T-LEVELS | IfATE Institute for Apprenticeships and Technical Education

T Level Technical Qualification in Maintenance, Installation and Repair for Engineering and Manufacturing

Specification

First teaching from September 2022
Version 1.3

City & Guilds | eal

Qualification at a glance

T Level route	Engineering and manufacturing
T Level pathway	T Level Technical Qualification in Maintenance, Installation and Repair for Engineering and Manufacturing
City & Guilds number	8730 8712
Age group approved	16+
Entry requirements	Formal entry requirements are not set by City & Guilds. However, it is expected that Learners have the appropriate attainment at Level 2 before commencing their studies.
Assessment	Core – knowledge tests are externally assessed Core – employer-set project is externally assessed Occupational Specialisms are externally moderated
First registration	September 2022

Title and level	City & Guilds number	Qualification Number
T Level Technical Qualification in Maintenance, Installation and Repair for Engineering and Manufacturing (Level 3)	8730 – Core 8712 – Occupational Specialism	610/0692/0

Version and date	Change detail	Section
1.1 July 2022	Qualification number added	Qualification at a glance
	Amendment to threshold competence	6. Technical qualification grading and result reporting
1.2 August 2023	Alignment of text in relation to ESP Assessment Objective (AO3) with assessment materials	Core component scheme of assessment Pg 32
	Core skill mapping references amended	Unit 300 Engineering common core
	Typographic error amended	Unit 300, 6.5
	T Level grading table	Awarding the T Level programme grade Pg 47
1.3 February 2024	Physical resource lists expanded	Physical Resources Pg 16
	Availability of assessment dates amended	Availability of Assessments Pg 47
	Range amended	Light & Electric Vehicles Occupational Specialism 1.15 Pg 205

We would like to take this opportunity to thank all the employers, trade associations, professional bodies, providers, subject matter experts and consultants who have dedicated time to review and validate the specifications and TQ documentation. This collaborative work is to ensure that a student studying the Maintenance, Installation and Repair T level has the best opportunities available to them as they progress through their career with a solid base as a starting point.

- Xtrac
- Warren Services
- RJ Power Group
- Thames Water
- National Skills Academy
- Uniper Technology Limited
- RWE Generation UK
- NHS
- Ingenia
- Cleasby Engine Services
- Didactic Services
- SMB Group
- BMW
- Nissan
- N&J Lining
- Denby Pottery
- Amazon
- North London Garages GTA
- Siemens
- EU Skills

The Outline Content for the T Level Technical Qualification in Maintenance, Installation and Repair for Engineering and Manufacturing (Level 3) has been produced by T Level panels of employers, professional bodies based on the same standards as those used for Apprenticeships. The outline content can be found on the institute website:

Maintenance, Installation and Repair Outline Content

City & Guilds has amplified the Outline Content to create the Technical Qualification specifications.

Contents

1 Introduction

What is this qualification about?

The following purpose statement relates to the **T Level [1] Technical Qualification in Maintenance, Installation and Repair for Engineering and Manufacturing (Level 3)**

Area	Description
OVERVIEW	
What is a T Level?	T Levels are new courses which will follow GCSEs and will be equivalent to three A Levels. These two-year courses have been developed in collaboration with employers and businesses so that the content meets the needs of industry and prepares learners for work. T levels are one of three post 16 options for young people which are: • A Levels • Apprenticeships • T Level
How does the Technical Qualification work within the T Level?	This Technical Qualification specification contains all the required information you need to deliver the qualification in the T Level Technical Qualification in Maintenance, Installation and Repair for Engineering and Manufacturing (Level 3) The Technical Qualification forms a significant part of the T Level Technical Qualification in Maintenance, Installation and Repair for Engineering and Manufacturing (Level 3). City & Guilds are responsible for the development and ongoing operational delivery of this Technical Qualification. All other parts of the T Level as listed below will need to be achieved by a Learner for the Department for Education to award the successful completion of this T Level. It is important to note that City & Guilds do not have responsibility of delivery for the other parts of the T Level but will continue to support centres where they can on all aspects of T Level delivery. Additional mandatory parts of the T Level that need to be achieved: • An industry placement of 315 – 350 hours (45 – 50 days).
Who is this qualification for?	This qualification is for you if you are a 16-19-year-old learner, who wishes to work within the engineering industry.

[1] T Level is a registered trade mark of the Institute for Apprenticeships and Technical Education

	It has been designed to deliver a high level of knowledge about the engineering industry as well as the occupational skills required to enter the industry (known as 'threshold competence'). A learner who completes this qualification is well placed to develop to full occupational competence with the correct support and training.
What does this qualification cover?	The qualification will help you gain an understanding of the engineering industry and the sector and you will cover topics such as: • Maintenance, installation and repair requirements • Fault detection and diagnosis • Isolation and resolution methods • Communication for maintenance, installation and repair activities A learner will have the choice of studying one standalone Occupational Specialism as listed below: • Mechanical • Mechatronic • Electrical and electronic • Control and instrumentation • Light and electric vehicles Centres and providers work with local employers who will contribute to the knowledge and delivery of training. Employers will provide demonstrations and talks on the industry and where possible work placements will also be provided by the employers.
WHAT COULD THIS QUALIFICATION LEAD TO?	
Will the qualification lead to employment, and if so, in which job role and at what level?	This technical qualification focuses on the development of knowledge and skills needed for working in the Engineering industry, which will prepare learners to enter the industry through employment or as an Apprentice. Furthermore, the completion of this qualification gives the learner the opportunity to progress onto higher education courses and training.
Why choose this qualification?	This technical qualification will suit someone who is not yet employed or looking to enter the industry post mainstream education. The structure of the qualification is designed to give learners the breadth of knowledge and understanding across the Engineering industry but also equips them with necessary occupational and core skills to enter the industry. This qualification is designed to support fair access and allows learners to manage and improve their own performance.
WHO SUPPORTS THIS QUALIFICATION?	
Employer route panels	The content of this qualification is outlined by a representative panel of employers from across the industry sector. It therefore prescribes the minimum knowledge and skills required to enter the industry. The content in this specification is approved by the Institute for Apprenticeships and Technical Education (IfATE).

Key information

Below is a summary of the key information provided to centres to support delivery of this technical qualification.

Guided learning hour (GLH) value

This value indicates the average number of guided learning hours a unit will require for delivery to a learner. This includes contact with tutors, trainers or facilitators as part of the learning process, and includes formal learning such as classes, training sessions, coaching, seminars and tutorials. This value also includes the time taken to prepare for, and complete, the assessment for the unit. Guided learning hours are rounded up to the nearest five hours.

Total qualification time (TQT) value

This is the total amount of time, in hours, expected to be spent by a learner to achieve a qualification. It includes both guided learning hours (which are listed separately) and hours spent in preparation and study.

Criteria

This section of the specification outlines the subject or topic that needs to be delivered and assessed. Criteria are often supported by **'range'** which provides the detail of the information required to be delivered as part of that topic. For example, with 'Design processes' as the topic, the range would list the processes that would need to be covered in delivery and assessment.

What do learners need to learn?

The primary purpose of these sections is to support the delivery of the content in the criteria. These sections provide context in relation to the depth and breadth to which a subject or topic needs to be taught.

Skills

This section provides a mapping reference to the core, maths, English and digital skills that are embedded within the technical qualification content.

Example

1.3 Fundamentals of **common mechanisms** and **lifting equipment.**

Range:
Mechanisms – gears (characteristics of gears including teeth, root, pitch, meshing, backlash), gear box, gear trains, governors, levers, brakes, friction devices/clutches (mechanical, hydraulic, electromagnetic), structural components (frames, bearings, springs).
Lifting equipment – pulleys, jacks, cranes, hoists.

What do learners need to learn?	Skills
The functions of common mechanisms. The application of lifting equipment and mechanisms, and how they operate. Types of gear trains, including compound gears and the role of idler gears. Identify ties and struts in frames. Simple harmonic motion of springs. Factors of safety, including safe working loads, when working with lifting equipment.	EC5, MC6.

T Level structure

To achieve the T Level learners must meet all requirements of the T Level framework of which the technical qualification is one part. Learners have to successfully complete an industry placement and any other requirements set by the Institute for Apprenticeships and Technical Education (IfATE) such as licence to practice qualifications.

Technical qualification structure

The technical qualification is made up of **two** components all of which need to be successfully achieved to attain the technical qualification as well as the full T Level Technical Qualification in Maintenance, Installation and Repair for Engineering and Manufacturing (Level 3).

The common core component:

The core content is designed to offer sufficient breadth of knowledge and skills for the learner to apply in a variety of contexts related to the engineering industry and those Occupational Specialisms linked to this T Level.

The common core content is the building blocks of knowledge and skills that will give a learner a broad understanding of the industry and job roles. At the same time, it will develop the core skills they will need to apply when working within the industry.

Occupational Specialisms:

Occupational Specialisms develop the knowledge, skills and behaviours necessary to achieve threshold competence in an occupation. Threshold competence is defined as when a learner's attainment against the knowledge, skills and behaviours is of a standard for them to enter the occupation and industry. They must also demonstrate the ability to achieve occupational competence over time with the correct support and training.

To achieve the **T Level Technical Qualification in Maintenance, Installation and Repair for Engineering and Manufacturing (Level 3) (delivered by City & Guilds)** learners must complete the **two** components of the Technical qualification. These are known as the core component and the Occupational Specialism:

- (300) plus **one** from (311 – 315)

T Level Technical Qualification in Maintenance, Installation and Repair for Engineering and Manufacturing (Level 3)					
Programme of Study (POS) number	**City & Guilds component number**	**Component title**	**Component level**	**GLH**	**TQT**
Mandatory					
8730-30	300	Engineering common core	Level 3	680	1000
Choose one standalone Occupational Specialism					
Standalone					
8712-31	311	Maintenance engineering technologies: Mechanical	Level 3	680	1000
8712-32	312	Maintenance engineering technologies: Mechatronic	Level 3	680	1000
8712-33	313	Maintenance engineering technologies: Electrical and Electronic	Level 3	680	1000
8712-34	314	Maintenance engineering technologies: Control and Instrumentation	Level 3	680	1000
8712-35	315	Light and Electric Vehicles	Level 3	680	1000

2 Centre requirements

Approval

All eligible providers must obtain Full Provider Approval with City & Guilds prior to delivering any T Level Technical Qualification (TQ).

Provider approval is not equivalent to centre approval; any provider which is already an existing City & Guilds approved centre must still obtain Full Provider Approval in the first instance. There is no fast-track approval for these qualifications.

Once successfully approved, providers can apply for additional TQs or apply to add additional occupational specialisms (OS) during each approval window.

The approval application consists of a comprehensive set of approval criteria agreed with the Institute to ensure an eligible provider is fit and ready to deliver T Level Technical Qualifications.

These criteria seek to ensure the integrity of the qualifications for both City & Guilds and the Institute. They must be adhered to throughout the delivery of the TQ and will be reviewed at the annual self-assessment.

Criteria A Management Systems
Criteria B Industry placement
Criteria C Resources
Criteria D Delivery
Criteria E Secure live assessment and administration
Criteria F Assessment and standardisation plan
Criteria G Conflicts of Interest (COI)

Please refer to our published provider approval and quality assurance information document available on our website here. This document includes information around the approval process, criteria for approval and the timeline for the relevant academic year.

Resource requirements

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

Centre staffing

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

- be occupationally competent and qualified at or above the level they are delivering
- have maths and English at Level 2 or be working towards this level of qualification
- be able to deliver across the breadth and depth of the content of the qualification being taught
- have recent relevant teaching and assessment experience in the specific area they will be teaching, or be working towards this
- demonstrate continuing CPD
- have experience or training in the following to support the delivery of this technical qualification:
    - delivering project-based qualifications
    - preparation for exam-based assessments.

Engineering common core

Staff who are familiar with L3 Engineering and Manufacturing qualifications will be able to teach the core elements.

Occupational Specialisms specific requirements

Maintenance engineering technologies: Mechanical

Level 3 or above engineering qualification or equivalent. Industrial experience or relevant CPD that demonstrates the occupational and technical competence to deliver the requirements for this specialism.

Maintenance engineering technologies: Mechatronic

Level 3 or above engineering qualification or equivalent. Industrial experience or relevant CPD that demonstrates the occupational and technical competence to deliver the requirements for this specialism.

Maintenance engineering technologies: Electrical and Electronic

Level 3 or above engineering qualification or equivalent. Industrial experience or relevant CPD that demonstrates the occupational and technical competence to deliver the requirements for this specialism.

Maintenance engineering technologies: Control and Instrumentation

Level 3 or above engineering qualification or equivalent. Industrial experience or relevant CPD that demonstrates the occupational and technical competence to deliver the requirements for this specialism.

Light and Electric Vehicles

Level 3 or above engineering qualification or equivalent. Industrial experience or relevant CPD that demonstrates the occupational and technical competence to deliver the requirements for this specialism.

It is recommended that staff assessing these qualifications must meet the above requirements and hold or be working towards a relevant recognised assessor qualification such as a Level 3 Certificate in Assessing Vocational Achievement and continue to practise to that standard. Assessors who hold earlier qualifications (D32, D33 or TQFE/TQSE) should have CPD evidence that meets current standards. Assessors must also hold a relevant trade qualification and/or have registration with a relevant trade organisation as 'Approved Tradesperson' or have 'Eng-Tech' status.

Physical resources

Centres must be able to demonstrate that they have access to the equipment and technical resources required to deliver this qualification and its assessment.

