unit 425	Principles of electrical and electronic engineering	15
Optional B1 – Learners must take a minimum of 30 credits from this group			
H/504/4026	Unit 409	Engineering mathematics	15
Y/504/4041	Unit 415	Maintenance of engineering systems and equipment	15
J/601/1417	Unit 416	Instrumentation and control principles	15
R/504/9626	Unit 418	Engineering design	15
Y/504/4458	Unit 426	Data communication and networks	15
Y/504/4461	Unit 427	Understand uses and operation of electrical machines for engineering operations	10
D/504/4462	Unit 428	Using electrical protection techniques for engineering operations	10
R/504/4460	Unit 429	Electrical services and installation	10
T/504/4466	Unit 430	Electrical supply and distribution	10

M/504/4465	Unit 431	Testing and measurement of electronic and electrical systems	15
A/504/4467	Unit 432	Programmable logic controllers	10
A/504/4453	Unit 433	Designing analogue circuits	15
R/504/4457	Unit 434	Designing sequential and combinational logic circuits	10
L/505/5912	Unit 435	Microprocessor-based systems	10
D/504/9631	Unit 445	Principles of composite materials	15
J/504/9638	Unit 446	Principles of composites manufacture	15

Optional B2 – Learners must take a minimum of 20 credits

F/601/1500	Unit 417	Engineering procurement	15
H/504/2910	Unit 420	Planning and implementing change within businesses	10
K/504/1449	Unit 421	Personal and professional development	10
T/504/1129	Unit 422	Project Management	15
F/602/1797	Unit 423	Managing information and knowledge	15
H/504/9713	Unit 450	Developing business improvement plans	10
H/504/4043	Unit 501	Work based project	20

To achieve the **Level 4 Diploma in Aeronautical Engineering**, learners must achieve **60** credits from the mandatory units and a minimum of **60** credits from the optional units available.

Unit accreditation number	City & Guilds unit number	Unit title	Credit value
Mandatory			
D/504/4011	Unit 401	Quality assurance and control	15
K/504/4030	Unit 402	Human factors in the workplace	15
M/504/4014	Unit 403	Engineering planning and scheduling	15
D/504/9628	Unit 440	Fundamentals of airworthiness management	15
Optional B1 – Learners must take a minimum of 10 credits from this group			
F/504/4017	Unit 404	Statistical analysis for Engineers	10
D/504/4025	Unit 408	Introducing CAD/CAM systems in advanced manufacturing	10
H/504/4026	Unit 409	Engineering mathematics	15
R/504/9626	Unit 418	Engineering design	15
K/504/4450	Unit 425	Principles of electrical and electronic engineering	15
F/601/1450	Unit 502	Mechanical principles	15
Optional B2 – Learners must take a minimum of 30 credits from this group			
Y/504/9630	Unit 441	Integrated aircraft systems	10
A/504/9765	Unit 442	Fault finding diagnosis	10
F/504/9766	Unit 443	Communication and navigation systems	15
J/504/9767	Unit 444	Efficient maintenance in aircraft operations	5
D/504/9631	Unit 445	Principles of composite materials	15

J/504/9638	Unit 446	Principles of composites manufacture	15

Optional B3 – Learners must take a minimum of 20 credits from this group

F/601/1500	Unit 417	Engineering procurement	15
H/504/2910	Unit 420	Planning and implementing change within businesses	10
K/504/1449	Unit 421	Personal and professional development	10
T/504/1129	Unit 422	Project Management	15
F/602/1797	Unit 423	Managing information and knowledge	15
H/504/9713	Unit 450	Developing business improvement plans	10
H/504/4043	Unit 501	Work based project	20

2 Centre requirements

Approval

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

To offer this qualification, new centres will need to gain both centre and qualification approval. Please refer to the *Centre Manual - Supporting Customer Excellence* for further information.

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

Centre staffing

It is important that centre staff involved in the delivery or internal quality assurance of this qualification have the appropriate knowledge and skills to ensure its effective delivery.

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

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

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

Assessors and internal quality assurers

Assessor/Verifier (A/V) units are valued as qualifications for centre staff, but they are not currently a requirement for the qualification. However, it is strongly recommended that Assessors and Internal Quality Assurers hold these qualifications or equivalent if they are going to be involved in writing and approving centre set and marked assignments.

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 quality assurance is in line with best practice, and that it takes account of any national or legislative developments.

Candidate entry requirements

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

Age restrictions

City & Guilds cannot accept any registrations for candidates under 19 as this qualification is not approved for under 19s.

3 Delivering the qualification

Initial assessment and induction

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

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

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

Support materials

The following resources are available for this qualification:

Description	How to access
Assessment pack	Available on the qualification pages on the **City & Guilds Website**
Exemplar assignments	Available on the qualification pages on the **City & Guilds Website**
Developing centre devised assessments (guidance for centre based assessment writers GM1)	Available on the qualification pages on the **City & Guilds Website**
Centre devised recording forms	Available on the qualification pages on the **City & Guilds Website**

Recording documents

City & Guilds has developed a set of Centre Devised Recording forms, for new and existing centres to use as appropriate when developing centre set and marked assignments.

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

4 Assessment

The units within this qualification are assessed by assignments, which are set and marked by the centre.

Detailed assessment guidance for all units is provided in a separate Assessment Pack. Exemplar assignments are also provided for the mandatory units and a sample of optional units which centres may use as is or tailor to suit local circumstances. Assessment materials are available to download from the qualification pages on the City & Guilds website **www.cityandguilds.com**

Centre set assignments must be approved by the Qualifications Consultant (QC) before use. For each assignment, the *Assignment Sign Off Sheet* (AD3) must be completed and be made available to the QC for inspection. For further guidance on the approval process for centre set assignments and guidance on how to produce, please refer to the document, 'Developing centre devised assessments – guidance for centre based assessment writers (GM1)', which is available to download from the qualification page on the City & Guilds website. Recording forms and generic marking and grading criteria are also provided on these pages.

Unit	Title	Assessment method	Where to obtain assessment materials
401	Quality assurance and control	Centre devised assignment.	City & Guilds Website
402	Human factors in the workplace	Centre devised assignment.	City & Guilds Website
403	Engineering planning and scheduling	Centre devised assignment.	City & Guilds Website
404	Statistical analysis for Engineers	Assignment.	City & Guilds Website
405	Principles of mechanical component manufacture	Centre devised assignment.	City & Guilds Website
406	Materials engineering	Centre devised assignment.	City & Guilds Website
407	Automated machining of materials	Centre devised assignment.	City & Guilds Website

Unit	Title	Assessment method	Where to obtain assessment materials
408	Introducing CAD/CAM systems in Advanced Manufacturing	Centre devised assignment.	City & Guilds Website
409	Engineering mathematics	Assignment.	City & Guilds Website
410	Industrial robotics	Centre devised assignment.	City & Guilds Website
411	Statistical process control	Centre devised assignment.	City & Guilds Website
412	Metal fabrication technology	Centre devised assignment.	City & Guilds Website
413	Welding technology and practice	Centre devised assignment.	City & Guilds Website
414	Quality assurance and testing of welded joints	Centre devised assignment.	City & Guilds Website
415	Maintenance of engineering systems and equipment	Centre devised assignment.	City & Guilds Website
416	Instrumentation and control principles	Centre devised assignment.	City & Guilds Website
417	Engineering procurement	Centre devised assignment.	City & Guilds Website
418	Engineering design	Centre devised assignment.	City & Guilds Website
420	Planning and implementing change within businesses	Centre devised assignment.	City & Guilds Website
421	Personal and professional development	Centre devised assignment.	City & Guilds Website
422	Project Management	Centre devised assignment.	City & Guilds Website
423	Managing information and knowledge	Centre devised assignment.	City & Guilds Website
425	Principles of electrical and electronic engineering	Assignment.	City & Guilds Website

Unit	Title	Assessment method	Where to obtain assessment materials
426	Data communication and networks	Centre devised assignment.	City & Guilds Website
427	Understand uses and operation of electrical machines in engineering operations	Centre devised assignment.	City & Guilds Website
428	Using electrical protection techniques for engineering operations	Centre devised assignment.	City & Guilds Website
429	Electrical services and installation	Centre devised assignment.	City & Guilds Website
430	Electrical supply and distribution	Centre devised assignment.	City & Guilds Website
431	Testing and measurement of electronic and electrical systems	Centre devised assignment.	City & Guilds Website
432	Programmable logic controllers	Centre devised assignment.	City & Guilds Website
433	Designing analogue circuits	Centre devised assignment.	City & Guilds Website
434	Designing sequential and combinational logic circuits	Centre devised assignment.	City & Guilds Website
435	Microprocessor based systems	Centre devised assignment.	City & Guilds Website
440	Fundamentals of airworthiness management	Centre devised assignment.	City & Guilds Website
441	Integrated aircraft systems	Centre devised assignment.	City & Guilds Website
442	Fault finding diagnosis	Centre devised assignment.	City & Guilds Website
443	Communication and navigation systems	Centre devised assignment.	City & Guilds Website

Unit	Title	Assessment method	Where to obtain assessment materials
444	Efficient maintenance in aircraft operations	Centre devised assignment.	City & Guilds Website
445	Principles of composite materials	Centre devised assignment.	City & Guilds Website
446	Principles of composites manufacture	Centre devised assignment.	City & Guilds Website
450	Developing business improvement plans	Centre devised assignment.	City & Guilds Website
501	Work based project	Centre devised assignment.	City & Guilds Website

Time constraints

Centre staff should guide candidates to ensure excessive evidence gathering is avoided. Centres finding that assignments are taking longer, should contact their Qualifications Consultant for guidance.

All assignments must be completed and assessed within the candidate's period of registration. Centres should advise candidates of any internal timescales for the completion and marking of individual assignments.

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.

Centre set and marked assessments

City & Guilds has provided separate guidance for writers of centre based assessments which should be read in conjunction with this document, entitled, **'GM1 - Developing centre devised assessments** – guidance for centre based assessment writers'.

A set of generic recording forms is also provided as follows:

- Assessment tasks (AD1)
- Assessment grading criteria (AD2)
- Assessment sign off form (AD3)
- Evidence recording form (GF1)
- Assessment unit front and mark sheet (GF2)
- Assessment task front sheet (GF3)
- Assessment unit mark sheet (GF4)
- Assessment feedback and action plan form (GF5)
- Qualification assessment tracking form (GF6)

- Group assessment tracking form (GF7)

A full explanation of the use of these forms can be found in the centre devised assessment writing guidance. All of this material is available to download from the City & Guilds website.

5 Units

Availability of units

The following units can also be obtained from the Register of Regulated qualifications: **www.register.ofqual.gov.uk**

Structure of units

These units each have the following:

- City & Guilds reference number
- unit accreditation number (UAN)
- title
- level
- credit value
- guided learning hours
- unit aim
- learning outcomes which are comprised of a number of assessment criteria.

Unit 401 Quality assurance and control

UAN:	**D/504/4011**
Level:	4
Credit value:	15
GLH:	42
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
Attributes Leadership; people management and motivation; process capability; communication; customer focus **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; zero errors or zero defects; mind set; internal and external customers; organisations focus on the customers to meet their needs by standardisation of procedures / policies; use of innovation through quality improvement techniques / methodology including quality circles, Kaizen; supply to customers should try to exceed their expectations; continuous improvement policy

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, checking, measurement and testing; teamwork **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

Interrelationships of BEMs Leadership; strategic planning; added value for customers; knowledge management; team/partnership building; 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 senior management; communication within organisation; involvement of the whole organisation; management of Six Sigma philosophy as a project; education and training of the workforce; identification of 'champions'

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 balanced scorecard; use of 'soft' metrics such as punctuality, customer satisfaction; use of 'hard' metrics such as mass, weight, length; sampling plans

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).

Unit 402 Human factors in the workplace

UAN:	**K/504/4030**
Level:	4
Credit value:	15
GLH:	60
Aim:	The purpose of this unit is to enable learners to develop an understanding of the principles of human factors in manufacturing environments. Learners will look at the importance and impact of human factors on performance in the workplace, gain an appreciation for workplace company culture, recognise effective methods of communication, know principles of leadership and management, and will be able to carry out risk assessments.

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

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

Learning outcome
The learner will: 2. Understand features and limitations of human performance
Assessment criteria
The learner can:

2.1 Explain how low and very high **light levels affect** visual performance 2.2 Explain how **levels of noise affect** human performance 2.3 Explain **factors** that affect limitations of the human memory 2.4 Assess how working in **challenging environments** increases risks occurrence

Range
Light levels Reflective index; strobe effect; peripheral vision; image flicker; colour rendering **Effect on visual performance** Fatigue; visual inspection; residual image; long term sight damage **Levels of noise** Prolonged; intermittent; percussive **Effects on human performance** Communication errors; fatigue **Factors** Attention span; time from exposure to information; fatigue; age; complexity of information; artificial stimulants; depressants; overconfidence; boredom **Challenging environments** Claustrophobia; fear of heights; limited access; confined space; low concentration; time constraints; cutting corners; poor vision; environmental extremes; peer pressure

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

Range
Company culture Different types of culture (shift, teams, social); safety culture; individuals; compromise **Individual and group responsibility**

Roles and responsibilities and the interaction between; groups and teams; individuals; inter group dynamics; shift handovers

Relationship
Differentiate between management and supervisor roles; expectations; organisations

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

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

Learning outcome
The learner will: 5. Understand how the execution of different tasks can affect human performance
Assessment criteria
The learner can: 5.1 Explain the importance of **planning and executing** tasks 5.2 Explain how **demanding work** can affect human performance 5.3 Analyse the **aspects** of working on complex systems

Range
Planning and executing tasks Define the tasks; resources; personal skills and proficiency information; planning of repetitive tasks (complacency; assumption of time) **Impact of demanding work**

Health and physical condition; effects of lack of physical fitness against the work standard for the occupation; work environment; physical effort; effects of ageing; visual inspection (importance of good eyesight, knowledge of inspection, illumination, concentration, systematic search)

Aspects

Simple system transparent; complex system opaque; clear understanding of the purpose of the system; pooling of knowledge and skills; comprehensive information and guidance; associated hazards

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

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

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

Range
Causes of error Complacency; overconfident; lack of knowledge; poor training; lack of information; lack of interest; inattention; distractions; environmental; violations; communication

Methods of managing and avoiding errors Self-discipline; safety management system; anonymous and blame-free reporting; review of error logs; formal briefing; coaching; mentoring; training (new and refresher)

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

Range
Five steps Identify hazards; evaluate; record findings; review and update

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

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

Unit 403 Engineering planning and scheduling

UAN:	**M/504/4014**
Level:	4
Credit value:	15
GLH:	66
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 404 Statistical analysis for Engineers

UAN:	**F/504/4017**
Level:	4
Credit value:	10
GLH:	45
Aim:	The purpose of this unit is to enable learners to develop an understanding of statistical concepts and operations used in analysis. Learners will understand the need to collect valid and appropriate sample data from a process to support the statistical analysis of process performance or of problems with that process. Learners will acquire skills and knowledge of statistical analysis techniques and will be able to apply them to the study of engineering products and processes. Learners will be able to provide unbiased conclusions and recommendations arising from the analysis undertaken.

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

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

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

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

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

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

Learning outcome
The learner will: 4. Be able to solve industrial problems using statistical analysis of sample data
Assessment criteria
The learner can: 4.1 Test proposed **statistical hypotheses** about given populations 4.2 Use **tests** to identify population distributions 4.3 Conduct one-way **analyses of variance** (ANOVA) 4.4 Produce **quality control** charts for monitoring production 4.5 Evaluate the **reliability** of manufactured engineering products

Range
Statistical hypotheses Null and alternative hypotheses (type 1 and 2 errors, level of significance, operating characteristic curves); tests for means (one sample and two sample t-tests with known or unknown variance, paired t-tests) **Tests to identify population distributions** Goodness of fit test; chi-square test **Analysis of variance** Assumptions; single factor (one-way) tests; fixed effects model; random effects model **Quality control** Process in statistical control; effects of assignable causes; sample selection; control charts for continuous variables and attributes; upper and lower control limits; warning limits; $\bar{x}$ and R charts; interpretation and use of control charts **Reliability** Failure rate function (hazard function); reliability modelling and estimation; exponential failure law; mean time to failure; use of Weibull plots; reliability of systems comprising components in serial and parallel combinations with active or standby redundancy

Unit 405 Principles of mechanical component manufacture

UAN:	**R/504/4023**
Level:	4
Credit value:	15
GLH:	52
Aim:	The purpose of this unit is to enable learners to develop an understanding of a wide range of manufacturing methods for metallic and non-metallic mechanical components and will be able to analyse the manufacturing requirements of mechanical components, compare and select from different manufacturing methods, determine suitable finishing processes for varying component specifications, and identify the requirements for, and methods of, component inspection.

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

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

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

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

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

Range
Processing methods

Casting; extrusion; forming; moulding; cutting and joining

Methods of casting

Die casting (both low and high pressure); investment casting (lost wax process); centrifugal casting; sand casting (sand bonded with chemicals or clay and water or oil); shell casting; spin casting

Methods of forming

Cold sizing; extrusion; drawing (including deep drawing); forging; hydroforming; roll forming; powder metallurgy.

Latest developments

Rapid prototyping; 3-D printing

Methods of moulding polymers

Polymerisation; thermoplastic and thermosetting polymers; injection moulding; extrusion moulding; compression moulding; roto-moulding.

Machining processes

Turning; milling; drilling; grinding; broaching; use of cutting fluid or coolant

Specialty machining processes

Ultrasonic machining; high pressure water jet cutting; abrasive water jet cutting and abrasive jet machining

Methods for joining

Welding (oxy-fuel, MIG, TIG); brazing; soldering and adhesive bonding

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

Range
Heat treatment processes Annealing; precipitation strengthening; quenching; tempering **Processes** Grinding; lapping; honing; super finishing

Surface treatment processes to improve resistance to wear
Nitriding; case hardening; hard chrome finish

Surface treatment processes to improve resistance to corrosion
Galvanising; anodising; tin plating; sheradising; electroplating

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

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

Unit 406 Materials Engineering

UAN:	**F/601/1626**
Level:	4
Credit value:	15
GLH:	60
Aim:	The purpose of this unit is to enable learners to develop an understanding of the properties, selection criteria, relationships between processes and behaviour, and causes of failure of engineering materials.