Common resources

- Virtual modelling and CAD software
- PPE
- Scientific calculator
- Technical documentation (digital or hard copy)
- Electrical / electronic equipment
- Measurement devices, instrumentation and gauges
- Machines
- Systems
- Materials
- Mechanisms
- Tools and equipment
- Devices and components
- Consumables
- Fixtures and fittings
- Testing and diagnostic equipment
- Video camera
- Camera
- Workshop (to include waste disposal facilities)
- ICT equipment and software

Maintenance engineering technologies: Mechanical

- Technical documentation - health and safety regulations, organisational procedures, quality inspection policies/ procedures, workshop/maintenance manuals, manufacturers specifications, maintenance schedules, maintenance instructions, inspection and test record sheets, equipment data sheets, material safety data sheets (MSDS), engineering drawings (exploded diagrams, schematics, component diagrams), maintenance reports/records/logs, test data/results/certificates, diagnostic information, standard operating procedures (SOP), method statements/planning sheets, risk assessments, permit to work, handover sheets.
- Materials – ferrous, non-ferrous (titanium and alloys), thermosetting polymers, thermoplastics, composites (CRP and GRP), smart materials (shape memory alloy (SMA), piezoelectric, quantum tunnelling composite (QTC), photochromic and thermochromic pigments).
- Machines (and associated tooling) - manual and computer numerical control (CNC), drills (pillar and bench), centre lathe, milling machine, linisher/belt sander, compressor.
- Work holding devices - machine vice, clamps, chucks, machine vice, jigs and fixtures.
- Systems and mechanisms - drive devices (motors, belts, shafts), gears, gear trains, gearbox, clutches (mechanical, electronic, fluid), pulleys, torque convertors, governors, rams/cylinder (pneumatic, hydraulic), braking systems, cams, linkages, levers, woodruff keys, cooling systems, lubrication (manual, gravity feed, forced, splash), structural components (frames, tie-bar, struts).
- Lifted components - bushes, bearings, belts, o-rings, oil seals, circlip, gaskets.
- Fastenings - nuts, bolts, screws, washers, shims, rivets, rivet nut, grease nipples/points.
- Consumables - lubricants, coolants.

- Lifting equipment - lifts, pulleys, jacks, hoists, chains, slings, D-shackles, eye bolts.
- Tools and equipment (hand and power) – spanners, wrenches/sockets (ratchet, universal joints, extension bars), screwdrivers, pry bars, punches, chisels, hacksaw, mole grips, side cutters, files, hammers, mallets, crimpers, taps and dies, jigsaw, angle grinder, drills, pliers, Allen keys, bearing pullers, metal vice, reciprocating saw, multitool.
- Measuring and diagnostic tools and equipment - steel rule, vernier callipers (internal, external, digital), micrometres (internal, external, depth), diagnostic test equipment (fault codes reader/scan tool), dividers/callipers, squares (engineer, combination), gauges (feeler, pressure, slip, height, thread, plug), dial tester indicator (DTI), multimeter, thermometer (contact and non-contact), thermocouples, coordinate measuring machine (CMM), laser level, comparison plates.

Maintenance engineering technologies: Mechatronic

- Technical documentation - standards and regulations, organisational procedures, manufacturers' catalogues and data sheets, material safety data sheets (MSDS), Maintenance manuals, instructions and schedules, inspection and test record sheets, test and calibration certificates, technical drawings (schematics, block diagrams, exploded diagrams, wiring diagrams), bill of materials (BoM), method statement, Standard operating procedures (SOP), risk assessments, permits to work.
- Electrical and Electronic devices and components – resistors, potentiometers, capacitors, inductors, switches (single pole single throw (SPST), single pole double throw (SPDT), double pole single throw (DPST), double pole double throw (DPDT), contact, reed, limit), transistors, operational amplifiers, diodes (Zener, photodiodes, light emitting diodes (LED's)), microprocessors, microcontrollers and integrated circuits (logic gates (AND, OR, NOT, NAND), counters, comparators and timers), speakers and buzzers, actuators, motors (electrical and mechanical), solenoids, relays, transformers, generators, invertors, thyristors, rectifiers, fuses, circuit breakers, residual current devices (RCD), circuit board (printed circuit board (PCB), breadboard), wiring and cables (single core, multicore, armoured, fire resistant, flexible, non-flexible), connectors, visual display units (VDU), surface mount technology (SMT), AC-DC converters.
- Control devices – programmable logic controllers (PLC), Human machine interface (HMI), electronic control unit (ECU).
- Software - Programming languages and software (for microcontrollers, PLCs, electronic circuit and PCB design), basic input/output system (BIOS), operating systems, AI.
- Digital technologies - laptops, tablets, mobile applications, personal digital assistant (PDA).
- Mechanical devices and components - levers, rams, gears, gear trains, gear box, clutches, pulleys and belts, governors, pulleys, rams/cylinders (air/hydraulic), valve blocks, pumps (mechanical, electronic, electrical, pneumatic) structural components (frames, bearings, springs, bushes, fixings), tensioning devices.
- Sensors – switches, photodiodes, photoresistors/light dependent resistors (LDR), thermistors (PTC, NTC), thermocouples, ultrasonic proximity sensors, capacitive and inductive sensors, piezoelectric, strain gauges, pressure pads, microphone, flow gauge, hall effect, accelerometer, sight glass.
- Machines – drills, lathes, milling machines and routers, manual and computer numerical control (CNC), robotics (SCARA, polar, cartesian, articulated).
- Machine tooling – drill bits, chucks, steadies, lathe cutting tools, boring bars, taps and dies, reamers, milling cutters.
- A range of systems – gearbox, cams and followers, pulleys, levers, actuation, cooling, lubrication, integrated systems, robotics, integrated circuits, amplifiers, power supplies, sequential, asynchronous/synchronous logic, programmable systems, data logging and measurement systems, automation, AC and DC units, pump.
- Consumables – lubricants, coolants, solder, surface treatment.

- Tool and equipment (hand and power) spanners, wrenches, sockets (ratchet, universal joints, extension bars), screwdrivers, pry bars, punches, chisels, hacksaw, metal vice, pliers, snips, wire strippers, wire cutters, soldering iron, de-soldering tool, mole grips, side cutters, bolt cutter, files, hammers, mallets, Allen keys, crimpers, drills, riveter, jigsaw, reciprocating saw, multitool, angle grinder, metal guillotine, metal vice, PCB etching,
- Lifting equipment - hoist, jacks, chains, slings, D-shackles, eye bolts.
- Measurement and diagnostic tools and equipment - micrometers, Vernier callipers, rules, multimeters, oscilloscopes, signal generators, logic probes, data logger, analysers (logic, dewpoint, hygrometers, hydrometers, thermometer), clamp meters, pressure gauges, temperature measurement devices, engineers try square, diagnostic testers, coordinate measuring machines (CMM), residual temperature devices (RTD's).
- Measures of protection - ESD-safe bags and foam, grounding mats, straps and tools, antistatic garments, wrist straps.
- Materials – metals (ferrous and non- ferrous), thermosetting polymers, thermoplastics, composites (CRP and GRP), smart materials (shape memory alloy (SMA), piezoelectric, quantum tunnelling composite (QTC), photochromic and thermochromic pigments).
- Fixings and fastenings - screws, nuts, bolts, cable ties, rivets.

Maintenance engineering technologies: Electrical and Electronic

- Technical documentation - Standards and regulations, maintenance manuals and instructions, material safety data sheets (MSDS), manufacturer data sheets, manufacturer specifications, technical manuals, maintenance logs, schematic diagrams, wiring diagrams, block diagrams, circuit diagrams, engineering drawings, bill of materials (BoM), risk assessments, method statements, standard operating procedure (SOP), permit to work, inspection and test record sheets.
- Devices and components – transistors (bi-polar (NPN, PNP), field effect (MOSFET, JFET)) complementary metal oxide semiconductor (CMOS), thyristors, operational amplifiers, microcontrollers and integrated circuits (logic gates (AND, OR, NOT, NAND, NOR, XOR), counters and timers), switches (single pole single throw (SPST), single pole double throw (SPDT), double pole single throw (DPST), double pole double throw (DPDT), contact, reed), diodes (P-N junction, Zener, photodiodes, light emitting diodes (LED)), rectifiers, capacitors (polarised, non-polarised, super-capacitors), resistors and potentiometers, inductors, relays, transformers, wiring and cables (single core, multicore, armoured, fire resistant, flexible, non-flexible), photovoltaic cells, electrical power outlets (three pin plug outlet, USB charging points, indoor, outdoor), speakers and buzzers, motors (servo, stepper, DC/linear, solar).
- Protection devices – residual current device (RCD), fuses, immobilisers, circuit breakers, isolators.
- Systems and circuits – power supplies, AC and DC units, series, parallel, series-parallel, closed, open circuits, power, amplifiers, timer, latching, pulse generation circuits, auxiliary, modulators, inverters, regulator, electrical motors, modulators, control units, sensing units, convertors, Wheatstone bridge/comparator.
- Tools and equipment - drills, pliers, insulated tool sets (wire cutters, wire strippers, pliers, screwdrivers), soldering irons, de-soldering tool, spanners, wrenches, files, hammers, Allen keys, crimping tools, potentiometer trimmers.
- Measurement and test equipment - multimeters, clamp meters, diagnostic testers, micrometers, engineer's rule, Vernier callipers, oscilloscopes, signal and function generators, logic probes, data loggers, logic pulser, insulation resistance testers, frequency meters, wire gauge.
- Anti-static protection measures - ESD-safe bags and foam, grounding mats, straps and tools, anti-static garments, wrist straps.

- Sensors – switches, photodiodes, photoresistors/light dependent resistors (LDR), thermistors (PTC, NTC), thermocouples, ultrasonic proximity sensors, piezoelectric, strain gauges, pressure pads, microphone, flow gauge, hall effect, accelerometer, sight glass.
- Materials –metals (non-ferrous, ferrous), thermosetting polymers, thermoplastics, composites (CRP and GRP), smart materials (shape memory alloy (SMA), piezoelectric, quantum tunnelling composite (QTC), photochromic and thermochromic pigments).

Maintenance engineering technologies: Control and Instrumentation

- Technical documentation - wiring diagrams, component datasheets, manufacturers specifications, material safety data sheet (MSDS), recording forms, manufacturers recommended procedures, operation and maintenance manuals/instructions, technical manuals, diagrams (circuit, block, schematic, wiring) maintenance logs, defect logs, reports, statements, checklists, data, test data, inspection sheets, method statements, risk assessments, bill of materials (BoM), standard operating procedures (SOP), test certificates, permits to work, organisational procedures, standards and regulations, representations (drawings, symbols, annotations, conventions, standards, reports, results, statements, signage, tags, labels, data plates), recall instructions.
- Sensors - switches, photodiodes, photoresistors/light dependent resistors (LDR), thermistors (PTC, NTC), thermocouples, ultrasonic proximity sensors, piezoelectric, strain gauges, pressure pads, microphone, flow gauge, hall effect, accelerometer, sight glass, seismic sensor, turbidity sensor.
- Components - visual display units (VDU), human machine interface (HMI), potentiometers, power supply units, transmitters, transducers, 4-20mA loops, alarms, trips, bulbs, lamps, solenoids, relays, fuses, circuit breakers, power source, gauges, indicators, controllers, motors (electric, stepper, invertor, servo, induction, brushed, brushless, AC, DC, three phase, single phase), generators, diodes, Zener, photodiodes, light emitting diodes (LED), AC – DC convertors, DC-AC convertors, DC-DC convertors, transformers, resistors, capacitors, inductors, residual current device (RCD), transistors, immobilisers, actuators, potentiometers, logic gates (AND, OR, NOT, NAND, NOR), isolators, push buttons, safety devices, filters, pipes, cable trays, isolators, transformers, guards, pipework, valves, manifolds, electrical supplies, air supplies, fluid supplies, communication equipment.
- Sensing technologies - inductive, capacitive, hall effect, piezoelectric transducers, automatic, proximity.
- Systems and circuits – Electrical/electronic systems, emergency, shutdown, control, feedback, analogue, digital, measurement, indicator, power, timing, latching, auxiliary, modulators, control units, microprocessors, microcontrollers, sensing units, output devices, DC networks, robotics (polar and Cartesian), inverters, control panels, regulators, rectifiers, rotary convertors, frequency control, power electronics and supplies, integrated circuits, Wheatstone bridge, amplifiers (operational, op-amps, sequential and asynchronous/synchronous logic, programmable systems, programmable logic controller (PLC), proportional integral derivative controller (PID), series, parallel, series-parallel, open and closed circuits, latching, timers, auxiliary, printed circuit boards (PCBs), surface mount technology (SMT), Drive devices - adjustable drive devices, hardware, motors, pumps, belts, rams, gear trains, gearboxes, clutches, modulators, AC and DC units, output devices, flywheels.
- Network systems and requirements – supervisory control and data acquisition (SCADA), distributed control system (DCS), process control system (PCS), electronic software distribution (ESD), safety instrumented systems (SIS), controller area network (CAN) bus, process field bus (Profibus), process field net (Profinet), foundation fieldbus (FF), Modbus (485, remote terminal unit (RTU)), device net, fibre optic networks, wireless systems, network LAN, ethernet, Bluetooth connectivity, fibre glass systems (FGS), bridges, bus interface, cables (RS485, RS422, RS232, ribbon, USB), adaptors, communication, control modules, devices, network, control loop, internet connection.