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

Range
Criteria for selection Characteristics; costs **Categories of engineering materials** Metals; ceramics; polymers; composites **Test data** Electrical conductivity/resistivity; magnetic susceptibility; mechanical strength; hardness; toughness; fatigue and creep resistance; corrosion and reactivity; wear resistance; optical and thermal properties; formability; appropriate statistical methods; processing of test data **Sources**

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

Learning outcome
The learner will: 2. Understand the relationships between manufacturing processes and material behaviour
Assessment criteria
The learner can: 2.1 Explain how one heat **treatment process** and two other treatment processes effect the structure properties and behaviour of the parent material 2.2 Explain how one **liquid processing** method and two **mechanical processing** methods affect the structure, properties and behaviour of the parent material 2.3 Investigate how the **composition and structure** of metal alloys, polymers and polymer matrix composites, influences the properties of the parent material

Range
Treatment processes Heat treatments (quench and precipitation hardening processes); complex heat treatments (conjoint mechanical/thermal treatments, glass transitions); other treatment processes (coated materials; chip technology; surface treatments/surface engineering; polymer treatments; composites/powder produced materials; matrix / reinforcement relationships; dispersion strengthening) **Liquid processing** Metal casting and injection moulding/extrusion of polymers **Mechanical processing** Mechanical working of metals; powder processing of metals and ceramics; extrusion and forming of polymer sheet; welding; use of adhesives **Composition and structure** Alloying; co-polymerisation; additives; cross-linking; crystallinity; lattice structure; slip planes

Learning outcome
The learner will: 3. Be able to select suitable materials and processing methods for a specific product
Assessment criteria
The learner can: 3.1 Analyse the function/s of a product in terms of the materials' **constraints** on its **design**

3.2	Identify the required **properties** for the product and select the most appropriate materials and processing methods
3.3	Identify and explain the possible **limitations** on the product imposed by the processing and by the need to safeguard the environment and minimise costs

Range

Design constraints

Working conditions; environment; electrical/magnetic requirements; shape; form and function of the product

Properties

Merit index/index of suitability; ability to be recycled

Processing limitations

Effects of the manufacturing processing capabilities on the structure of materials; preventing or facilitating product design; effect on environment (sustainability, emissions, energy conservation, disposal)

Learning outcome

The learner will:

4. Understand the in-service causes of failure of engineering materials

Assessment criteria

The learner can:

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

Range

Causes of in-service failure

Creep; fatigue; impact; overstressing; corrosion; temperature; thermal cycling; residual stresses; stress relaxation; degradation (composition change); radiation; electrical; breakdown

Methods

Simulation; experimentation; research data

Early failure

Inappropriate maintenance; inappropriate use; faults in manufacture; material selection and design faults; changes in service conditions such as environment; loading and temperature

Improving service life

Changes to material; product design; protective systems for corrosion and degradation; adjustment loading and working temperature; preventative maintenance

Unit 407 Automated machining of materials

UAN:	**Y/504/4024**
Level:	4
Credit value:	10
GLH:	40
Aim:	The purpose of this unit is to enable learners to develop an understanding of modern machining systems, the importance of information links between CAD product data and manufacturing data, the role of process planning in manufacturing and the types of process planning available. On successful completion of this unit, learners will be able to prepare part-programs for a CNC machine, set up a CNC machine to safely machine a part, test and prove a new part-program and, if necessary, edit the program, and produce the part on a CNC machine.

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

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

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

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

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

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

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

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

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

Learning outcome
The learner will: 5. Be able to produce parts using CNC machines
Assessment criteria
The learner can:

5.1	Describe essential **safety features** needed when setting and operating CNC machines
5.2	Describe the **main steps** to take when testing/proving part-programs
5.3	Describe **tooling systems** used in CNC machining
5.4	Produce **simple CNC part-programs**
5.5	Explain the functions and features available in **part-holding and setting devices** used with CNC machines

Range

Essential features

Identify precautions that need to be taken to prevent accidents when setting and operating CNC machines; be familiar with the location and function of emergency stop and program stop controls; check that guards; interlocking devices and fail safe mechanisms are operating correctly

Main steps

Set work datum and tool length offset values; perform a trial run of the part-program to identify unwanted rapid tool movements; reduce unnecessary tool movements; make adjustments to speeds and feeds or compensate for errors; look for potential hazards; tool collisions; swarf/chips problems; rapid movement of machine parts and tooling; entrapment; avoidance using machine over-ride controls; edit the part-program if changes are required during the trial run

Tooling systems

Preset; qualified and semi-qualified tools; tool libraries; tool identification; geometry; offset values; speed; feed and tool life data; devices for monitoring tool life and cutting conditions; tool breakage detection; tool offset measurements

Simple CNC program

Use programming codes and sequence of operations to define a program; test the program with tool path simulation; implement on a CNC machine; run program; evaluate performance

Part-holding and setting devices

Conventional part-holding devices modified to suit CNC operation; positioning part datum relative to machine datum; the need for zero shift controls and how they are used; use of air and hydraulic part-holding devices for gripping delicate components; methods for accurately setting part-holding devices relative to machine slide movements

Unit 408 Introducing CAD/CAM systems in advanced manufacturing

UAN:	**D/504/4025**
Level:	4
Credit value:	10
GLH:	40
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. Understand the benefits of using CAD/CAM systems
Assessment criteria
The learner can: 1.1 Explain the **need** to integrate and automate computer-based engineering applications 1.2 Explain the philosophy of concurrent engineering 1.3 Explain how design **techniques** can take advantage of CAD/CAM systems 1.4 Describe the **benefits** of simulation and testing using CAD/CAM systems 1.5 Assess rapid prototyping and other latest developments

Range
Need Greater flexibility; improved response to customer requirement; reduced inventory; integrated systems **Techniques** Design For Manufacture and Assembly (DFMA) **Benefits** Safety; efficiency

Learning outcome
The learner will: 2. Understand methods of data transfer between systems
Assessment criteria
The learner can: 2.1 Explain the different **file formats** for transferring geometrical data from one system to another 2.2 Describe the data transfers between **different systems** 2.3 Describe how the **integration** of different systems can be achieved

Range
File formats DWG, DXF, IGES, STL, VRML, HPGL, STEP **Different systems** CAD to CAM to CNC; CAD to STL and rapid prototyping; CAD to Bill of materials **Integration** High speed; fibre optic; www; LAN; high speed serial links(USB)

Learning outcome
The learner will: 3. Be able to recommend introducing CAD/CAM to manufacturing processes
Assessment criteria
The learner can: 3.1 Carry out **reviews** of exiting manufacturing **capabilities** 3.2 Define specifications for appropriate CAD/CAM systems 3.3 Produce **business cases** for introducing CAD/CAM systems to manufacturing processes

Range
Review SWOT analysis **Capabilities** Staff; costs; loans; equipment; training; devaluation **Business cases** Objectives; expected benefits; options; costs; gap analysis; risk analysis

Unit 409 Engineering mathematics

UAN:	**H/504/4026**
Level:	4
Credit value:	15
GLH:	60
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 used by other units in the qualification and are needed for the solution of many 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

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 (axn, (ax ± b)n, sinn(ax ± b), cosn(ax ± b), e(ax ± b) , ln(ax ± 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, axn (n ≠ -1), 1/x, sin(ax± b), cos(ax± b), e(ax± 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 = √-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 410 Industrial robotics

UAN:	**K/504/4027**
Level:	4
Credit value:	10
GLH:	35
Aim:	The purpose of this unit is to enable learners to develop an understanding of the reasons for using robots in manufacturing and gain knowledge of the many application areas in which robots are already used. They will have knowledge of the classification and geometrical and kinematic configurations of robot arms, their accuracy and repeatability and the types of computer-based control systems used. Also, they will gain knowledge of the tooling (robot end effectors) needed for robots to carry out manufacturing tasks. Robot programming methods will be introduced in the unit and learners will have the opportunity to produce and test working robot programs. Learners will also have knowledge and understanding of the technology requirements for integrating robots into manufacturing operations involving other machines and equipment and will have a clear understanding of the safety needs of human operators when interacting with robots.

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

Range
Advantages

Remove humans from hazardous areas; repetitive; boring tasks; lifting heavy loads; decrease labour costs; increase precision and productivity; provide more flexibility than specialised machines; consistency of performance

Application areas
Materials handling (palletising); machine loading and unloading; welding (spot and MIG welding); spray painting; assembly

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

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

components

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

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

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

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

Unit 411 Statistical process control

UAN:	**T/504/4029**
Level:	4
Credit value:	10
GLH:	52
Aim:	The purpose of this unit is to enable learners to develop an understanding of Statistical Process Control and the application of statistical tools and methodology to achieve process control, the acceptability of product quality and determine process capability. The unit will extend the learner's knowledge and understanding in an area closely related to Quality Assurance and Quality Control and give the opportunity to apply and develop previously acquired knowledge of mathematical statistics.

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

Range
Principles Adding value to products; waste management (Toyota's 7 Wastes); effects of quality on real costs of production **Features** Mean; standard deviation **Types of data**

Attribute; variable

Control charts
c charts; p charts; u charts

Datum values
Upper warning or control limits (UCL); lower warning or control limit (LCL); the centre line (actual nominal size); the upper and lower action limits.

Interpretation of control charts
Causes of variation (tool wear, vibration, coolant, environmental changes, human error)

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

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

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

Range
Metrics Acceptable Quality Level (AQL); Lot Tolerance Percent Defective (LTPD); Type 1 Error (Producers Risk) and Type 2 Error (Consumer's Risk); Average Outgoing Quality (AOQ); Average Total Inspection (ATI). **Lot sizes** Large lot; small sample size (non-replaced)

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

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

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

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

Unit 412 Metal fabrication technology

UAN:	**M/504/4031**
Level:	4
Credit value:	15
GLH:	75
Aim:	The purpose of this unit is to enable learners to develop an understanding of a broad range of processes used within the fabrication and welding sector including forming, cutting and joining. This knowledge will allow candidates to assess the suitability of various methods and techniques to suit practical situations in the workplace. A range of welding and cutting processes are also considered to inform production decisions.

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

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

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

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

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

Range
Cutting methods and equipment used • *Oxy-fuel*

Safety; equipment; gases; procedures; mechanisation.

- *Air Plasma*

Safety; plasma theory; equipment; procedures, mechanisation/CNC control

- *Water Jet cutting*

Safety; abrasives; applications

Mechanical cutting methods and equipment

- *Cutting by shear processes*

Shear theory; guillotines; punching; blanking; calculation of punching force; tool clearance calculations

- *Chip forming cutting processes*

Chip theory; reciprocating saws; band saws; circular saws; drilling machines and drill nomenclature; coolants.

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

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

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

Unit 413 Welding technology and practice

UAN:	**L/504/4036**
Level:	4
Credit value:	10
GLH:	35
Aim:	The purpose of this unit is to enable learners to develop an understanding of a broad range of welding processes. This knowledge will allow candidates to be able to identify a preferred welding process for various production situations. It will also highlight a variety of defects that could be attributable to incorrect welding process, joint design or material properties. In addition, candidates will develop skills and understanding that will allow them to consider the cost implication of each process and the benefits of the mechanisation of each process when applicable.

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

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

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

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

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

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

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

Unit 414 Quality assurance and testing of welded joints

UAN:	**F/504/4034**
Level:	4
Credit value:	10
GLH:	43
Aim:	The purpose of this unit is to enable learners to develop an understanding of the requirements of quality and assurance systems in the welding and fabrication sector. This unit covers welder certification, weld testing and the identification and maintenance of relevant documentation to ensure welding quality is assured.

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

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

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

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

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

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

Unit 415 Maintenance of engineering systems and equipment

UAN:	**Y/504/4041**
Level:	4
Credit value:	15
GLH:	56
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 d.c., shunt d.c., separately excited d.c., stepper, servo, single phase induction, three phase induction)

Motor control (basic d.c. 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
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; 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** 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 416 Instrumentation and Control Principles

UAN:	**J/601/1417**
Level:	4
Credit value:	15
GLH:	60
Aim:	The purpose of this unit is to enable learners to develop an understanding of the principles and practice of instrumentation and control in process industries.

Learning outcome
The learner will: 1. Understand instrumentation systems used in process control
Assessment criteria
The learner can: 1.1 Describe the **terminology** used in process measurements 1.2 Evaluate a range of **sensors** and **transducers** with reference to manufacturers' terminology 1.3 Explain the construction and operation of modern **sensors** used to measure pressure, level, temperature and flow 1.4 Describe typical applications for the sensors examined 1.5 Explain **signal conditioning** and **transmission**

Range
Terminology Accuracy; error; repeatability; precision; linearity; reliability; reproducibility; sensitivity; resolution; range; span; zero drift; hysteresis **Sensors** Pressure; level; flow; temperature; displacement **Transducers** Pressure; level; flow; temperature; displacement **Signal conditioning** Industry-standard devices; industry-standard signal ranges and conversion between them **Transmission** Pneumatic; hydraulic; electrical; fibre-optic; wireless

Learning outcome
The learner will: 2. Understand process control systems and controllers
Assessment criteria
The learner can: 2.1 Explain the **need for process control** 2.2 Describe **process control terminology** 2.3 Determine the medium required for successful transmission 2.4 Name sensors, conditioners and display units for a range of specific purposes 2.5 Examine **tuning techniques** 2.6 Describe the control actions required for different systems 2.7 Represent systems using **standard diagrams**

Range
Need for process control Quality; safety; consistency of product; optimum plant performance; human limitations; efficiency; cost; environmental considerations **Process control terminology** Deviation; range; span; absolute deviation; control effect; set point; process variable; manipulated variable; measured variable; bumpless transfer; process variable tracking; direct and reverse acting; offset; on-off control; two step control; cycling; three-term control (proportional band, gain, proportional, proportional with integral, proportional with integral and derivative, proportional with derivative); system terminology (distance velocity lags, transfer lags, multiple transfer lags, capacity, resistance, dead time, reaction rate, inherent regulation, open loop, closed loop, load, supply, static gain, dynamic gain, stability, loop gain) **Tuning techniques**: Zeigler-Nichols; continuous cycling; reaction curve; ¼ decay methods; tuning for no overshoot on start-up; tuning for some overshoot on start-up **Standard diagrams:** P and I; loop; wiring; flow; block

Learning outcome
The learner will: 3. Understand the use of regulating units
Assessment criteria
The learner can: 3.1 Identify the main **parts** of a regulating unit

3.2	Evaluate a regulating unit with reference to standard **terminology**, including manufacturers' specifications
3.3	Select the plug characteristics required for a specified process
3.4	Describe the **characteristics** of a range of regulating units
3.5	Describe the use of valve positioners

Range

Parts

Body; trim; plug guide and seat; valve; stem; bonnet; packing gland; yoke; actuator; motor

Terminology

Stroke; direct and reverse action; air fail action; repeatability; constant velocity; turndown; flow characteristics; linear; equal percentage; quick-opening; modified parabolic; split range

Characteristics

Dampers; power cylinders; louvres; valve positioners; valves (globe; ball; diaphragm; gate; double seated; 3-way; solenoid; split bodied; butterfly)

Unit 417 Engineering Procurement

UAN:	**F/601/1500**
Level:	4
Credit value:	15
GLH:	60
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 418 Engineering design

UAN:	**R/504/9626**
Level:	4
Credit value:	15
GLH:	60
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 Planning and implementing change within businesses

UAN:	**H/504/2910**
Level:	4
Credit value:	10
GLH:	30
Relationship to NOS:	This unit is linked to the Business and Administration NOS, BAA114.
Endorsement by a sector or regulatory body:	This unit is endorsed by the Council for Administration.
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 421 Personal and Professional Development

UAN:	**K/504/1449**
Level:	4
Credit value:	10
GLH:	25
Relationship to NOS:	This unit is linked to the Business and Administration NOS, BAA627.
Endorsement by a sector or regulatory body:	This unit is endorsed by the Council for Administration.
Aim:	The purpose of this unit is to enable learners to develop an understanding of the different methods and resources available to them to help them plan for 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

Skills; knowledge; qualifications; enterprise opportunities.

Internal and external development opportunities with reference to skills; knowledge; qualifications; enterprise opportunities with reference to benefits for self and organisation.

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. **Learning resources** Libraries; organisation's resources; IT; Internet.

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 Feedback from others; skills scan; looking at job role. **Targets** SMART target setting. Learners should investigate and select appropriate mechanisms to monitor own progress. **Methods** Task manager; blog; project management tools; diaries; performance review/plan; objectives.

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 including any changes in expectations; further support required; barriers to progress. **Progress** The learner should identify further personal and professional development.

Unit 422 Project Management

UAN:	**T/504/1129**
Level:	4
Credit value:	15
GLH:	50
Relationship to NOS:	This unit is linked to the Business and Administration NOS, BAA151 and BAA152.
Endorsement by a sector or regulatory body:	This unit is endorsed by the Council for Administration.
Aim:	The purpose of this unit is to enable learners to develop an understanding of the principles of project management and how projects are set up. Learners will gain an understanding of how to mitigate for risks and develop their skills in using management tools to monitoring and reviewing projects.

Learning outcome
The learner will: 1. Understand why organisations use project management
Assessment criteria
The learner can: 1.1 Describe the **principles** of project management 1.2 Explain the **benefits** of project management to organisations and individuals

Range
Principles Business justification; learning from experience; defined roles and responsibilities; manage by stages; manage by exception; focus on products; objectives; constraints; lifecycle. **Benefits** Possible benefits will include: Increased efficiency; improved customer satisfaction; organisations may be more effective in delivering services; improvements in quality and output; development opportunities within the project team; increase in an organisation's competitive edge; opportunities to expand services; more flexibility; improved risk assessment.

Learning outcome
The learner will: 2. Understand how to set up projects
Assessment criteria
The learner can: 2.1 Explain the **considerations** when reviewing project proposals 2.2 Explain **how to set clear goals** for projects 2.3 Analyse project **resource requirements** 2.4 Explain **how roles and responsibilities are allocated** within project teams 2.5 Identify project **communication needs** 2.6 Assess **possible risks** to successful completion of projects 2.7 Explain how to **mitigate** for possible risks.

Range
Considerations Financial viability of the project; time; legal; resource; budget; constraints; dependencies; confidentiality eg restrictions in relation to the Data Protection Act, who has access to data and project documentation. **How to set clear goals** Identify stakeholders; identify needs; use SMART principles; record goals in project plans. **Resource requirements** Project requirements against goals; time constraints; budget; human resources; training needs; communication needs; IT requirements. **How roles and responsibilities are allocated** Use of experts from different areas of the organisation; use of key stakeholders; identify training needs; meeting schedules; timing of reports. **Communication needs** Formal/informal communication; identifying who requires communication eg stakeholders, management, team members. **Possible risks** Safety issues; optimistic time and cost estimates; unexpected budget costs; unclear roles and responsibilities; stakeholder needs not sought; changing requirements after the start of the project; new requirements; poor communication; lack of commitment. **Mitigate** Health and safety training; regular project review meetings; appropriate communication; training and monitoring.