- Tools and equipment - screwdrivers, spanners, hammers, Allen keys, wrenches, pliers, files, mole grips, side/wire cutters, wire strippers, crimping tool, potentiometer trimmer, drills, air compressors, soldering and de-soldering equipment, multi-function calibrators, highway addressable remote transducer (HART), pressure sources, temperature baths, clamp meters, loop calibrator, digital technologies (laptops, tablets, mobile applications, personal digital assistant (PDA)).
- Measurement and diagnostic tools and equipment - multimeters, oscilloscopes, signal generators, thermocouples, thermal cameras, residual temperature devices (RTDs), venturi tubes, orifice plates, data logging, analysers (logic, dewpoint, hygrometers, hydrometers, thermometer), proximity, Logic probes, electronic control unit (ECU), diagnostic testers, flow meters, portable appliance tester (PAT tester), micrometers, Vernier callipers, rule.
- Software - Programming languages and software (for microcontrollers and PLCs), basic input/output system (BIOS), operating systems, AI.
- Fixings, fasteners and consumables- mechanical fixings/fastening, solder, adhesives, conduits, block connectors, lubricants.
- Materials - non-ferrous metals, ferrous metals, thermosetting polymers, thermoplastics, composites (CRP and GRP), smart materials (shape memory alloy (SMA), piezoelectric, quantum tunnelling composite (QTC), photochromic and thermochromic pigments).

Light and Electric Vehicles

- Technical documentation - vehicle technical data, maintenance manuals and instructions, manufacturers specifications, service information sheets/records, risk assessment, Calibration certificates/Portable Appliance Testing (PAT), technical representations (schematic/circuit/wiring/assembly drawings), inspection record sheets, vehicle referencing and numbering systems (vehicle registration number, part numbers (original equipment manufacturer (OEM), after-market), vehicle identification numbers (VIN), tyre specification (construction, size, width, direction of rotation, aspect ratio, speed rating, load rating, ply type), wiring identification (low voltage, high voltage), wheel alignment specifications, standards, regulations and policies, fault data/codes, reports, measurements, manufacturers technical bulletins, electronic document and management systems, permit to work, electrical and electronic component symbols, test results, job cards, environmental requirements, organisational procedures, customer information, performance data and diagnostic information, preparatory checks, standard operating procedures (SOP).
- Vehicles – selection of petroleum, diesel (including common rail) and full hybrid/electric vehicles with a high voltage system that learners can work on (mild hybrid vehicles without a high voltage system cannot be used, i.e. stop start).
- Automotive training rigs - transmission systems, chassis systems, electrical & electronics, selection of different engine arrangements.
- Power sources and units – petrol/diesel, hydrogen, battery electric vehicle (BEV), Hybrid electric vehicle (HEV), Plug -in hybrid electric vehicle (PHEV), Fuel cell electric vehicle (FCEV), volts, kilowatt hours (kWh), horsepower, torque.
- Engine types – engine configuration (longitudinally mounted, transverse, front, mid and rear engines) cylinder arrangements, cylinder configuration (in-line, vee, W, horizontally opposed), engine cycle (four stroke, Atkinson, Otto), hybrid layout system, spark ignition (SI), compression ignition (CI), rotary.
- Systems
    - engine (pistons, belts, chains, bearings, shafts),
    - ancillary systems (fuel, lubrication, cooling),
    - transmission - clutch (mechanical, electronic, hydraulic), torque convertor, drivetrain), manual and automatic gearboxes axles, differential, gear reduction systems, gears, gear trains, flywheel
    - electrical and electronic management system - Electronic Control Unit (ECU), motors, modulators, control units (mechanical, electro-mechanical, electrical, electronic, instrumentation, engine/powertrain), controller area network (CAN bus),

sensors, actuators, AC and DC units, lighting, wiper, security and alarm, electric window, monitoring and instrumentation, voltage and current sources, alternator (diodes, rectifiers, voltage regulator, stator and rotor), inventors, DC-DC convertors, single phase, three phase, DC networks, lighting circuits (lamps, light emitting diodes (LED), incandescent, halogen, xenon, high intensity discharge (HID)), cables, wiring looms, electrical power outlets, USB charging points, relays, potentiometers, power supply units, circuit breakers, immobiliser, capacitors (polarised, non-polarised) resistor, inductor, transformer, transistors (bipolar (NPN, PNP)),
    - chassis (steering, suspension, braking, wheels, tyres),
    - heating, ventilation and air conditioning (HVAC) (refrigerant removed)
    - antilocking braking system (ABS), brakes hydraulic (brakes discs, brake pads, brake fitting kit, brake drums, brake shoes, wheel cylinders)
    - batteries (lithium-ion, nickel metal hydride (NiMH), lead acid, auxiliary), battery cell modules.
- Mechanisms – governors, levers.
- Structural components - frames, bearings, springs, bushes.
- Sensing and sensing technologies - engine load, temperature, speed/position, pressure, knock, air and fuel parameters, exhaust emissions/lambda, inductive, Hall effect, optical, variable resistors, negative temperature co-efficient (NTC) and positive temperature co-efficient (PTC), security/warning systems.
- Tools and equipment (hand and power) - spanners (open ended, ring, combination), screwdrivers, Allen keys, ratchets and sockets (metric hex and imperial hex, bi-hex, socket drive sizes (1/4, 3/8 and ½ inch), universal joints, extension bars), hammers, mallets, files, cold chisels, punches, clamps, pliers, hacksaws, crimping tools, measuring tools (engineers' rule, micrometer (internal, external, depth), hydrometer, Vernier callipers), feeler gauge, angle gauges, torque wrench, tyre tread depth gauge, spark plug adaptor, hand diagnostic equipment, vehicle specific tools, refractometer, electric and hybrid tool set (insulated), impact wrenches, drills (compressed air/electric), power tools (cordless drill, hammer drill, electric screwdriver, compressed air driven tools) liquid draining equipment, metal vice.
- Lifting equipment – jacks (pneumatic, hydraulic, mechanical, scissor, trolley, bottle, ramps, transmission), hoists, crane, axle/vehicle stands, pullers, chain blocks.
- Measurement and diagnostic tools and equipment - diagnostic analysers, data logging/self-diagnosis equipment, dial tester indicator (DTI), emissions testers, frequency meter, hydraulic pressure, thermal checks, torque devices, testers (coolant, brake fluid, battery, discharge, diagnostic, compression, cooling system pressure, fuel pressure, oil pressure, vacuum gauge, emission), wheel alignment, beam setting, roller brake efficiency tester/rolling road, European on-board diagnostic (EOBD2) compliant, multimeters, oscilloscopes, battery chargers, compressors.
- Vehicle protective equipment (VPE).
- Specialist PPE - auto-darkening welding helmet, air-fed welding helmet, welding jacket or apron, welding shoes/boots, gloves, safety glasses, ear plugs or ear defenders, mask or respirator, Electrical Vehicle PPE.
- Health and Safety signage and equipment (including spill kit/absorbent granules).
- Service parts - filters (pollen, air, oil, fuel), fluids (oil, transmission, power steering, coolant, screen wash, brake fluid, anti-freeze).
- Replacement parts – wiper blades, spark plugs, batteries, remote/intelligent key/fob battery, bulbs/lamps.
- Workshop machinery – pillar drill, bench grinder, hand drill, bearing puller.
- Joining and Welding equipment - bonding equipment (adhesive (anaerobic, cyanoacrylate, epoxy, plastisol, polyurethane, solvent rubber), friction, fusion, composites, fasteners (threaded fixings (bolts, studs, set screws, self-tapping screws), non-threaded fixings (rivets (snap head, pan head, countersunk heads, pop rivets)), nuts, washers, pins, plastic, joint configurations (self-secured, lap joints, flanged joints grooved seams, double grooved

seams, knocked up, panned down, slip joints, flexible joints, threaded joints)) spot welding, flux, clamps, magnets, sheet metal gauge, conduit, electrode, wire and electrode feed system (pinch rolls, push-pull, spool on gun), gun, angle grinder, wire brush, cables, fume extractors, local exhaust ventilation systems (LEV), metal inert gas (MIG) rig, gas shielded metal arc (MAG) welding rig, manual metal arc (MMA), resistance/spot welder, tungsten inert gas (TIG) welding, gas (brazing, soldering), plasma cutting.

- Materials - ferrous, non-ferrous, thermosetting polymers, thermoplastics, composites (CRP and GRP), smart materials (shape memory alloy (SMA), piezoelectric, quantum tunnelling composite (QTC), photochromic and thermochromic pigments.

Internal quality assurance

Internal quality assurance is key to ensuring accuracy and consistency of tutors and assessors. Internal quality assurers (IQAs) monitor the work of all tutors involved with a qualification to ensure they are applying standards consistently throughout assessment activities. IQAs must have, and maintain, an appropriate level of technical competence and be qualified to make both marking and quality assurance decisions through a teaching qualification or recent, relevant experience.

Supervision and authentication of candidate work

The Head of Centre is responsible for ensuring that assessment evidence is conducted in accordance with City & Guilds' requirements.

City & Guilds requires:

- candidates to sign the Declaration of authenticity form to confirm that any work submitted is their own
- tutors to confirm on the record form that the work submitted for assessment is solely that of the candidate concerned and was conducted under the conditions laid down in the assessment documentation

The tutor must be sufficiently aware of the candidate's standard and level of work to make a judgement whether the work submitted is within the expected ability and style of the candidate or whether a further investigation into the authenticity of the work is required.

If the tutor is unable to sign the authentication statement for a particular candidate, then the candidate's work cannot be accepted for assessment.

Learner entry requirements

Centres must ensure that all learners have the opportunity to gain the qualification through appropriate study and training, and that any prerequisites stated in the **What is this qualification about?** section are met when registering for this qualification.

Formal entry requirements are not set by City & Guilds, but it is expected that learners will have qualifications at Level 2 or equivalent. This may include:

- Level 2 vocational qualification or equivalent in a related subject.

3 Delivering the technical qualification

Initial assessment and induction

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

- if the learner has any specific training needs
- support and guidance they may need when working towards their qualification
- the appropriate type and level of qualification.

City & Guilds recommends that centres provide an introduction so that learners fully understand the requirements of the qualification, their responsibilities as learners, and the responsibilities of the centre. This information can be recorded on a learning contract.

Programme delivery

The technical qualification should be delivered through approaches that meet the needs of learners. City & Guilds recommends using a variety of delivery methods, including in classrooms and real work environments. Learners may benefit from both direct instruction in more formal learning environments and taking part in investigative projects, e-learning and their own study and learning through indirect approaches to delivery.

4 Competency frameworks

The technical qualification has been developed to include competency frameworks for T Levels, which demonstrate an array of competencies across maths, English and digital skills as well as four key core skills that have been mapped on to the core content. This can be seen in the skills section for each criterion.

Core skills

In the design, delivery and assessment of the technical qualification the following core skills are fundamental in the development of the required knowledge, skills and behaviours that learners will need to use when they progress onwards from completing their T Level. These core skills have been mapped to the design of the qualification content and developed in consultation with the industry and providers. The mapping identifies opportunities where these core skills can be developed and embedded into teaching and learning. It is not expected that all criteria will develop core skills, but where these skills exist in the core content it has been referenced to support centres.

Core Skill A (MIR-CSA) - Analysing and interpreting an employer-set brief

- Evaluate and confirm the brief with reference to context, objectives and constraints (eg requirements, resources, precedents, technical issues, costs, health and safety, regulations, possibilities)

Core skill B (MIR-CSB) - Planning and preparation of suitable responses to the brief

- Propose and plan key activities, stages, methods, processes, techniques, documentation, resources (inc. types of tools and equipment) and risk assessments.

Core skill C (MIR-CSC) - Carry out or develop these response/s using key skills and processes

- Propose maintenance, installation and repair processes for achieving specific objectives and quality outcomes, using relevant techniques, and technology, within limits of own authority.

Core Skill D (MIR-CSD) - Evaluating and quality assuring processes and outcomes

- Investigate components and systems, to gather and evaluate relevant evidence and data, and to confirm the suitability of processes, actions and outcomes (including quality control and quality assurance activities).

Core Skill E (MIR-CSE) - Communication and presentation of outcomes and evidence

- Record, report, communicate and present plans, proposals, processes, issues, risks and outcomes to both technical and non-technical audiences, across a range of suitable formats and media (eg diagrams; physical and digital records, presentations).

For the T Level Technical Qualification in Maintenance, Installation and Repair for Engineering and Manufacturing, in achieving the assessment objectives and meeting the brief, learners must demonstrate the following core skills (which are relevant across design, manufacture, and maintenance and repair practices):

Core Skill A (MIR-CSA) - Analysing and interpreting an employer -set brief

Evaluate and confirm the brief with reference to context, objectives and constraints (eg requirements, resources, precedents, technical issues, costs, health and safety, regulations, possibilities)

- Obtain brief requirements, specifications, and objectives.
- Conduct thorough checks on the information obtained to ensure thorough understanding of brief requirements.
- Confirm requirements for the brief and agree required outcomes
- Evaluate the brief considering and highlighting any potential constraints.
- Consider costing and time issues.
- Identify resources that are required including method statements, safe systems of work, permits, instructions and diagrams.
- Interpret the information accurately ensuring full understanding.
- Check documents for errors and follow procedures where discrepancies are identified.
- Consider all Health and Safety requirements and identify regulations and legislations to be followed as part of the task.
- Seek guidance from resources including HSE when interpreting brief requirements and specifications
- Conduct discussions and gain insight from others where applicable to ensure full understanding and interpretation of the task.

Core skill B (MIR-CSB) - Planning and preparation of suitable responses to the brief

Propose and plan key activities, stages, methods, processes, techniques, documentation, resources (inc. types of tools and equipment) and risk assessments.

- Identify key stages of the brief to include designing, installation and testing activities.
- Create a work plan in response to the brief as part of the planning process.
- Prioritise key factors of the task
- Identify potential issues that may arise
- Produce a risk assessment ensuring consideration of working area, activities, tools and equipment.
- Decide strategies and methods to be applied to meet brief specifications and requirements.
- Use techniques to ensure thorough planning and preparing for the tasks including contingency plans.
- Analyse key factors including working area, tools and equipment and identify potential limitations and constraints.
- Consider and identify tools and equipment which would be required, including regulatory compliance.
- Clear and concise steps planned to ensure effectiveness and efficiency of the whole process.
- Clear objectives and goals
- Propose work plan to customer and confirm acceptance of work plan.