Learning outcome
The learner will: 3. Be able to use management tools to maintain, control and monitor projects
Assessment criteria
The learner can: 3.1 Describe different **management tools** for monitoring and control of projects 3.2 Justify the use of management tools for monitoring and controlling projects 3.3 Use management tools to **monitor** projects

Range
Management tools Progress reports; budget monitoring reports; GANTT charts; Critical Path Analysis; use of relevant and current project software packages. **Monitor** Updating task status; re-scheduling uncompleted tasks; updating project elements.

Learning outcome
The learner will: 4. Be able to review projects at all stages
Assessment criteria
The learner can: 4.1 Explain **reasons** for reviewing projects after completion 4.2 Review projects against original proposals

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

Unit 423 Managing information and knowledge

UAN:	**F/602/1797**
Level:	4
Credit value:	15
GLH:	60
Relationship to NOS:	This unit is linked to the Business and Administration NOS, BAD112.
Endorsement by a sector or regulatory body:	This unit is endorsed by the Council for Administration.
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. Learners who aspire to positions in information and knowledge management will develop the fundamental knowledge, understanding and skills necessary for such job roles.

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** 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 etc, to 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. **Organisational learning** Peter Senge model of organisational learning. **Competitive advantage** Increases profits; less resistance to change.

Unit 425 Principles of electrical and electronic engineering

UAN:	**K/504/4450**
Level:	4
Credit value:	15
GLH:	60
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 the theory of electromagnetic circuits
Assessment criteria
The learner can: 1.1 Explain the occurrence of **properties** in relation to the behaviour of magnetic materials undergoing cyclic magnetisation 1.2 Explain the relationship between the shapes of hysteresis loops of **materials** and their application in magnetic and electromagnetic circuits

Range
Properties Coercivity; remanance; saturation; permeability **Materials** Magnetically soft and magnetically hard

Learning outcome
The learner will: 2. Be able to solve design problems using electromagnetic circuit 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 **problems** relating to electromagnetic circuits

Range
Variables m.m.f, circuit dimensions and permeability **Problems** Magnetic field strength; flux density; total flux

Learning outcome
The learner will: 3. Be able to apply electrical theorems to solve d.c. network problems
Assessment criteria
The learner can: 3.1 Explain methods of resolving d.c. network problems using electrical **theorems** 3.2 Use electrical **theorems** to solve problems involving d.c networks

Range
Theorems Kirchoff's current and voltage laws; Thévenins theorem and Norton's 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 **representation** of series R, L and C circuits 4.2 Evaluate complex variables in **operations** using complex conjugates 4.3 Convert electrical values between polar and rectangular form 4.4 Evaluate real and apparent power using **relationships**

Range
Representation By complex impedance and complex admittance **Operations** Addition; subtraction; multiplication; division **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 Explain how to represent differing **types** of R, L and C circuits using phasor diagrams 5.2 Explain how the conditions of resonance for **RLC circuits** are derived

Range
Types Series; parallel; series-parallel **RLC circuits** Series; parallel

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; dynamic impedance **RLC circuits** Series; parallel; 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) and h (hybrid model); elementary matrix algebra

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) and h (hybrid model); elementary matrix algebra **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 Analyse methods of three-phase power measurement for different **systems**

Range
Problems Involving line and phase values; power and power-factor correction **Systems** Balanced; unbalanced; star; 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 426 Data communication and networks

UAN:	**Y/504/4458**
Level:	4
Credit value:	15
GLH:	54
Aim:	The purpose of this unit is to enable learners to develop an understanding of data communication and networks used for engineering operations.

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 1.10 Describe network **applications and services**

Range
Types Coaxial cable; twisted pair (shielded and unshielded); optical fibre; radio waves **Cable connectors** BNC (plugs, sockets, 'T' connectors, terminators); RJ45 connectors **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)

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: 2. Understand how to make direct connections between devices
Assessment criteria
The learner can: 2.1 Explain different **codes** used for data transmission 2.2 Describe standard **character sets** for data representation 2.3 Describe **standards** used for data transmission 2.4 Explain RS232 **connection formats** 2.5 Explain the **protocols** used between **connections** 2.6 Explain the function of modems used in **connections** 2.7 Describe the working principles of the Integrated Services Digital Network (ISDN)

Range
Codes Character; control signal **Character sets** ASCII; EBCDIC **Standards** RS232; V24; X21 **Connection formats** 9-way and 25-way D type **Protocols**

XON; XOFF; CTS; RTS

Connections
DTE to DTE; DTE to DCTE

Connections
DTE to DTE; DTE to PSTN

Learning outcome
The learner will: 3. Be able to safely establish connections between similar devices for data transfer
Assessment criteria
The learner can: 3.1 Use **safe working practices** on mains-powered equipment 3.2 Use cables and connectors to provide a serial port direction **connection** 3.3 Apply **communication software protocol** to allow file transfer

Range
Safe working practices Safe isolation methods; appropriate to national standards; use of anti-static equipment **Connection** DTE to DTE **Communication software protocol** Number of data bits; parity; number of start bits; number of stop bits; baud rate

Learning outcome
The learner will: 4. Understand communication network concepts and components
Assessment criteria
The learner can: 4.1 Explain the advantages and disadvantages of networking devices 4.2 Evaluate attributes of local area networks (LAN) and wide area networks (WAN) 4.3 Explain the purpose and **types of servers** available on a network 4.4 Evaluate types of **network topologies** 4.5 Explain **methods** used for accessing a data transmission network 4.6 Explain **types** of data error detection methods 4.7 Describe the operational principles of **main hardware** components in networks

4.8 Explain the functions of **network components** 4.9 Evaluate different **protocols** used in networks 4.10 Explain the relevance of using **international standards** for data transmission

Range
Types or servers File; client/server; web; mail **Network topologies** Bus; ring; mesh; star **Methods** Token passing and CSMA/CD data control flow **Types** Parity checking; checksum; CRC **Main hardware** Server; PCs; terminals; peripherals **Network components** Hubs; repeaters; bridges; routers; gateways **Protocols** TCP/IP; NetBEUI; IPX/SPX **International standards** CCITT; ISO; ANSI; IEEE; EIA

Learning outcome
The learner will: 5. Be able to install a functioning data network interface card in peer to peer networks
Assessment criteria
The learner can: 5.1 Describe the operation of peer to peer networks 5.2 Explain the purpose of different types of network interface cards (NIC) 5.3 Describe security issues of externally connected networks 5.4 Explain **problems** that may prevent networks from operating correctly 5.5 Install appropriate network interface card 5.6 Use software and **hardware resources** to connect devices 5.7 Explain the purpose of software drivers for network hardware operation 5.8 Install network software drivers using appropriate operating systems 5.9 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 **User access** Client logon and directory/folder facilities

Learning outcome
The learner will: 6. Be able to commission peer to peer network operation
Assessment criteria
The learner can: 6.1 Produce **network implementation documents** 6.2 Evaluate network **installation and configuration**

Range
Network implementation document 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: 7. Understand data network services maintenance and management
Assessment criteria
The learner can: 7.1 Explain **tasks** involved in the management of networks 7.2 Explain the process for **managing** individual and group accounts on networks 7.3 Evaluate **network security techniques** to prevent unauthorised access to data 7.4 Assess the importance of anti-virus 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; firewall; proxy server; encryption

Unit 427 Understand uses and operation of electrical machines in engineering operations

UAN:	**Y/504/4461**
Level:	4
Credit value:	10
GLH:	50
Aim:	The purpose of this unit is to enable learners to develop an understanding of the uses and operations of electrical machines in engineering operations.

Learning outcome
The learner will: 1. Understand the principles and operation of d.c. machines
Assessment criteria
The learner can: 1.1 Describe components and characteristics of d.c. machines 1.2 Explain the effects of armature reaction 1.3 Describe **types** of winding arrangements and their effects on operation 1.4 Solve problems involving d.c. machine parameters

Range
Types Lap and wave

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 Analyse the relationship between the speed of rotation of a 3-phase rotating field and the slip frequency of an induction motor 2.5 Illustrate the equivalent circuit of three phase induction motors

2.6 Assess **types** of induction motor starter systems 2.7 Interpret **standards** of motor identification letters relating to types of enclosure and mounting 2.8 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 and Rotor resistance **Standards** BS4999 and ISO equivalent

Learning outcome
The learner will: 3. Understand the principles and operation of synchronous induction motors
Assessment criteria
The learner can: 3.1 Analyse the operation of synchronous motors for different rotor **types** 3.2 Explain the production of torque in synchronous motors using phasor diagrams 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
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 Outline **standards** for power transformer terminal **markings** 4.2 Assess the functions of transformer winding vector **groups** 4.3 Evaluate transformer types according to **properties** 4.4 Evaluate the use of centre tapped reactor tapchanging 4.5 Explain faults that can occur with power transformers

4.6	Explain the method of 3-phase power transformer earth fault detection using current transformers
4.7	Explain the Buchholz Relay system of transformer protection
4.8	Calculate on-load transformer heating and cooling times
4.9	Solve problems involving transformer parameters

Range

Standards

BS171; ISO equivalent

Markings

HV; LV; potential; phase shift and winding method

Groups

1(0°), 2(180°), 3(-30°) and 4(+30°)

Properties

Winding type; low voltage displacement; high voltage displacement and methods of cooling

Unit 428 Using electrical protection techniques for engineering operations

UAN:	**D/504/4462**
Level:	4
Credit value:	10
GLH:	45
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.

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 **Protection** Overload; short-circuit; earth fault

Unit 429 Electrical services and installation

UAN:	**R/504/4460**
Level:	4
Credit value:	10
GLH:	41
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. On completion of this unit learners will be able 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 430 Electrical supply and distribution

UAN:	**T/504/4466**
Level:	4
Credit value:	10
GLH:	54
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 components and economic factors of electrical transmission and distribution systems
Assessment criteria
The learner can: 1.1 Explain the functions of system **components** 1.2 Explain the operation of overcurrent protection equipment on contactors and circuit breakers 1.3 Evaluate advantages and disadvantages of **network systems** for use in engineering 1.4 Evaluate circuit breaker operations relative to fault positions 1.5 Assess advantages of IDMT and Directional Overcurrent relays for use in engineering 1.6 Analyse **costs** involved with electricity supply systems for selection of use

Range
Components Isolating switches; contactors; fuses and circuit breakers **Network systems** Radial; parallel and ring **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 engineering 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 loci **Given data** Stator phase voltage; stator phase current; synchronous impedance; short circuit ratio; power; reactive power; load angle; power factor

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** Units represented as p.u. impedance **Principles** Arc suppression; control; interruption **High voltage protection devices** Plain break oil circuit breakers; air blast circuit breakers; vacuum interrupters; sulphur hexafluoride circuit breakers; HRC liquid and HRC expulsion fuses and high voltage fuses **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 supply system **protection systems** 6.3 Explain over-voltage protection **methods** 6.4 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 IDMT characteristic curve and to give the required discrimination in radial feeder circuits with various load take off points

Unit 431 Testing and measurement of electronic and electrical systems

UAN:	**M/504/4465**
Level:	4
Credit value:	15
GLH:	66
Aim:	The purpose of this unit is to enable learners to develop an understanding of testing and measurements of electrical and electronic systems.

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 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 432 Programmable logic controllers

UAN:	**A/504/4467**
Level:	4
Credit value:	10
GLH:	60
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. On completion of this unit, learners will be able 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 processor 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
Test – Debug 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 433 Designing analogue circuits

UAN:	**A/504/4453**
Level:	4
Credit value:	15
GLH:	97
Aim:	The purpose of this unit is to enable learners to develop an understanding of designing 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 and applications of semiconductor diodes
Assessment criteria
The learner can: 1.1 Describe the electrical properties of a semiconductor diode 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
Types Silicon; Germanium; Schottky; Voltage reference. **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 Explain the operation of a common emitter amplifier using **hybrid parameters** 2.2 Analyse Common Emitter transistor **characteristics** 2.3 Analyse the quiescent conditions of transistor amplifiers using different **methods** 2.4 Analyse the operation of **field effect transistors** (FET) in terms of their construction 2.5 Evaluate the application of transistor amplifier **biasing** against **parameters** 2.6 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 **Biasing** Common emitter; common source; common collector; common drain; common base; common gate. **Parameters** Input impedance; output impedance; gain; stability. **Actual** Static (VDS; VGS; IG; ID; saturation, pinch-off; ohmic region)Dynamic (quiescent values and voltage gain)

Learning outcome
The learner will: 3. Understand the principles of gain and loss, 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 Assess the principles of **noise** affecting components and circuits 3.3 Evaluate the application of different **classes** of transistor amplifies

Range
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 Assess amplifier stability using Bode plots 4.7 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 (R/C) oscillator; Wein bridge oscillator **Design parameters** At given operating frequency

Learning outcome
The learner will: 7. Be able to design and simulate filters using operational-amplifiers
Assessment criteria
The learner can: 7.1 Explain the **parameters** of first 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 how to relate the pulse response of an operational amplifier circuit to other circuit parameters
Assessment criteria
The learner can: 8.1 Describe pulse response **specifications** 8.2 Explain how to relate **small** and **large** signal pulse responses to other **parameters**

Range
Specifications Rise time; slew rate; overshoot and settling time. **Small parameters** Frequency response in terms of rise time and half-power bandwidth **Large Parameters** Frequency response in terms of slew rate, bandwidth

Learning outcome
The learner will: 9. Understand properties of data converters
Assessment criteria
The learner can: 9.1 Explain **terms** associated with data conversion 9.2 Explain the operational properties of analogue to digital **(A to D) converters**

Range
Terms Conversion time; conversion rate; conversion code; resolution; settling time; quantization error; nominal full-scale output; missing code. **(A to D) converters** 'R-2R' ladder; slope; successive approximation and flash

Unit 434 Designing sequential and combinational logic circuits

UAN:	**R/504/4457**
Level:	4
Credit value:	10
GLH:	66
Aim:	The purpose of this unit is to enable learners to develop an understanding of designing sequential and combinational logic circuits. Learners will understand the function and features of logic device circuits. On completion of this unit, learners will be able 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** and **characteristics** of **logic gates** 1.2 Evaluate the **operational performance** of different logic **families**

Range
Function Symbols; truth tables; Boolean algebra. **Characteristics** Fan-in; fan-out; propagation delay; power consumption; operating voltage; calculations; manufacturers' data (data sheets: printed; CD ROM; websites) **Logic gates** AND; OR; NOT; EXOR; NAND; NOR **Operational performance** Speed, power, cost and interface requirements.

Families
Complementary metal oxide – semiconductor (CMOS); transistor-transistor logic (TTL)

Learning outcome
The learner will: 2. Be able to design sequential logic circuits
Assessment criteria
The learner can: 2.1 Assess **types** of sequential logic circuit 2.2 Outline **standards** of graphical symbols for binary logic elements 2.3 Describe the function of sequential **logic devices** 2.4 Explain the operation of sequential circuits using **state diagrams** 2.5 Produce state-transition tables from **state** diagrams 2.6 Evaluate the minimum number of binary elements required to implement a sequential circuit from the number of internal system states 2.7 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) **State diagrams** Mealy or Moore model **State** Previous; next

Learning outcome
The learner will: 3. Be able to design combinational logic circuits
Assessment criteria
The learner can: 3.1 Explain the **operation** of combinational **logic circuits** 3.2 Produce minimised Boolean expressions using the **laws** of Boolean algebra

3.3	Use **methods** to simplify Boolean functions
3.4	Illustrate minimised Boolean expressions using **universal gates**
3.5	Design minimised circuits using simulation to test against specifications

Range
Operation Using Boolean expressions **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 and variable entry mapping (VEM) techniques). **Universal gates** NAND; NOR - Illustrate using logic diagrams; or other

Unit 435 Microprocessor based systems

UAN:	**L/505/5912**
Level:	4
Credit value:	10
GLH:	60
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 and on completion of this unit will be able 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; 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) **Specifications** Testing; control; monitoring

Unit 440 Fundamentals of airworthiness management

UAN:	**D/504/9628**
Level:	4
Credit value:	15
GLH:	75
Aim:	The purpose of this unit is to enable learners to develop an understanding of the fundamentals of airworthiness management.

Learning outcome
The learner will: 1. Understand the requirements of legislation within aviation
Assessment criteria
The learner can: 1.1 Outline the responsibilities of aviation authoritative **organisations** 1.2 Explain the content and purpose of **sub-parts** specific to **legislation** 1.3 Evaluate the **relationship** between aviation authoritative organisations

Range
Organisations ICAO; EASA; CAA; MAA; FAA **Sub-parts** Design; certification; continuing airworthiness; training; personnel licencing; maintenance; operations (eg EASA/MAA Part 21, Part M, Part 147, Part 66, Part 145, EU-Ops) **Legislation** International; national; regional **Relationship** Purpose; areas of operation; powers; obligations; responsibilities for aviation safety.

Learning outcome
The learner will: 2. Understand the requirements of aircraft design, manufacture and repair
Assessment criteria
The learner can: 2.1 Outline the purpose and responsibilities of an aircraft design authority 2.2 Explain the **regulatory requirements** for aircraft design 2.3 Explain the **regulatory requirements** for aircraft manufacture 2.4 Explain the **requirements** by which an aircraft is declared 'fit to fly' 2.5 Evaluate the **limitations** on aircraft 'fitness to fly' imposed by maintenance activities

Range
Regulatory requirements for aircraft design Certification specifications; categories of certification **Regulatory requirements for aircraft manufacture** Different cert specs eg EASA (CS 23/25/27/29); appropriate national/military alternatives **Requirements** General aircraft certification rules eg Design organisation (type certification / supplemental type certification); certificate of airworthiness, registration, noise, weight schedule, radio; reasons for certification, criteria for retention, withdrawal, validity, issuing authority **Limitations** Repair outside of SRM; airworthiness directives; military; ADD; operational restrictions

Learning outcome
The learner will: 3. Understand the requirements of aircraft flight testing
Assessment criteria
The learner can: 3.1 Explain the **regulatory requirements** for aircraft **flight testing** 3.2 Assess the effect of **aircraft serviceability status** on suitability for flight

Range
Regulatory requirements eg responsibilities of authorities; approved design standards; airworthiness limitations; certification maintenance requirement ; flights outside design envelope; military; customs; police aircraft. **Flight testing** Development testing; post-production; post-maintenance **Aircraft serviceability status:** Eg Certificate of Airworthiness; Permit to fly; certificate of registration; noise certificate; weight schedule; radio station license and approval; restricted certificate of air worthiness; reason for certification; information shown on certificate; criteria for retention; criteria for withdrawal; authority to issue; validity; reason for issue; responsibilities; criteria; test flights for EASA and Non-EASA Aircraft; responsibilities; aircraft affected; conditions; approvals; MEASSL; MEL/CDL

Learning outcome
The learner will: 4. Understand the need for continuing airworthiness
Assessment criteria
The learner can: 4.1 Analyse the requirements for **aircraft maintenance organisations** 4.2 Assess the certification requirements for **aircraft maintenance personnel** 4.3 Evaluate the **effects** maintenance has on aircraft operations

Range
Aircraft maintenance organisations Eg Part 145 (Maintenance Organisations Exposition (MOE) would include: facilities, personnel requirements, certifying staff, quality system etc); Part M (Subpart F: Maintenance Organisation Manual (MOM) would include: personnel requirements, limits of responsibilities, authorisations etc.) **Aircraft maintenance personnel** Eg Part 66; basic training course; issue of licences; examinations; practical experience; log books; privileges; Part 145 including (overview of Commercial Air Transport Operations) **Effects**

eg limitations to operations; increased operating cost; reduced capacity; restrictions on flight envelope; reduced availability

Unit 441 Integrated aircraft systems

UAN:	**Y/504/9630**
Level:	4
Credit value:	10
GLH:	50
Aim:	The purpose of this unit is to enable learners to develop an understanding of integrated aircraft systems.