Core skill C (MIR-CSC) - Carry out or develop these response/s using key skills and processes

Propose maintenance, installation and repair processes for achieving specific objectives and quality outcomes, using relevant techniques, and technology, within limits of own authority.

- Develop and use diagrams and aids supplied at the beginning of the task to aid with installation of the processes.
- Develop and follow clear guidance and steps produced as part of the planning process to aid with the installation.
- Develop maintenance requirements and guidance for the proposed system considering usage and purpose of the system.
- Develop guidance on the component maintenance considering manufacturer's specifications, instructions and other technical information.
- Consider regularity of proposed and required maintenance.
- Identify potential faults which may occur as part of maintenance and installation activities, creating a fault guide to aid with repair processes.
- Use manufacturer's fault guidance to aid with development of repair guides and processes.
- Follow and complete key stages of the work plan to ensure objectives and outcomes are met.
- Where practical activities within workshop environment commence, follow guidance, procedures and protocols correctly.
- Follow legal and regulatory requirements throughout the installation process, developing/conducting maintenance and developing/conducting repairs.
- Seek guidance on installation requirements and standards including HSE website.

Core Skill D (MIR-CSD) - Evaluating and quality assuring processes and outcomes

Investigate components and systems, to gather and evaluate relevant evidence and data, and to confirm the suitability of processes, actions and outcomes (including quality control and quality assurance activities).

- Regular checks and reviews throughout project to check progress, meeting of targets and success.
- Quality checks and investigations at regular points to ensure maximum efficiency and success of project.
- Review suitability of individual components for the project
- Collate evidence and data at regular points from each task/activity analysing and reviewing the process.
- Analyse and review actions taken assessing the quality and efficiency
- Actively identify areas for improvements and enhancements and make changes to the process where required.
- Use methods and techniques including verification and validation to quality assure processes and steps.
- Use collaborative approach to discuss progress and quality of completed tasks and monitor progress.
- Quality and assurance strategies including reviews, self-assessment and audits.

Core Skill E (MIR-CSE) - Communication and presentation of outcomes and evidence

Record, report, communicate and present plans, proposals, processes, issues, risks and outcomes to both technical and non-technical audiences, across a range of suitable formats and media (eg diagrams; physical and digital records, presentations).

- Present work plans to customer.
- Explain how the project outcomes and specifications will be met.
- Communicate and present clear objectives and goals set in place to achieve project aims.
- Write written reports including process diagrams and flow charts.
- Use technology and ICT to present project plans and proposals in a clear manner to the customer and stakeholders.
- Deliver a presentation to both technical and non-technical audiences.
- Report to customer and other audiences at regular intervals of the project to maintain clear communication and progress reports.
- Communicate data, evaluations and evidence of brief success and progress to audiences.
- Report potential implications such as budgeting constraints and time management issues.
- Communicate any changes and improvements that may have been identified.
- Communicate responsibilities and roles of individuals involved with the project.

Maths, English and digital skills

Maths, English and digital skills have been mapped across the core content and each of the Occupational Specialisms. The lists below identify the core competencies which can be found in the skills section of each performance criteria.

General English Competencies

The General English Competencies outline a framework of six General English Competences, with no prioritisation or interpretation of order intended:

- EC1. Convey technical information to different audiences
- EC2. Present information and ideas
- EC3. Create texts for different purposes and audiences
- EC4. Summarise information/ideas
- EC5. Synthesise information
- EC6. Take part in/lead discussions

General Mathematical Competencies

The General Mathematical Competencies outline a framework of ten General Mathematical Competences, with no prioritisation or interpretation of order intended:

- MC1. Measuring with precision
- MC2. Estimating, calculating and error spotting
- MC3. Working with proportion
- MC4. Using rules and formulae
- MC5. Processing data
- MC6. Understanding data and risk
- MC7. Interpreting and representing with mathematical diagrams
- MC8. Communicating using mathematics
- MC9. Costing a project
- MC10. Optimising work processes

General Digital Competencies

The following outlines a framework of six General Digital Competences, with no prioritisation or interpretation of order intended:

- DC1. Use digital technology and media effectively
- DC2. Design, create and edit documents and digital media
- DC3. Communicate and collaborate
- DC4. Process and analyse numerical data
- DC5. Be safe and responsible online
- DC6. Controlling digital functions

5 Scheme of assessment

Assessment methods

Learners must complete:

Two externally set exams covering knowledge from the engineering common core (component 300).

The exams provide sufficient sampling of the content and consist of a mixture of short answer questions (SAQs), some of which will be structured, and extended response questions (ERQs). The balance of questions in assessing across assessment objectives (AOs) 1, 2 and 3 will allow for the appropriate differentiation of learners to support the reliable setting of boundaries.

One Employer-set project covering knowledge and core skills from the engineering common core (component 300).

The employer-set project will consist of a well-defined, real industry-style brief. The brief will be complex and non-routine, and will require the use of relevant maths, English and digital skills. The brief will provide a valid context for the Level 3 learner to demonstrate their knowledge and understanding of the core content and their core skills to solve occupationally relevant situations and/or problems.

And

One Occupational Specialism from (311 – 315)

These assessments will feature a considerable practical element and are composed of a series of holistic practical tasks relating to the specialism at hand. The assessments should be scheduled according to the occupational specialism window identified annually in the key dates schedule published by City & Guilds. By nature of the considerable practical elements, the tasks will generate significant ephemeral evidence and be heavily reliant on Internal Assessor observation notes and records for validation.

Grading and marking

The engineering common core (component 300) is graded overall A*–E plus ungraded (U).

The Occupational Specialisms (components 311 – 315) are graded overall Distinction, Merit, Pass and Ungraded. Each Occupational Specialism achieved will receive a grade.

Technical qualification scheme of assessment overview

Core Component – Learners must complete **all** assessment components						
Assessment component	**Method**	**Duration**	**Marks**	**Weighting**	**Marking**	**Grading**
Exam paper 1	Externally set exam	2.5 hours	100	35%	Externally marked	This component will be awarded on the grade scale A* - E
Exam paper 2	Externally set exam	2.5 hours	100	35%	Externally marked	
Employer-set project	Externally set project	12.5 hours	90	30%	Externally marked	
Occupational Specialism Component - Learners must complete **one** assessment component						
Assessment component	**Method**	**Duration**	**Marks**	**Weighting**	**Marking**	**Grading**
Maintenance engineering technologies: Mechanical	Externally set assignment	22 hours	90	100%	Externally moderated	All Occupational Specialism components will be awarded on the grade scale P, M, D
Maintenance engineering technologies: Mechatronic	Externally set assignment	22 hours	90	100%	Externally moderated	
Maintenance engineering technologies: Electrical and Electronic	Externally set assignment	22 hours	90	100%	Externally moderated	
Maintenance engineering technologies: Control and Instrumentation	Externally set assignment	22 hours	90	100%	Externally moderated	
Light and Electric Vehicles	Externally set assignment	22 hours	90	100%	Externally moderated	

Core component scheme of assessment

The assessments for this component consist of two core exams and an Employer-set project, which are set against a set of assessment objectives (AOs) used to promote consistency among qualifications of a similar purpose. They are designed to allow judgement of the learner to be made across a number of different categories of performance.

Each assessment for this component has been allocated a set number of marks against these AOs based on weightings recommended by stakeholders of the qualification. This mark allocation remains the same for all versions of the assessments, ensuring consistency across assessment versions and over time.

AO weightings for the assessment components related to the core components are detailed below.

Core exam

Assessment objective	Description
AO1 Demonstrate knowledge and understanding	All AOs require the ability to recall knowledge. AO1 refers to instances where the learner is required to demonstrate basic recall. In the test, this helps to give confidence in sufficiency of coverage of the content, and recognises that not all knowledge requires further understanding e.g. terminology, number facts etc. AO1 also covers the ability to explain principles and concepts beyond recall of definitions in order to be able to transfer these principles and concepts between contexts. Learners have built connections between related pieces of knowledge. AO1 therefore also covers the ability of the learners to show understanding by summarising or explaining concepts in their own words, exemplifying, or comparing and making inferences in general terms that show e.g. cause and effect.
AO2 Apply knowledge and understanding to different situations and context	Using and applying knowledge and understanding, of processes, procedures, generalisations, principles and theories to specified, concrete situations. AO2 is about being able to take the understanding of generalities and apply them to specific novel situations. It is more granular than the more extended synthesis/creation that may respond to an analysis of a more holistic complex situation/brief.
AO3 Analyse and evaluate information and issues	Learners will be provided with information e.g. in the form of a detailed / complex scenario, problem or data set. Learners analyse the interrelated issues arising, and where appropriate evaluate the approaches or decisions they may take (for example, the strengths and weaknesses or advantages and disadvantages) to achieve a good solution or outcome. Marks will be given for the quality of analysis and evaluation and the range of factors considered.

Assessment objective	Weightings	Description
AO1a Demonstrate knowledge	10%	The ability to demonstrate basic recall of relevant knowledge in response to straightforward questioning e.g. material properties.
AO1b Demonstrate understanding	22%	The ability to explain principles and concepts beyond recall of definitions, but in a general way – i.e. out of a particular context in response to straight forward questioning e.g. simple concepts and terms of description in engineering contexts.
AO2 Apply knowledge and understanding to different situations and context	46%	Using and applying knowledge and understanding taking the understanding of generalities and applying them to specific situations. Questions are likely to ask for application in relation to a straightforward situation – e.g. assessing the application of a single concept and the application of essential mathematical concepts.
AO3 Analyse and evaluate information and issues	22%	The ability to analyse the interrelated issues arising from a complex scenario and to evaluate these to propose a best solution or predict impacts etc e.g. – evaluating materials properties and requirements for engineered products.

Component	Assessment method	Description and conditions
Core exam	Externally marked tests	These tests are **externally set and externally marked** and will be sat through question papers provided by City & Guilds. These tests are designed to assess learners' depth and breadth of understanding across the core component in the qualification at the end of the period of learning and will be sat under invigilated examination conditions. See JCQ requirements for details: **http://www.jcq.org.uk/exams-office/ice---instructions-for-conducting-examinations** Learners who fail either one or both exams in the core component will need to retake both exams and must do so in the same assessment window. These exams will be made up of different question types that include short answer questions, structured questions, and extended response questions. The level of difficulty will increase through the paper with lower demand questions at the beginning of the question paper to higher demand questions at the end of the question paper.

Component	Assessment method	Assessment overview
Paper 1	Externally marked test	Content overview: • Essential mathematics for engineering and manufacturing • Essential science for engineering and manufacturing • Materials and their properties • Mechanical principles • Electrical and electronic principles • Mechatronics
Paper 2	Externally marked test	Content overview: • Working within the engineering and manufacturing sectors • Engineering and manufacturing past, present, and future • Engineering representations • Engineering and manufacturing control systems • Quality management • Health and safety principles and coverage • Business, commercial and financial awareness • Professional responsibilities, attitudes, and behaviours • Stock and asset management • Continuous improvement • Project and programme management

Employer-set project

Component	Assessment method	Assessment weighting
AO1 Plan approach to meet brief	Evidence of a planned approach to work, considered sequence of activity, evidence of prioritisation, review and iterative working. Clearly structured response to brief, cohesive response with ordered sections, logical approach to referencing, research and use of sources, response completed meeting required parameters, sources used effectively and integrated into response, effective use of time allocation available for presentations.	13.3%
AO2 Apply knowledge and skills to contexts	Linking knowledge principles and ideas and applying them in context of the brief when considering compiling response use of materials, concepts etc. Applying core skills e.g. communication, problem solving appropriately throughout tasks within project.	50%
AO3 Select techniques and resources to meet brief	Selection of techniques and resources in order to support a response to the brief; consideration of the techniques and resources that are most effective and appropriate to use, and accurate and informed use of these.	13.3%
AO4 Use maths, English and digital skills	Use of correct terminology, abbreviations, units of measurement in context, consideration of audience of brief response (technical versus non-technical wording), use of calculations/diagrams etc appropriately, consideration of the use of ICT and digital methods both in brief response and in presentation.	10%
AO5 Realise project outcome and evaluate	Considered analysis and evaluation of project outcome, response conclusion or evaluation, identification of solutions in response to brief problem with evidence of evaluation of other options and reasons for rejection of other options where not appropriate.	13.3%

Component	Assessment method	Description and conditions
Employer-set project	Externally marked project	This project is **externally set and externally marked** by City & Guilds and is designed to require the learner to identify and use effectively in an integrated way an appropriate selection of skills, techniques, concepts, theories and knowledge from across the whole of the engineering core content. Projects will be released to centre staff in advance of any of the assessment windows for each task. City & Guilds will provide centres with assessment windows for centres to timetable assessment sessions within, in accordance with the assessment times prescribed in the Employer-set project centre guidance. Centres will be required to maintain the security of all live assessment materials until assessment windows are open. Projects will therefore be password-protected and released to centres through a secure method. Guidance on equipment, resources and duration will be released as appropriate to ensure centres can plan for delivery of the project in advance. Learners who fail the Employer-set project on first submission can retake in any assessment window.