Learning outcome
The learner will: 1. Understand the interaction between integrated aircraft systems
Assessment criteria
The learner can: 1.1 Explain the interaction between **system** functions to control aircraft operation 1.2 Differentiate between aircraft data bus standards 1.3 Evaluate **types** of signal transmission used in integrated aircraft systems 1.4 Assess the need for built-in redundancy in **integrated aircraft systems**

Range
System eg pilot; air data; engine controls; flight management system; hydraulics; pneumatics; auto-pilot; navigation; communications; fuel control; flight controls **Types** eg human; electronic; fluid **Integrated aircraft systems** eg communication systems (fibre optics, shielded copper wires, training); navigation systems; on-board maintenance systems; integrated modular avionic systems; cabin systems; emergency

systems; information systems; flight management systems; flight control systems

Learning outcome
The learner will: 2. Understand how the serviceability of integrated aircraft systems is monitored
Assessment criteria
The learner can: 2.1 Explain how **management systems** are used to maintain aircraft reliability 2.2 Determine the effects of **operational requirements** on integrated aircraft systems

Range
Management systems eg EHMS; OBMS **Operational requirements** eg minimum equipment list; configuration deviation list

Unit 442 Fault finding diagnosis

UAN:	**A/504/9765**
Level:	4
Credit value:	10
GLH:	20
Aim:	The purpose of this unit is to enable learners to develop an understanding of fault finding diagnosis.

Learning outcome
The learner will: 1. Understand the principles of fault diagnosis
Assessment criteria
The learner can: 1.1 Explain the **process** involved in fault detection and diagnosis 1.2 Explain the systems involved in fault detection and diagnosis

Range
Process Fault isolation, root cause, detection + isolation = diagnosis, determining size of fault, determining the time of onset of the fault

Learning outcome
The learner will: 2. Understand how to identify faults
Assessment criteria
The learner can: 2.1 Explain how to identify faults 2.2 Explain the **methods** used in identifying and isolating faults 2.3 Analyse the different **symptoms** of faults

Range
Methods Quantitative; qualitative **Symptoms** Non-optimal operation; poor choice; operating targets; poor feedstock; poor controller tuning; partial loss of activity; sensor, calibration errors; human error

Learning outcome
The learner will: 3. Understand how to rectify faults
Assessment criteria
The learner can: 3.1 Explain how to **rectify faults** 3.2 Explain how to **prevent faults** from reoccurring

Range
Rectify faults Fault management; abnormal condition management; detection steps; filtering; event generation; detection; diagnosis; correlation; mitigation; analysis **Prevent faults** Fault signatures; pattern recognition and classifiers; neural networks; procedural; workflow approaches; event-orientated fault detection; passive system monitoring vs active testing; rule-based approaches; hybrid approaches; filtering

Learning outcome
The learner will: 4. Be able to recommend ways to minimise/mitigate
Assessment criteria
The learner can: 4.1 Evaluate the **risks** for concluded faults 4.2 Propose solutions to minimise fault occurrences

Range
Risks Visibility of knowledge; false conclusions; fault propagation models; logic trees; procedural methods; transparency

Unit 443 Communication and navigation systems

UAN:	**F/504/9766**
Level:	4
Credit value:	15
GLH:	30
Aim:	The purpose of this unit is to enable learners to develop an understanding of communication and navigation systems.

Learning outcome
The learner will: 1. Understand the principles of aircraft communications
Assessment criteria
The learner can: 1.1 Research the **working principles** of radio communications 1.2 Research the **working principles** of radio transmitters and receivers used in communication systems 1.3 Explain how atmospheric conditions affect communication systems

Range
Working principles of radio communications eg properties of atmospheric layers in relation to radio wave propagation; frequency spectrum; radio frequency bands (LF, HF, VHF, UHF, SHF eg Satcom); operating characteristics of radio antennas; transmission lines (antenna feeder cables) **Working principles of radio transmitters and receivers** eg radio signal transmission (generation, modulation, transmission); radio signal reception (receive, process, present) **Atmospheric conditions** eg weather; solar activity; terrain; polar region; stratosphere; troposphere

Learning outcome
The learner will: 2. Understand the principles of aircraft navigation systems
Assessment criteria
The learner can: 2.1 Research the **working principles** of airborne navigation systems 2.2 Analyse the working principles of **safety airborne systems**

Range
Working principles eg DME; VOR; ADF; TACAN; GPS/GNSS; ILS; MLS; VLF; RNAV; e-LORAN **Safety airborne systems** eg traffic; atmospheric conditions (eg weather, solar activity, terrain, polar region, stratosphere, troposphere); TCAS; transponder; radio; radar altimeter; secondary surveillance radar

Learning outcome
The learner will: 3. Understand national and international regulations for aircraft communications and navigation systems
Assessment criteria
The learner can: 3.1 Analyse the **national and international regulations** in relation to radio communication and navigation systems 3.2 Evaluate the **requirements** for secondary/back-up systems for aircraft navigation systems

Range
National and international regulations eg ICAO; EASA; FAA; CAA; MAA; national governments **Requirements** eg different data/signal source

Learning outcome
The learner will: 4. Understand how data communication systems are used in aircraft operations
Assessment criteria
The learner can: 4.1 Explain the **key features** of aircraft instrumentation systems 4.2 Review the use of data communication systems in aircraft operations

Range
Key features eg multi-function display; navigation; flight status; standby; emergency; positioning of sensors; preparation of sensor signals; display and transmission of data **Use of** eg aircraft instrumentation system; system and structural monitoring; operational and maintenance planning; flight status, atmospheric conditions

Unit 444 Efficient maintenance in aircraft operations

UAN:	**J/504/9767**
Level:	4
Credit value:	5
GLH:	15
Aim:	The purpose of this unit is to enable learners to develop an understanding of efficient maintenance in aircraft operations.

Learning outcome
The learner will: 1. Understand the requirements of flight operations
Assessment criteria
The learner can: 1.1 Assess **planning methods** required for maintaining aircraft airworthiness 1.2 Analyse the **effect** of maintenance in continuing airworthiness planning

Range
Planning methods eg CAMO / CAME **Effect** Efficiency of operation of aircraft dependant on clients requirements

Learning outcome
The learner will: 2. Understand the design principles of maintenance schedules and the impact these have on flight operations
Assessment criteria
The learner can: 2.1 Outline the principles of maintenance policy/programmes 2.2 Describe **design criteria** for maintenance schedules 2.3 Assess the **impact** of maintaining continuing airworthiness against the operations and maintenance schedule of the aircraft 2.4 Assess the different maintenance **practices** available for continuing airworthiness 2.5 Evaluate **authority and manufacturer requirements** on continuing airworthiness

Range
Design criteria eg theatre and mode of operation; age (flight cycles, calendar, flying hours) **Impact** eg conflict between operations vs maintenance; aircraft on ground; costs; reliability and safety penalties; deviations to maintenance; time tables; aircraft availability **Practices** Base; line maintenance **Authority and manufacturer requirements** eg Airworthiness Directives; Service Bulletins etc; design; CAA; EASA; FAA; MAA

Learning outcome
The learner will: 3. Understand the implications of mandatory maintenance on the operation of aircraft
Assessment criteria
The learner can: 3.1 Outline the need for mandatory maintenance 3.2 Evaluate the **requirements** of mandatory maintenance 3.3 Evaluate the intervention of the **aviation authorities** 3.4 Analyse the **continuing airworthiness requirements** and **restrictions** for aircraft operations

Range
Requirements eg MMEL Origin; operator MEL; maintain flight safety; continuing airworthiness; CDL; multiple systems; ETOPS; AWOPS **Aviation authorities** eg CAA; EASA; FAA; MAA **Continuing airworthiness requirements** eg safety requirements; environmental; efficiency; cost **Restrictions** eg thrust settings; TORA; TODA; noise abatement; landing distance

Unit 445 Principles of composite materials

UAN:	**D/504/9631**
Level:	4
Credit value:	15
GLH:	75
Aim:	The purpose of this unit is to enable learners to develop an understanding of the principles of composite materials. Learners will understand the different structures of composite materials, the fundamentals of polymer chemistry and will look in detail at the materials and techniques used with pre-preg, pre-form materials and in dry fibre moulding. Learners will also gain an understanding of the preparation and assembly methods used for composite components in the manufacture of composite structures.

Learning outcome
The learner will: 1. Understand the principles and structure of composite materials
Assessment criteria
The learner can: 1.1 Explain different **types** and applications of composite materials 1.2 Explain the concept of **reinforcement** embedded within a **matrix** and the resultant integrated properties 1.3 Explain types of **reinforcement** and their selection for particular applications 1.4 Explain reinforcement **presentation** and their selection for particular applications 1.5 Explain the purpose and concept of **core materials** and their selection for particular applications 1.6 Describe the **composition** of commonly used composite matrix materials 1.7 Analyse **mechanical properties** of composite materials 1.8 Explain the concept and **principles** of laminate characteristics 1.9 Evaluate the **application** of composites 1.10 Review the **advantages and disadvantages** of composites

1.11 Describe health and safety **requirements** for handling and using composite materials

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

Learning outcome
The learner will: 2. Understand elementary polymer chemistry
Assessment criteria
The learner can: 2.1 Describe the chemistry of the **main classes of resin systems** 2.2 Compare the **properties** of thermoplastics and thermosets

2.3 Analyse the **performance** of resin systems in different applications
2.4 Evaluate the use of **additional materials** in resin systems
2.5 Assess the curing cycle for different resin systems
2.6 Explain how resin systems are recycled and/or disposed of

Range

Main classes of resin systems
Thermoplastics; thermosets

Properties
Physical; chemical

Performance
eg strength; corrosion resistance; UV resistance; toughness

Additional materials
Additives; fillers; pigments; fire retardants

Learning outcome

The learner will:

3. Understand the materials and techniques used with pre-impregnated (pre-preg) and pre-formed (pre-forms) materials

Assessment criteria

The learner can:

3.1 Explain the **benefits** of pre-combined materials
3.2 Describe **pre-preg materials** and their use in manufacturing
3.3 Describe pre-form materials and their use in manufacturing
3.4 Explain storage requirements for pre-preg materials
3.5 Explain laminate preparation and efficient use of consumables
3.6 Explain techniques for manufacturing components from pre-preg materials
3.7 Review advantages and disadvantages of using pre-preg materials

Range

Benefits
Quality control; productivity; cost effective

Pre-preg materials
Woven; uni-directional; B-stage material; filler

Pre-form materials
eg 3D; cloths

Storage requirements
Refrigeration

Preparation
Nesting; cutting; kitting; bagging materials; release films; safe disposal of waste

Techniques
Manual (use of heat and pressure; autoclave, out of autoclave; vacuum bag); automated (automatic tape laying)

Advantages
Easier to lay up; greater consistency; less voids; better surface finish

Disadvantages
Equipment expenditure; storage; cost

Learning outcome
The learner will: 4. Understand the materials and techniques used in dry fibre moulding
Assessment criteria
The learner can: 4.1 Describe **materials** used in dry-fibre moulding 4.2 Describe manufacturing **techniques** used in dry-fibre moulding 4.3 Describe **components** that can be added during manufacture for specific purposes 4.4 Review **advantages** and **disadvantages** of using dry fibre moulding techniques

Range
Materials Cores; resins; fibres **Techniques** Manual; resin infusion; resin transfer; filament winding; pultrusion; fibre placement **Components** Fixings; optical fibre sensors for stress monitoring; conductive strips for lightning strike protection **Advantages** Price; set-up cost; component parts; higher productivity; less/skilled labour **Disadvantages** Cost of machinery; comparatively poorer quality control

Learning outcome
The learner will: 5. Understand preparation and assembly methods for composite components in the manufacture of composite structures
Assessment criteria
The learner can: 5.1 Describe **adhesive and bonding agents** and their application in composite structures

5.2	Describe **mechanical fastening methods and fittings** used for composite structures
5.3	Evaluate the effectiveness of mechanical and chemical techniques in composite structures for different **applications**
5.4	Explain the importance of correct surface preparation, sealing and curing

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

Unit 446 Principles of composites manufacture

UAN:	**J/504/9638**
Level:	4
Credit value:	15
GLH:	60
Aim:	The purpose of this unit is to enable learners to develop an understanding of the principles of composites manufacture. Learners will understand the different manufacturing processes used for thermoplastics and thermosets, implications of manufacturing processes on design for manufacture, types and sources of defects, different applications of NDT methods and the process and quality systems required for composite component and structure manufacture.

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

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

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

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

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

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

Range
Types eg Cavities; wrinkling; porosity; de-lamination; bridging; disbonds; pre-release **Sources** eg Contamination and cleanliness; incorrect process control; environmental; equipment failure; manufacturing damage **Effects** eg Unsatisfactory properties; cost; rework; delivery; service life; premature failure

Learning outcome
The learner will: 4. Understand Non-Destructive Testing (NDT) methods of testing
Assessment criteria
The learner can: 4.1 Explain the principles of **NDT methods**

4.2 Review **types**, functions and limitations of NDT systems 4.3 Review the **selection criteria** of NDT type to suit manufacture processes and materials

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

Learning outcome
The learner will: 5. Understand process and quality systems required for composite component and structure manufacture
Assessment criteria
The learner can: 5.1 Analyse the need for materials life control and correct storage of raw materials and finished product 5.2 Analyse the need for environmental controls in composite manufacture and storage 5.3 Explain the process of defect management and concessions for composite materials

Unit 450 Developing business improvement plans

UAN:	**H/504/9713**
Level:	4
Credit value:	10
GLH:	35
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

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

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

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

Unit 501 Work based project

UAN:	**H/504/4043**
Level:	5
Credit value:	20
GLH:	20
Aim:	The purpose of this unit is to enable to • apply underlying concepts and principles of their area of study to address an identified workplace problem or issue • evaluate different approaches to the problem or issue identified • initiate and use strategies to address an identified workplace issue • demonstrate effective and appropriate communication skills.

Learning outcome
The learner will: 1. Be able to research workplace problems
Assessment criteria
The learner can: 1.1 Investigate processes, practices or structures in the workplace to identify an area for development 1.2 Propose project ideas

Learning outcome
The learner will: 2. Be able to set project objectives
Assessment criteria
The learner can: 2.1 Identify information required for inclusion in work place project proposals 2.2 Produce project proposals to **required scope** 2.3 Produce project objectives

Range
Required scope Increase efficiency; improve customer satisfaction; deliver services more effectively; improvements in quality and output; increase

organisation competitive edge; opportunities to expand services; more flexibility; other (to be specified in proposal)

Learning outcome
The learner will: 3. Be able to source information, concepts and principles relevant to workplace problems
Assessment criteria
The learner can: 3.1 Review theories and practices relevant to **workplace project proposal** 3.2 Select key **sources of data and information** to support project

Range
Workplace project proposal Determined by sector / subject **Sources of data and information** Quantitative and qualitative information; internal workplace/organisation materials; published research

Learning outcome
The learner will: 4. Be able to select project methods to address objectives
Assessment criteria
The learner can: 4.1 Evaluate the strengths of **methods** in relation to project objectives 4.2 Justify selected method(s) used to address project objectives 4.3 Identify strategies appropriate to carry out selected method

Range
Methods Qualitative research (may include interviews; forums; observation; shadowing, research journal articles, books); quantitative research (may include small sample surveys; questionnaires, sector data, organisational data); application / test of a theory; examination / evaluation of a process

Learning outcome
The learner will: 5. Be able to apply methods to meet objectives
Assessment criteria
The learner can: 5.1 Produce **work plans** to meet objectives 5.2 Implement work plans

5.3 Review work plan, adjusting timescales and deliverables accordingly

Range
Work plan must • include phases and tasks • include task distribution • include project requirements against objectives • include time constraints • use SMART principles • record objectives in project plan

Learning outcome
The learner will: 6. Be able to report on the outcomes of projects
Assessment criteria
The learner can: 6.1 Produce project outcome report to specified audience 6.2 Evaluate the effectiveness of the project 6.3 Reflect on learning achieved through the project process 6.4 Recommend further learning and/or training needed

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 Manual - Supporting Customer Excellence contains detailed information about the processes which must be followed and requirements which must be met for a centre to achieve 'approved centre' status, or to offer a particular qualification, as well as updates and good practice exemplars for City & Guilds assessment and policy issues. Specifically, the document includes sections on:

- The centre and qualification approval process
- Assessment, internal quality assurance and examination roles at the centre
- Registration and certification of candidates
- Non-compliance
- Complaints and appeals
- Equal opportunities
- Data protection
- Management systems
- Maintaining records
- Assessment
- Internal quality assurance
- External quality assurance.

Our Quality Assurance Requirements encompasses all of the relevant requirements of key regulatory documents such as:

- Regulatory Arrangements for the Qualifications and Credit Framework (2008)
- SQA Awarding Body Criteria (2007)
- NVQ Code of Practice (2006)

and sets out the criteria that centres should adhere to pre and post centre and qualification approval.

Access to Assessment & Qualifications provides full details of the arrangements that may be made to facilitate access to assessments and qualifications for candidates who are eligible for adjustments in assessment.

The **centre homepage** section of the City & Guilds website also contains useful information such on such things as:

- **Walled Garden:** how to register and certificate candidates on line
- **Qualifications and Credit Framework (QCF)**: general guidance about the QCF and how qualifications will change, as well as information on the IT systems needed and FAQs
- **Events**: dates and information on the latest Centre events
- **Online assessment**: how to register for e-assessments.

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Useful contacts

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