Component	Assessment Method	Assessment overview
Employer-set project	Externally marked project	**Content overview:** The employer-set project samples knowledge drawn from across the core content in relation to the specific project version context. **Assessment overview:** The employer-set project is an assessment made up of several tasks that will take place within controlled conditions, assessing the knowledge and skills learned as part of the core element of the T Level. Each project will be developed together with employers in the industry to reflect realistic types of developments, activities and challenges. The project is made up of a number of tasks which all relate to the same employer-set project brief and tender specification. • Research • Report • Plan • Present The project draws on the content from the core knowledge that sits across all specialisms in Maintenance, Installation and Repair for Engineering and Manufacturing (specific knowledge and skills for each specialism will be assessed in the practical assignments). The project is linked to the core skills: • Analysing and interpreting • Planning and preparation • Developing a proposal • Evaluation • Communication

Scheduling of the Employer-set project assessments

The employer-set project assessment window will occur from March to May annually. Specific dates will be released annually through the key date schedule for the following academic year.

Task	Scheduling	Task duration
1 Research	City & Guilds sets the assessment window for the centre to timetable	3 hours
2 Design	City & Guilds sets the assessment window for the centre to timetable	4 hours
3 Plan	City & Guilds sets the assessment window for the centre to timetable	3 hours
4 Present	City & Guilds sets the assessment window for the centre to timetable	2.5 hours

A supporting document and guidance will be shared in advance of the assessment to support timetabling and planning for centres, for example outlining any required resources or conditions. This will be released to centres as part of the Key Dates Schedule.

Occupational Specialism component scheme of assessment

What is the Occupational Specialism component?

The Occupational Specialism assignment consists of a project brief presented as client requirements or a specification of work that is realistic to the Occupational Specialism rather than detailed instructions on what to do, to allow the learner to demonstrate that they have the knowledge required to implement the brief. There will be several high-level tasks in every version of the assessment, and these will take the form of planning and carrying out industry relevant practical tasks. Within each high-level task there will be several sub-tasks that learners will need to complete as directed within the assessment documents. The sub-tasks will reflect the project brief for that version of the assignment.

How is the Occupational Specialism component marked?

Occupational Specialism assessments will be set and marked against a number of assessment themes. Once learner evidence has been marked, Internal Assessors will make a holistic judgement on performance by applying the knowledge and skills that have been demonstrated to assessment themes within the marking grid.

Each learner will receive a total mark for each assessment theme. The total for each assessment theme is accumulated, giving a total mark for the assessment. Assessment themes will be common across every version of the assessment and will assess a similar range of evidence across assessment versions, ensuring comparability of demand between every version of the assessment.

Although evidence from across all tasks can be used to demonstrate performance against an assessment theme, internal assessors will be directed to specific task evidence that must be used to support judgements on performance against the assessment theme. The assessment themes will be broad enough to ensure that all the performance criteria across the specialism are assessed, supporting reliability of the assessment.

In order to ensure reliability, and consistent and accurate judgements on performance, assessment themes may consist of sub-assessment themes due to the potentially wide content coverage and to ensure that the Performance Outcome (PO) is assessed to the appropriate depth and breadth. This still allows for the appropriate base mark to be applied to the assessment theme, but also ensures that the distribution of marks within and across bands is more manageable and increases the reliability of judgements made and marks awarded. Internal assessors will give an appropriate mark in relation to the learner's performance for each individual sub-assessment theme, but this will contribute to the overall mark for that assessment theme. Internal assessors will then need to evidence the decision for the mark awarded for each assessment theme on the Candidate Record Form (CRF).

Component	Assessment method	Overview and conditions
Occupational Specialism assignment	Externally set, externally moderated	This assignment is **externally set, internally marked and externally moderated**, and is designed to require the learner to identify and use effectively in an integrated way an appropriate selection of skills, techniques, concepts, theories and knowledge from across the occupational area. Assignments will be released to centre staff towards the end of the learners' programme, usually the week before Easter each year. Centres will be required to maintain the security of all live assessment materials until assessment windows are open. Assignments will therefore be password-protected and released to centres through a secure method. Guidance on equipment, resources and duration will be released as appropriate to ensure centres can plan for delivery of practical assignments in advance. Learners who fail the Occupational Specialism following the first submission can retake in any assessment window. Please note that for externally set assignments City & Guilds provides guidance and support to centres on the marking process and associated marking grid in the assessment pack for the qualification, and guidance on the use of marking grids

Component	Assessment method	Overview and conditions
Maintenance engineering technologies: Mechanical	Externally set, externally moderated	**Content overview** Learners will be able to: • Analyse and interpret requirements for mechanical engineering maintenance, installation and repair • Plan and prepare for mechanical engineering maintenance, installation and repair • Perform maintenance, installation and repair activities on mechanical plant and equipment • Review and evaluate mechanical engineering maintenance, installation and repair activities • Communicate mechanical maintenance, installation, servicing and repair information **Assessment overview:** Learners will be assessed against the following assessment themes: • Health and safety • Planning and preparation • Systems and components • Working with faults • Reviewing and reporting

Component	Assessment method	Overview and conditions
Maintenance engineering technologies: Mechatronic	Externally set, externally moderated	**Content overview** Learners will be able to: • Analyse and interpret requirements for mechatronic maintenance, installation and repair • Plan and prepare for mechatronic maintenance, installation and repair activities • Perform maintenance, installation and repair activities on mechatronic technology, systems and equipment • Review and evaluate mechatronic maintenance, installation and repair activities • Communicate mechatronic maintenance, installation, servicing and repair information **Assessment overview:** Learners will be assessed against the following assessment themes: • Health and safety • Planning and preparation • Systems and components • Working with faults • Reviewing and reporting

Component	Assessment method	Overview and conditions
Maintenance engineering technologies: Electrical and Electronic	Externally set, externally moderated	**Content overview** Learners will be able to: • Analyse and interpret requirements for electrical and electronic maintenance, installation and repair • Plan and prepare for electrical and electronic maintenance, installation and repair activities • Perform maintenance, installation and repair activities on electrical and electronic technology, systems and equipment • Review and evaluate electrical and electronic maintenance, installation and repair activities • Communicate electrical and electronic maintenance, installation, servicing and repair information **Assessment overview:** Learners will be assessed against the following assessment themes: • Health and safety • Planning and preparation • Systems and components • Working with faults • Reviewing and reporting

Component	Assessment method	Overview and conditions
Maintenance engineering technologies: Control and Instrumentation	Externally set, externally moderated	**Content overview** Learners will be able to: • Analyse and interpret requirements for control and instrumentation maintenance, installation and repair • Plan and prepare for control and instrumentation maintenance, installation and repair activities • Perform maintenance, installation and repair activities on control and instrumentation technology, systems and equipment • Review and evaluate control and instrumentation maintenance, installation and repair activities • Communicate control and instrumentation maintenance, installation, servicing and repair information **Assessment overview:** Learners will be assessed against the following assessment themes: • Health and safety • Planning and preparation • Systems and components • Working with faults • Reviewing and reporting

Component	Assessment method	Overview and conditions
Light and Electric Vehicles	Externally set, externally moderated	**Content overview** Learners will be able to: • Analyse and interpret requirements for vehicle maintenance, servicing and repair • Plan and prepare for vehicle maintenance, servicing and repair activities • Perform maintenance, servicing and repair of vehicles • Review and evaluate vehicle maintenance, servicing and repair activities • Communicate vehicle maintenance, servicing and repair information **Assessment overview:** Learners will be assessed against the following assessment themes: • Health and safety • Planning and preparation • Systems and components • Working with faults • Reviewing and reporting

Availability of assessments

Scheduled assessment windows will be set annually for the T Level Technical Qualification in Maintenance, Installation and Repair for Engineering and Manufacturing (Level 3). Exact key dates for assessments that are externally marked (core exams and the Employer-set project) will be communicated to approved providers annually through the key date schedule.

Component	Series	Exam type	Calendar Month/s	Assessment window/set date
Core exam 1	Summer	Written exam	May/June	Set date
	Autumn	Written exam	November	Set date
Core exam 2	Summer	Written exam	May/June	Set date
	Autumn	Written exam	November	Set date
Employer-set project	Summer	Project	March – May	Assessment window
	Autumn	Project	October	Assessment window
Occupational specialism	One series annually	Project	April – May	Assessment window

6 Technical qualification grading and result reporting

Awarding the technical qualification grade

The technical qualification components are awarded as shown below:

Component	Grading
Core	A* – E
Occupational Specialism	Pass, Merit and Distinction

Core component

Calculating the grade of the core component uses the aggregation of points from across all assessment components in the core to calculate the overall grade for the core component.

Core component grade descriptors

Component	Grade	Descriptor
Core	A	To achieve an 'A' grade a candidate will: Show clear ability to demonstrate a comprehensive understanding of the full range of principles that influence engineering activities in routine contexts and allow successful implementation to non-routine contexts. Make links between relevant knowledge and understanding when responding to problems in a logical and methodical format. Legitimate and justified approaches are provided in response to complex engineering briefs and problems. Demonstrate the ability to comprehensively identify and interpret a full range of considerations when analysing complex briefs or problems, including the impacts their decisions have on design, manufacture and maintenance in engineering contexts. There is a meticulous approach in the selection of processes, tools and equipment, materials, methods and health and safety considerations when planning approaches or responses to engineering briefs or problems. Use a range of communication strategies and an ability to adapt their style and format to respond well to audience and stakeholder needs in presenting approaches to solving problems. Demonstrate a high degree of accuracy in knowledge and skills from across the core content and critically evaluate their own performance in meeting a brief or problem, identifying areas for improvement where appropriate.

Component	Grade	Descriptor
Core	E	To achieve an 'E' grade a candidate will: Demonstrate a limited understanding some of the key principles and how they influence engineering activities in routine contexts. Make general links in knowledge and understanding when responding to routine engineering problems. The response can sometimes be superficial, not evidence-based and supported by partial reasoning. Respond to engineering briefs or problems with little awareness of the impact their decisions have on design, manufacture or maintenance in engineering contexts. There is some understanding in the selection of processes, tools and equipment, materials, methods and health and safety considerations to meet the requirements of routine engineering briefs or problems. Demonstrate a small range of communication strategies that are sometimes not suitable in language and format for audiences and stakeholders with inaccuracies in technical references. Provide some evaluation of performance and how requirements have been met when addressing an engineering brief, with no reference on how to improve. Candidates need to complete all components to be awarded the Technical Qualification. Any performance determined as not meeting the standard by City & Guilds will receive an unclassified (U) result.

Occupational Specialism component

Calculation of the grade for the Occupational Specialism is based on setting grade boundaries for Pass and Distinction. The setting of grade boundaries is based on judgemental evidence, against the grade descriptors for the Occupational Specialisms, review of the Guide Standard Exemplification Materials (Grade Standard Exemplification Materials after the first award) and review of statistical evidence.

Pass and Distinction grade descriptors can be found in the centre occupational assessment materials.

To successfully achieve an Occupational Specialism the learner needs to be recognised at threshold competence (Pass).

Threshold competence refers to a level of competence that:

- signifies that a student is well placed to develop full occupational competence, with further support and development, once in employment
- is as close to full occupational competence as can be reasonably expected of a student studying the TQ in a classroom-based setting (for example, in the classroom, workshops, simulated working and (where appropriate) supervised working environments)
- signifies that a student has achieved at least a pass in relation to the relevant occupational specialism component

If a learner does not meet the minimum standards as determined by City & Guilds for either/both the core component and Occupational Specialism they will be issued with an unclassified (U) grade.

Awarding the T Level programme grade

To achieve a T Level Technical Qualification in Maintenance, Installation and Repair for Engineering and Manufacturing (Level 3) a learner must complete all elements of the T Level framework set by the Institute for Apprenticeships and Technical Education (IfATE). This includes the technical qualification, industry placement and other requirements set, such as a license to practice qualification.

In meeting the above requirements, the learner will be eligible to be awarded an overall qualification grade for the T Level Technical Qualification in Maintenance, Installation and Repair for Engineering and Manufacturing (Level 3). The overall qualification grade will be based on performance in the core component and Occupational Specialism, as set out below.

T Level Qualification Grade				
	Occupational specialism grade			
Core component grade	**Grade**	**Distinction**	**Merit**	**Pass**
	A*	Distinction*	Distinction	Distinction
	A	Distinction	Distinction	Merit
	B	Distinction	Merit	Merit
	C	Distinction	Merit	Pass
	D	Merit	Merit	Pass
	E	Merit	Pass	Pass

7 Administration

Factors affecting individual learners

If work is lost, City & Guilds should be notified immediately of the date of the loss, how it occurred, and who was responsible for the loss. Centres should use the JCQ form, JCQ/LCW, to inform City & Guilds Customer Services of the circumstances.

Learners who move from one centre to another during the course may require individual attention. Possible courses of action depend on the stage at which the move takes place. Centres should contact City & Guilds at the earliest possible stage for advice about appropriate arrangements in individual cases.

Malpractice

Please refer to the City & Guilds guidance notes *Managing cases of suspected malpractice in examinations and assessments*. This document sets out the procedures to be followed in identifying and reporting malpractice by candidates and/or centre staff and the actions which City & Guilds may subsequently take. The document includes examples of candidate and centre malpractice and explains the responsibilities of centre staff to report actual or suspected malpractice. Centres can access this document on the City & Guilds website.

Examples of candidate malpractice are detailed below (please note that this is not an exhaustive list):

- falsification of assessment evidence or results documentation
- plagiarism of any nature
- collusion with others
- copying from another candidate (including the use of ICT to aid copying), or allowing work to be copied
- deliberate destruction of another's work
- false declaration of authenticity in relation to assessments
- impersonation.

These actions constitute malpractice, for which a penalty (e.g. disqualification from the assessment) will be applied.

Where suspected malpractice is identified by a centre after the candidate has signed the declaration of authentication, the Head of Centre must submit full details of the case to City & Guilds at the earliest opportunity. Please refer to the form in the document *Managing cases of suspected malpractice in examinations and assessments*.

Accessibility

In the design of the Technical Qualification and its assessments, the following principles have been applied:

- In the development of content, tasks and assessments all learners are considered
- Well-designed materials that do not create barriers to attainment. This will include content being presented logically and uncluttered
- No particular characteristic or group of learners are disadvantaged by features of a qualification
- Language is appropriate including carrier language which is presented in its simplest for fair access to all learners
- In the design of content and assessments the impact on learners social, behavioural and emotional well-being will be considered
- Physical and sensory needs of learners in accessing content and assessments.

Access arrangements

Access arrangements are adjustments that allow candidates with disabilities, special educational needs and temporary injuries to access the assessment and demonstrate their skills and knowledge without changing the demands of the assessment. These arrangements must be made before assessment takes place.

It is the responsibility of the centre to ensure at the start of a programme of learning that candidates will be able to access the requirements of the qualification.

Please refer to the *JCQ access arrangements and reasonable adjustments and Access arrangements - when and how applications need to be made to City & Guilds* for more information. Both are available on the City & Guilds website: **http://www.cityandguilds.com/delivering-our-qualifications/centre-development/centre-document-library/policies-and-procedures/access-arrangements-reasonable-adjustments**

In the design of the technical qualification and its assessments the following principles have been applied:

- In the development of content, tasks and assessments, **all** learners are considered.
- Materials are well designed and do not create barriers to attainment. This includes content being presented logically and in an uncluttered way.
- No particular characteristics or groups of learners are disadvantaged by features of the qualification.
- Language is appropriate and presented in its simplest form to provide fair access to all learners.
- In the design of content and assessments, the impact on learners' social, behavioural and emotional wellbeing is considered.
- Physical and sensory needs of learners in accessing content and assessments are considered.

Special consideration

We can give special consideration to candidates who have had a temporary illness, injury or indisposition at the time of the examination. Where we do this, it is given after the examination.

Applications for either access arrangements or special consideration should be submitted to City & Guilds by the Examinations Officer at the centre. For more information please consult the current version of the JCQ document, *A guide to the special consideration process*. This document is available on the City & Guilds website: **http://www.cityandguilds.com/delivering-our-qualifications/centre-development/centre-document-library/policies-and-procedures/access-arrangements-reasonable-adjustments**

Informing candidate of pre-moderated marks

Centres are required to inform candidates of their marks **before** external moderation. It is important that candidates are informed of their pre-moderated marks are provisional and allow sufficient time for them to appeal if felt necessary while still allowing their agreed centre marked work to be available for external moderation on time.

Centres must also provide candidates with a copy of their marked work and the centre's internal appeals procedures on request.

Internal appeals procedure

For internally marked assessments, all centres must have an internal appeals procedure for candidates, which gives them the opportunity to appeal the centre mark for their work, before moderation takes place. The procedure must ensure:

- the person completing the appeal is competent and did not mark the work originally
- that any marking errors are identified and corrected
- the candidate is informed of the outcome, reason and any change in mark.

The City & Guilds appeals process also covers access arrangements, special consideration, and malpractice. Applications are not accepted directly from candidates, but the centre can apply on a candidate's behalf. Where relevant, centres must tell candidates how to request this. The centre can refuse to make the application to City & Guilds, but the candidate must be given the opportunity to appeal this decision. This information must be included in the centre's internal appeals procedure.

Centres must provide candidates and City & Guilds with a copy of their internal appeals procedure, on request.

Results reporting

The Institute for Apprenticeships and Technical Education (IfATE) will certificate Learners who have successfully completed all elements of the T Level Technical Qualification in Maintenance, Installation and Repair for Engineering and Manufacturing (Level 3).

T Level results will be released on the Level 3 results day in August.

Post-results services

The services available include a review of marking and review of moderation. Requests must be submitted within the specified period after the publication of results for individual assessments.

For further details of enquiries about results services, please visit the City & Guilds website at **www.cityandguilds.com**

8 Components

Content of components

The components in this qualification are written in a standard format and comprise the following:

- City & Guilds reference number
- Title
- Level
- Guided learning hours (provisional)
- Assessment method
- Introduction section
- Underpinning knowledge outcome – including range and 'what learners need to learn' sections
- Skills outcomes – including range and 'what learners need to learn' sections
- Links to maths, English and digital skills
- Guidance for delivery*
- Suggested learning resources*

*To be developed further

300 Engineering common core content

Level:	3
GLH:	680
Assessment method:	Externally set exam Employer-set project

What is this component about?

An introduction to Engineering and Manufacturing, designed to help learners choose a specific pathway and specialism once the common core is delivered.

It covers the theoretical knowledge of the Engineering and Manufacturing industry and various disciplines across all sectors that are indicative to the industry.

Learners gain an understanding of what theoretical principles and practices integral to the industry and sector are required to work in it.

Learners will develop their knowledge and understanding of, and skills in:

- Knowledge of working within the engineering and manufacturing sectors and the professional responsibilities, attitudes, and behaviours required to do so.
- Knowledge of the essential mathematics and science for engineering and manufacturing.
- Knowledge of mechanical, electrical and mechatronic principles.
- Knowledge of health and safety principles.
- An understanding of the business management required within the sector to provide a product or service with success.
- Skills in project management and delivery of a project.

Learners may be introduced to this component by asking themselves questions such as:

- What are the different sectors in engineering and manufacturing?
- What does the future look like for this sector, where could it take me?
- What mathematics and science are involved in engineering and manufacturing?
- How do I read engineering diagrammatic representations?
- How do I manage and present a project?

Underpinning knowledge outcomes

On completion of the Common Core component, learners will understand

1 Working within the engineering and manufacturing sectors
2 Engineering and manufacturing past, present, and future
3 Engineering representations
4 Essential mathematics for engineering and manufacturing
5 Essential science for engineering and manufacturing
6 Materials and their properties
7 Mechanical principles
8 Electrical and electronic principles
9 Mechatronics
10 Engineering and manufacturing control systems
11 Quality management
12 Health and safety principles and coverage
13 Business, commercial and financial awareness
14 Professional responsibilities, attitudes, and behaviours
15 Stock and asset management
16 Continuous improvement
17 Project and programme management

Completion of the Engineering and Manufacturing Common Core will give learners the opportunity to develop their Maths, English and Digital Skills. Details are presented in the skills section of each criterion.

Content

1 Working within the engineering and manufacturing sectors

1.1 Key **principles** and methodologies in engineering and manufacturing design.

Range:
Principles
Types of manufacturing process (wasting, forming, shaping, joining, finishing, casting, additive).
Fitness for purpose (influences on design and manufacture, functional requirements, environmental requirements).
User requirements (design brief, specification, needs to be met).
Approaches to design (linear design, iterative design, inclusive design, user centred design, anthropometric data (ergonomic design), design for manufacture, design for assembly, sustainable design, 6Rs (reduce, refuse, rethink, repair, reuse, recycle)).
Research and testing methodologies.
Methods of communicating design requirements to technical and non-technical audiences.

What do learners need to learn?	Skills
How different types of manufacturing processes influence the design of engineered products. How different requirements affect the user and designs related to the manufacture of products. The steps of the linear and iterative design processes and the contribution that testing makes to achieve a suitable and effective design. How to interpret anthropometric data.	MIR-CSA, MIR-CSE.

1.2 The role of **maintenance, repair and installation** in engineering.

Range:
Maintenance, repair and installation
Types of maintenance activity (planned, reactive, preventative, condition-based monitoring).
Roles and functions (machine operator, maintenance engineer, maintenance manager).
Operations (monitoring, repair, shutdown, servicing).
Tools and equipment (mechanical (hand tools, portable power tools), electrical/electronic (hand tools, soldering irons).
Measurement devices, instrumentation and gauges).
Installation requirements (provision of services, commissioning).
developments in maintenance (influence of new technologies, environmental influences).

What do learners need to learn?	Skills
The role and purpose of maintenance, repair and installation. The advantages and disadvantages of different approaches to maintenance. The responsibilities of the different roles involved in maintenance. Approaches to monitoring and the reasons for carrying out monitoring. The reasons for, and implications of shutdown and servicing. An overview of the types of tools and equipment used. The reasons for commissioning activities.	MIR-CSB, MIR-CSC.

How effective maintenance reduces impact on the environment and the safe and environmentally friendly disposal of waste.

1.3 Approaches to **manufacturing**, processing and **control**.

Range:

Manufacturing – Scale of manufacture (one off, batch, mass, continuous), infrastructure (functional, product and matrix arrangements, cellular manufacture, production lines), level of automation (manual, computer aided manufacture (CAM), fully automated, robotic).
Control – Infrastructure (monitoring of performance, quality assurance, quality control).

What do learners need to learn?
How the scale of manufacture affects the level of automation.
Examples of products made at different scales of manufacture.
Different types of manufacturing infrastructure, their purpose and relative advantages and limitations.
The purpose and application of CAM systems and software.
The advantages and limitations of different levels of automation.

2 Engineering and manufacturing past, present, and future

2.1 **Sectors** of the engineering industry.

Range:
Sectors – Aerospace, rail, agriculture, automotive, chemical, structural, materials, logistics, defence, electrical and electronic, control, medical, manufacturing, marine, petrochemical, power generation (renewables, non-renewables, nuclear), telecommunications, water and waste management.

What do learners need to learn?
An overview of the main activities, the products and/or services provided by the stated sectors.

2.2 Significant **technological advances** in engineering from a historical perspective.

Range:
Technological advances – Development of materials, electrical power and electrical sources of artificial lighting, the internal combustion engine, electric motors, replaceable parts and mass production, television (valves, cathode ray, LED, OLED, curved screens, 4K/5K), radio, automated machines, computers and the internet.

What do learners need to learn?
How technology advances and their operations have evolved and contributed to engineering, and social and economic development, to include transportation, healthcare, housing, employment and sustainability.

2.3 **Areas of innovation and emerging trends** in engineering.

Range:
Areas of innovation and emerging trends – Artificial intelligence (AI), virtual reality (VR), augmented reality (AR), digitalisation, robotics, drones, autonomous systems, distributed energy, hybrid technologies, cyber-physical systems, the internet of things (IOT), cloud computing, sustainability (product life cycle, circular economy, exploring alternatives, renewables, waste and disposal).

What do learners need to learn?
How innovation and emerging trends are evolving and could influence manufacturing, environmental considerations, social and economic development.

3 Engineering representations

3.1 **Drawings** and **information** conveyed by drawings.

Range:

Drawings – Computer aided design models, freehand sketching, isometric, orthographic projection (first angle, third angle, section, assembly, general arrangement), exploded views, block diagrams, flowcharts, circuit diagrams, schematics (wiring diagrams, pneumatics, hydraulics).

Information – Scale, title block, view (elevation, plan, end, section, auxiliary), types of line (outlines, hidden detail, centre line, projection, dimension, leader, construction), surface finish, manufacturing detail, standard features (screw threads, nuts, bolts, pins, repeated items, counterbore, countersink, centre mark), abbreviations (across flats AF, centre line CL, diameter DIA, drawing DWG, material MTL, square SQ, chamfer CHAM, countersunk CSK, hexagon head HEX, radius R, thread THD, undercut UCUT, pitch circle diameter PCD), graphical symbols used on drawings (projection symbols, diameter, surface finish).

What do learners need to learn?	Skills
The characteristics of, purposes of, and audience for different drawing types. The purpose and application of CAD systems and software. How to interpret and present information, symbols, conventions and annotations on engineering drawings in accordance with the conventions of BSEN8888 and BS3939.	MC3, DC4.

3.2 **Dimensions and tolerancing** on engineering drawings.

Range:

Dimensions and tolerancing – Dimensions (linear, diameter, radius, angular), tolerances, limits and fits, geometric dimensioning and tolerancing (GDT) symbols (datum, parallelism, perpendicularity, concentricity, straightness).

What do learners need to learn?	Skills
How to interpret dimensions and related drawing symbols. How to calculate tolerances, limits and fits.	MC4, MC8.

4 Essential mathematics for engineering and manufacturing

4.1 Applied **mathematical theory** in engineering applications.

Range:

Mathematical theory

Standard arithmetic – Ordering, integers, decimals, standard forms, fractions, percentages, ratios.

Algebra – Factorising and manipulating equations, solving quadratics, using indices and logarithms, determining numbers in a sequence, standard matrices and determinants.

Geometry – Calculation of areas and volumes.

Calculus – Graphs and charts relevant to engineering and manufacturing contexts, differentiation and integration.

Trigonometry – Pythagoras' theorem, triangle calculations, circular measure, trigonometric functions and graphs of trigonometric functions, sine and cosine rules, common trigonometric identities and values, applications of vectors and coordinates, scalars.

Statistical analysis – Analysis of data and calculation of probabilities in engineering contexts, estimation.

What do learners need to learn?	Skills
Perform arithmetic operations on integers, decimal numbers and numbers in standard form using rules of arithmetical preference: brackets indices division multiplication adding and subtraction (BIDMAS).	MC2, MC3, MC4, MC5, MC6, MC7, MC8.
Work to a specified number of decimal places or significant figures.	
Carry out calculations using fractions, percentages, ratios and scale.	
Simplify, factorise and manipulate equations to change the subject.	
Solve simultaneous and quadratic equations.	
Apply rules of indices.	
Apply laws of logarithms (base 10 and natural) - problem solving including problems involving growth and decay.	
Determine numbers in a sequence using arithmetic and geometric progression, power series.	
Addition, subtraction and multiplication of matrices in engineering contexts.	
Calculate the area of 2D shapes (square, rectangle, triangle, circle) and the volume of 3D shapes (cube, cuboid, cylinder, cone).	
Interpret and express changes in an engineering system from a graph (straight line, trigonometrical and exponential relationships).	
Determine the equation of a straight line from a graph (y = mx + c).	
Determine standard differentials and integrals (basic arithmetic operations, powers/indices, trigonometric functions).	
Calculate maximum and minimum values in engineering contexts using differentiation.	
Use of Pythagoras' theorem and triangle measurement.	
Circular measure including conversion between radians and degrees.	
Application of trigonometric functions (sin, cos, tan), their common values, rules and graphical representation.	
Determining dimensions of a triangle using sine and cosine rules.	
Common trigonometric identities (sec, csc, cot).	
Use of vectors including addition, dot and cross product.	
Calculation of range, cumulative frequency, averages (mean, median and mode) and standard deviation for statistical data in an engineering context.	
Determination of probabilities in practical engineering situations.	

4.2 **Number systems** used in engineering and manufacturing.

Range:
Numbering systems – Decimal, binary, hexadecimal.

What do learners need to learn?	**Skills**
How to identify and convert between numbering systems. The applications of numbering used in engineering and manufacturing.	MC5, MC6.

5 Essential science for engineering and manufacturing

5.1 **Units of measurement** used in engineering.

Range:

Units of measurement –

SI units: Metre (m), kilogram (kg), second (s), newton (N), metre cubed (m^3), metre per second ($m\ s^{-1}$), metre per second squared ($m\ s^{-2}$), newton metre (N m), Pascal (Pa or $N\ m^{-2}$), mass per unit volume ($kg\ m^{-3}$), unit multiples and submultiples (tera, giga, mega, kilo, milli, micro, nano, pico).

Imperial units: Foot (ft), inches (in), yard (yd), ounce (oz), gallon (gal).

What do learners need to learn?	Skills
The difference between base and derived units. The units applicable to different properties. How to convert between SI units and comparable imperial units. How to convert between different multiples and submultiples.	MC4.

5.2 **Vector and coordinate** measuring systems.

Range:

Vector and coordinate – Vectors and scalar quantities (distance, displacement, speed, velocity, acceleration), polar coordinates, Cartesian coordinates.

What do learners need to learn?	Skills
The definitions of, and differences between, scalar and vector coordinates. How to convert between Cartesian and polar coordinates where angles are in degrees.	MC4, MC7, MC8.

5.3 Scientific methods and approaches to scientific inquiry and research.

What do learners need to learn?
The concept of the scientific method (observation, questioning, making a hypothesis, prediction / simulation, testing, conclusion, iteration). How to analyse, evaluate, synthesise and apply information, data, research findings, deliberation, and the processes, results and outcomes of testing, modelling and experimenting (accuracy, reliability, precision and replication).

5.4 Measurement **equipment**, techniques and **principles**.

Range:

Equipment – Rule, callipers (digital, Vernier), micrometers (inside, outside, depth), gauges (angle, slip, go/no-go), dial test indicator (DTI), coordinate measuring machines (CMM).

Principles – Precision, accuracy, uncertainty, resolution, calibration, tolerance.

What do learners need to learn?	Skills
What can be measured by each item of equipment. The techniques used to carry out measurements using the stated equipment. The accuracy and relative limitations and benefits of the listed devices. How the principles and techniques are used in measuring and problem solving.	MC1, MC5, MC6, MC8, DC1, DC4.

5.5 **Chemical composition** and **behaviours**.

Range:

Chemical composition – Atomic structure (atom, nucleus, electron, proton, neutron, valence, valence shell, ion, element, molecule), chemical structure (solutions, suspensions, solubility, compound and mixture), periodic table.

Behaviours – Chemicals in electricity (cells (simple, primary and secondary), cell capacity, power capacity, internal resistance), electrolysis (anode, cathode, electrolyte, anion, cation, dissociation, plating, galvanic protection), reactions of metals and alloys with weak and strong acids and alkalis.

What do learners need to learn?	Skills
The definitions of the term atom, element, molecule, compound and mixture. The applications, characteristics, management and control of chemical interactions and reactions used in engineering (chemical etching, surface finishing, bonding, applications for oils and lubricants, high-risk operations).	EC4, MC3, MC5, MC6, DC1, DC4.

5.6 **Forces and motion** in engineering.

Range:

Forces and motion – Types of motion (rotary, linear, reciprocating, oscillating), pressure, vector representation of forces, balanced and unbalanced forces, moments about a force, torque, conditions for equilibrium, coplanar forces.

What do learners need to learn?	Skills
The application of theory and calculations to solve practical engineering problems involving forces and motion.	MC4, MC5, MC6, MC7, MC8, DC1, DC4.

5.7 **Fluid dynamics** in engineering.

Range:

Fluid dynamics – Hydrostatic pressure ($p = r\ g\ h$), hydrostatic thrust on an immersed plane surface ($F = \rho\ g\ A\ x$), centre of pressure, viscosity, Bernoulli's principle, immersion of a body, flow characteristics around a two-dimensional shape (laminar, turbulent, vortices, separation points), principles of aerodynamics (drag, thrust, lift).

What do learners need to learn?	Skills
The application of theory and calculations to solve practical engineering problems involving fluids. The key differences between liquid flow and aerodynamics.	MC4, MC5, MC6, MC7, MC8, DC1, DC4.

5.8 **Thermodynamics** in engineering.

Range:

Thermodynamics – Heat transfer mechanisms (conduction, convection, radiation), systems (open, closed, temperature, pressure, volume), sensible heat, latent heat of fusion, latent heat of vaporisation, expansivity, coefficient of heat transfer, equations (absolute temperature, absolute pressure, volume, mass, density, Boyle's law (pV = constant), Charles' law (V/T = constant), general gas equation (pV/T = constant), characteristic gas equation (pV = mRT)).

What do learners need to learn?	**Skills**
The application of theory and calculations to solve practical engineering problems involving thermodynamics.	MC4, MC5, MC6, MC7, MC8, DC1, DC4.

6 Materials and their properties

6.1 **Physical** and **mechanical** properties of materials.

Range:
Physical properties – Density, melting point, thermal and electrical conductivity (resistivity), thermal expansivity, corrosion resistance, specific heat capacity, hardenability, weldability, permeability, permittivity, ability to be recycled.
Mechanical properties – Strength (tensile, compressive, shear, torsion), hardness, toughness, brittleness, ductility, elasticity, plasticity, malleability.

What do learners need to learn?
The difference between physical and mechanical properties.
The definitions of the stated properties.
Calculation of density.

6.2 **Types** of material and their **structures**.

Range:
Types –

- Ferrous metals (cast iron, low carbon steel, medium carbon steel, high carbon steel, stainless steel).
- Non-ferrous metals (aluminium and alloys, copper, brass and bronze, nickel, zinc).
- Thermoplastic polymers (ABS, HIPS, PLA, sheet and polystyrene foam, polycarbonate, polypropylene, PMMA/acrylic).
- Thermosetting polymers (urea formaldehyde, melamine formaldehyde, phenol formaldehyde, epoxy resin, polyester resin).
- Elastomers (rubber, neoprene).
- Composites (GRP, CRP, MDF).
- Engineering ceramics (silicon carbide, glass).
- Timber (soft wood, hard wood, engineered wood).
- Smart materials: shape memory alloys, quantum tunnelling composite, thermochromic materials, photochromic materials, piezoelectric crystals.

Structures – Atomic structure (atoms, compound), bonding mechanisms (metallic, covalent, ionic, van der Waal's forces), microstructure (grains), lattice structure in metals (dislocation movement and pinning), crosslinking of polymers, ceramic structures (crystalline and non-crystalline (amorphous) materials), composite (particulate, fibrous, laminated).

What do learners need to learn?
The common forms of supply, relative properties, applications and methods of disposal of the listed materials.
The differences between: pure metals and alloys, ferrous and non-ferrous metals, thermoplastic and thermosetting polymers, composites and alloys.
The definition of a smart material, the characteristics and typical applications of smart materials.
The relationship between the structure of a material and its properties.
The difference between crystalline and non-crystalline materials.

6.3 The effects of processing **techniques** on materials.

Range:
Techniques –

Metals – forming (rolling, forging, moulding/press forming), welding, brazing, casting, sintering, coating, hot working, cold working.

Thermoplastic polymers – temperature, mould/injection pressure.

Thermosetting polymers – curing.

Ceramics – sintering pressing force and firing temperature.

Composites – influence of alignment of reinforcement on anisotropy of properties, influence of matrix/reinforcement ratio on tensile strength.

What do learners need to learn?

How the stated processes affect the structure, physical and mechanical properties of materials.

6.4 **Heat treatments** and **surface treatments**.

Range:
Heat treatments – Case hardening, quench hardening, tempering, normalising, annealing and precipitation hardening.
Surface treatments – Painting, plastic coating, galvanising and electrolytic (galvanic) protection.

What do learners need to learn?

How heat treatment and surface treatment processes affect the structure and properties of materials.

Common applications of each method.

6.5 **Causes** of material failure and their **prevention**.

Range:
Causes – Corrosion (oxidation of metals including rusting of ferrous metals, chemical composition and attack, stress corrosion), aging, physical (deformation, fracture, fatigue, creep, erosion).
Prevention – Coatings, sacrificial anodes and cathodes, galvanising.

What do learners need to learn?

Materials fail due to corrosion as a result of material consumption, chemical composition and attack, reduction in thickness and perforation.

The factors that contribute to fatigue failure and the three stages of creep.

The different methods of preventing corrosion and their relative benefits and limitations.

6.6 Materials testing **methods** and **interpretation of results**.

Range:
Methods – Visual inspection, tensile testing, toughness testing, hardness, corrosion resistance, wear resistance, fatigue (Wohler), electrical conductivity.
Interpretation of results – Hooke's law, load-extension graphs (tensile strength, elastic limit, ultimate tensile strength, maximum plastic deformation, calculation of stress, strain and Young's modulus), characteristic graphs of different materials, necking and transition zone in steel.

What do learners need to learn?	Skills
The advantages and limitations of different testing methods. The steps involved in the materials testing methods and how these determine the material properties. How to interpret load extension graphs.	MIR-CSD, MC4, MC7.

7 Mechanical principles

7.1 Principles of **motion and mechanics** in engineering and manufacturing systems.

Range:
Motion and mechanics – Newton's three laws of motion, types of forces (concurrent, non-concurrent, co-planar, non-contact), simply supported beams (loading, load distribution (point, uniformly distributed, combination of point and uniformly distributed), reaction forces, loaded components, shear force, bending moments).

What do learners need to learn?	Skills
The practical application of Newton's three laws of motion, including appropriate calculations. Calculation of stated variables for simply supported beams.	MC2, MC4, MC7, MC8.

7.2 Principles of **forces and energy**.

Range:
Forces and energy – Principle of conservation of momentum, principle of conservation of energy, D'Alembert's principle, potential and kinetic energy, gravitational force, frictional resistance, mechanical work, power, types of power sources (mechanical, electrical, renewable).

What do learners need to learn?	Skills
Calculations using equations of motion to determine displacement, velocity and uniform linear acceleration relating to falling objects and collisions between two objects in line. Explanation and examples of tractive effort, braking force, frictional resistance, rotational kinetic energy, moment of inertia, mechanical work, power in practical applications (fly wheels, springs, height, pressurised fluids). The function and relative advantages of the alternative power sources and examples of their use, including solar, hydro, wind, biofuel, geothermal, electric motors, internal combustion, fossil fuels, nuclear.	MC2, MC4, MC7, MC8.

8 Electrical and electronic principles

8.1 **Principles** of electrical and electronic systems.

Range:

Principles –

Basic principles of electricity and electronics – flow of electrons, charges, energy, power, networks, force, current, capacitance, waves, conduction, magnetism (flux density, field strength), electromagnetism, inductance, measurements of electrical quantities in electrical systems (standard units of measure, multimeters).

Electric circuit theories – voltage, current (alternating current (AC), direct current (DC)), power, resistance, potential difference and dividers, basic electrical elements, Ohm's law (series, parallel and combination circuits), Kirchhoff's current and voltage laws, phasor diagrams, protection systems (lightning arrestors, time graded over current protection, distance protection), residual current devices (RCD)).

DC circuit networks – resistors, capacitors and inductors in series, parallel circuits, combined circuits, semiconductors (forward and reverse bias, N-type and P-type), hierarchical design.

Signals – types (analogue, digital), waveforms (sinusoidal, square, rectangular, triangular, sawtooth), signal processing, signal conditioning, fan in and fan out.

What do learners need to learn?	**Skills**
The physical principles underpinning electrical and electronic systems and devices. The basic properties and principles of magnetism and electromagnetism and their common applications. The relationship between flux density and field strength. The definitions of terms used in electric circuit theory and their applications. The use of Ohm's law and electric circuit theories to calculate values in circuits, such as voltage, current and resistance. The relationship between voltage, current and power in AC circuits and how to represent them in graphs and phasor diagrams. Factors affecting the operation and applications of high-power electrical equipment and electronic devices. How differential protection schemes work to protect transmission lines. How transformer protection schemes work for common faults. The characteristics of DC circuit networks comprising resistors, capacitors and inductors in various arrangements, including time constants. The properties and applications of semiconductor diodes and transistors. The characteristics of the different concepts related to signals. The characteristics of analogue and digital systems, including their waveforms and applications.	EC1, EC2, MC2, MC4, MC5, MC7.

9 Mechatronics

9.1 The key **components** of a mechatronics system.

Range:

Components – Mechanical (gears, cams, linkages, levers, pulleys), electrical/electronic (sensors and transducers, microprocessors, microcontrollers, actuators), common drive devices (standard electrical motors, servo motors, stepper motors).

What do learners need to learn?

Mechatronics is the integration of mechanical and electronic systems to produce a functioning system.

The purpose and function of the mechanical and electrical components.

9.2 The **operation**, **function** and **applications** of **programmable logic controllers (PLC)** in mechatronic systems.

Range:

Programmable logic controllers – Types (unitary, unitary with modular features, modular), architecture.

Operation – Sensor signal conditioning, programming.

Function – Process blocks, motor driver integrated circuits, interface devices.

Applications – Robotic arms, conveyor belts, packaging, supervisory control and data acquisition (SCADA), remote technical units, animatronics.

What do learners need to learn?	Skills
The differences between the types of PLCs. An overview of how a PLC operates. An overview of the functions. The advantages and limitations of using PLCs for the applications given, compared to the alternatives (dedicated integrated circuits, computer-based systems).	DC1

9.3 The basic **principles** of hydraulics and pneumatics.

Range:

Principles – Transmission of power, fluid compressibility, components (valves, pumps, actuators, cylinders, compressors).

What do learners need to learn?

The differences between hydraulic and pneumatic systems, and their advantages and limitations.

The purpose and function of the stated components and how they are they are represented on schematic diagrams.

10 Engineering and manufacturing control systems

10.1 **Principles** and **applications** of control system theory.

Range:

Principles – Input, process (logic gates (AND, OR, NOT), timer, comparator, pulse unit, counter, latch), output, signal, feedback, open and closed loop systems, transfer function, summing points, analogue, digital, pulse width and amplitude modulation, how control systems are represented in diagrams.

Applications – Electrical, pneumatic, hydraulic, measured parameters (pressure flow, temperature, speed, position).

What do learners need to learn?	Skills
How to produce a system diagram with multiple inputs, outputs, a combination of process blocks and feedback, and explain its operation. Applications of open and closed loop control systems (under or over-damped, and time dependency). The advantages and disadvantages of open and closed loop control systems. The relationship between input and output (steady rate error). The relative advantages and disadvantages of analogue and digital signals in control systems. Applications of control systems in industry, including effective and efficient networked communication and data transmission.	MC5, DC1, DC4, DC6.

10.2 How **sensors and actuators** are **used in automation** control systems.

Range:

Sensors and actuators – Types (analogue, digital, active, passive), applications (switches, proximity sensors, laser, vision systems), power sources, hard-wired, wireless.

Uses in automation – Position and volume of objects being processed, mechanised lifting and moving of objects, measurement applications (electrical, mechanical, thermal, chemical, biological, optical, acoustic, radiation).

What do learners need to learn?	Skills
The purpose and function of the different types of sensors and actuators. Applications and uses of sensors and actuators.	DC1, DC4, DC6.

11 Quality management

11.1 Quality **standards**, **assurance, control** and **improvement**.

Range:
Standards – British standards, ISO standards, CE, engineering bodies (Engineering Council, Institution of Engineering and Technology (IET), Institution of Mechanical Engineers (IMechE), Society of Operations Engineers (SOE), Chartered Institution of Building services Engineers (CIBSE), Institute of Agricultural Engineers (IAgrE), Institute of the Motor Industry (IMI), The Welding Institute (TWI)).
Assurance and control – Culture of quality, right first time, quality standards (ISO9001), inspection and testing, traceability, document management and version control, process capability, statistical process control (SPC), six sigma, total quality management (TQM).
Improvement – Failure mode effect analysis (FMEA), Pareto analysis, cause and effect diagrams, quality circles.

What do learners need to learn?	**Skills**
The function, purpose and value of standards (safety, quality, compliance) and how to access this information. The roles and responsibilities of the engineering bodies. The main principles, purposes and outcomes of quality assurance, quality control, inspection and testing. The difference between quality control and quality assurance. The main requirements of quality standards. The reasons for document management and version control. The advantages and disadvantages of 100% sampling compared to statistical process control (SPC). The use of six sigma for high volume manufacture. The main principles, purposes, advantages and disadvantages of different approaches to quality improvement.	MIR-CSD, MC4, MC5, MC7.

11.2 **Types and applications** of Standard Operating Procedures (SOPs) and their **purposes**.

Range:
Types and applications – Manufacturing, quality, maintenance.
Purposes – Standardisation of activity, customer satisfaction, safety, training.

What do learners need to learn?	**Skills**
The typical format and content of SOPs. How SOPs are used in the different applications. The reasons for using SOPs (consistency, conformance to standards). How SOPs are produced, implemented and evaluated.	MIR-CSC, MIR-CSD, EC1, EC3.

12 Health and safety principles and coverage

12.1 The main requirements of key health and safety **legislation** applicable to engineering activities.

Range:
Legislation –

The Health and Safety at Work Act (HASAWA)
Management of Health and Safety at Work Regulations
Provision and Use of Work Equipment Regulations (PUWER)
Personal Protective Equipment (PPE) Regulations
The Control of Noise at Work Regulations
Manual handling operations regulations
Lifting operations and lifting equipment regulations (LOLER)
Work at Height Regulations
Electricity at Work Regulations
The Control of Electromagnetic Fields at Work Regulations (CEMFAW)
Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR)
Control of Substances Hazardous to Health (COSHH)

What do learners need to learn?	Skills
The main requirements of the current key legislation, how to access it and how it affects their own activities in the workplace. That the legislation should be satisfied by their company's safe systems of work and other procedures, and they therefore do not need to know every detail of the law. The purpose of legislation within the engineering industry: · why there is a need for the legislation · that there is legislation to cover every aspect of the workplace · how the legislation keeps them safe in the workplace · who is responsible for compliance with current regulations and legislation · health and safety culture, training and information	MIR-CSA.

12.2 The importance of health and safety practices within the workplace.

What do learners need to learn?
How health and safety legislation affects the frequency of accidents and related incidents. The importance of mental health and wellbeing in the workplace. The persons responsible for ensuring compliance – employer, employee, Health and Safety Executive (HSE). Implications of non-compliance.

12.3 **Responsibilities** for health and safety.

Range:

Responsibilities – Individual, employee and employer obligations, local, national, and global requirements.

What do learners need to learn?

Health and safety responsibilities of employees, including:

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

Health and safety responsibilities of employers, including:

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

Differences between local, national and global requirements.

12.4 **Risk assessment**.

Range:

Stages of **risk assessment** – Identification of hazards (hazard and operability study (HAZOP), hazard identification (HAZID)), evaluation of risks (likelihood, severity, number of people affected), implementation of control measures (hierarchy of control: elimination, reduction/substitution, isolation, controls, administration/training/safe system of work, PPE).

What do learners need to learn?

The hazards associated with engineering and manufacturing contexts (equipment, stored energy, tools, electricity, harmful substances including gases, environments).

Common industrial injuries that can occur without appropriate precautions.

Methods of identifying hazards.

How to evaluate risks.

The hierarchy of control for control measures.

Types of control measures typically used in engineering (guarding, machine isolation, PPE (eye protection, safety shoes, ear protection, gauntlets, helmets).

Skills

MIR-CSB.

12.5 Health and safety **considerations** in specific engineering **contexts**.

Range:

Considerations – Safe systems of work, oxygen use in the workplace, asphyxiation hazards, heat, moving parts, fire and explosion hazards, fire safety, guarding, manual handling, permit to work, lock out tag out (LOTO), maintenance.

Contexts – Chemicals, equipment with moving parts, confined spaces, electrical testing, high voltage electrical (generation, distribution, isolation and storage).

What do learners need to learn?	Skills
The different considerations appropriate to a range of engineering contexts.	MIR-CSA.

12.6 Principles and practices relating to environmental **legislation** and **considerations**.

Range:
Legislation –

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

Considerations – ISO 14001, waste disposal.

What do learners need to learn?

The main requirements of the current key environmental legislation, how to access it and how it affects their own activities in the workplace.

That the legislation should be satisfied by their company's environmental policies and other procedures, and they therefore do not need to know every detail of the law.

The purpose of legislation within the engineering industry:

· why there is a need for the legislation

· who is responsible for compliance with the regulations

ISO 14001: Aims, benefits and consequences.

Methods of waste disposal (landfill, reuse, recycling, controlled waste) and their implications.

13 Business, commercial and financial awareness

13.1 **Principles** of commercial operations and **markets**.

Range:
Principles – Commercial priorities (profit, addressing stakeholder needs), efficiency, value added, non-value added, competition, supply and demand.
Markets – Customers, local, national, international.

What do learners need to learn?
The goals of commercial operations and how these are addressed.
How organisations address the needs of different customers and markets.
How organisations evaluate activities in terms of quality, cost and time.
The role of research and development and innovation to address changing customer needs.

13.2 Business and commercial **practices**.

Range:
Practices – Legal (tendering, contracts, warranties, force majeure, indemnity clauses, liabilities), management (resource allocation and planning, staffing, training and development), business models (traditional, agile), company management systems, policies and procedures.

What do learners need to learn?
How business practices influence the operation of engineering organisations.
The legislation affecting tendering and contracts.

13.3 Financial and economic **concepts**.

Range:
Concepts – Financial responsibility, recording financial transactions, sources of finance (loans, shares, capital), budgets, transactions, costs (direct, indirect, overheads), payment terms, revenue, creditors and debtors, cash flow, profit and loss, break even, assets (depreciation), liabilities, solvency, taxes, rates.

What do learners need to learn?
The meaning of the stated financial concepts and their implications for the operation of a business.

14 Professional responsibilities, attitudes, and behaviours

14.1 Professional **conduct and responsibilities** in the workplace.

Range:
Conduct and responsibilities – Job descriptions, behaviours required in the workplace, personal conduct (reputation, ethical responsibilities), levels of accountability in organisational structures (apprentice, operator, management, director), equality, diversity, accessibility, inclusion.

What do learners need to learn?
Purpose, function and typical content of job descriptions.
How behaviour and personal conduct in the workplace influence interactions with people.
How to seek advice and guidance, where necessary.
Expectations for reputation and ethical behaviour in the workplace.
The main responsibilities of the different roles in an organisation and how they affect the business in terms of accountabilities and inter-dependencies.
The main duties of an organisation regarding equality, diversity, accessibility and inclusion.

14.2 Continuous professional development (**CPD**) and professional recognition.

Range:
CPD – Training courses, industry placement, academic study, events and seminars.

What do learners need to learn?
What is CPD and how it motivates staff and improves performance.
Professional standards for engineering, as set out by the Engineering Council.

14.3 **Human factors** within engineering and manufacturing contexts.

Range:
Human factors – Human characteristics (physical, mental), workplace design (considerations, assessment criteria), human error.

What do learners need to learn?
How human characteristics, capabilities and limitations affect the company and production.
How the design of the workplace affects safety, comfort and productivity.
Causes of human error (insufficient training, fatigue, workload, stress) and methods to reduce these.

15 Stock and asset management

15.1 Stock and inventory management **principles** and **practices**.

Range:
Principles – Demand, stock turnover, cost of inventory, redundant stock / write down, obsolescence, minimum stock levels, supply chain, packaging/storage.
Practices – Just in time, made to stock, made to order, material requirements planning.

What do learners need to learn?
The purpose of effective stock and inventory management and control.
Key issues, risks, advantages and disadvantages associated with the different practices.

15.2 Asset management and control **principles**.

Range:
Principles – Capacity management (manufacturing resource planning, bottleneck), key stages of asset life cycle management (planning, acquisition, operation and maintenance, disposal), budgetary control practices (life cycle, whole life approach, depreciation).

What do learners need to learn?
The purpose and methodology of effective asset management.
Advantages and disadvantages associated with methods of capacity management.

16 Continuous improvement

16.1 Continuous improvement **principles** and **practices**.

Range:
Principles – Reflection and evaluation of processes, incremental change and improvement, key performance indicators (KPIs), implementation (plan, do, check, act – PDCA), 8 wastes (transportation, inventory, motion, waiting, excess production, overprocessing, defects, unused talent), lean, Kaizen.
Practices – Value stream mapping, visual management, 6S (sort, set in order, shine, standardise, sustain, safety), single minute exchange of dies (SMED), operation effective efficiency (OEE), total productive maintenance (TPM), kanban.

What do learners need to learn?	**Skills**
Methods of gathering feedback and evidence about performance, including types of KPIs and how these can be used to evaluate continuous improvement activities. How the 8 wastes affect the performance of engineering activities. Purpose, methodology, benefits and limitations of the different practices.	MIR-CSD.

17 Project and programme management

17.1 **Principles** of project management.

Range:
Principles – Project brief, project goals, success criteria, project life cycle (initiation, planning, implementation, monitoring, reporting, evaluation), constraints, risk management (budget, cost, quality, time, safety, resource availability, communication, reputation, changing requirements), collaborative working (matrix working, collaborative technologies).

What do learners need to learn?	Skills
How projects are defined and structured. The management practices, processes and documentation needed at each stage of the project. Types of risk and how these are managed throughout the life of the project, including the role of research and development. The benefits and limitations of collaborative working.	MIR-CSA, MIR-CSB.

17.2 **Roles** and **responsibilities** in projects.

Range:
Roles – Stakeholders (clients, regulators), project manager, team members.
Responsibilities – Communication, monitoring, planning, finance, reporting.

What do learners need to learn?	Skills
The responsibilities of the different roles and how they contribute to a project.	MIR-CSE.

17.3 Project **planning** and **control**.

Range:
Planning – Resource requirements (time, budget, human resources, training needs, communication needs, production facilities), Gantt charts, critical path analysis (CPA), project evaluation review technique (PERT), management of interdependencies, contingency planning.
Control – Monitoring reports (budget, quality, cost, time), manage by stages, manage by exception.

What do learners need to learn?	Skills
How to identify the resources required to carry out a project. The benefits and limitation of the different planning methods. How to plan projects using the different methods. How to monitor and evaluate the progress of projects. The reasons for reviewing and evaluating of projects to improve subsequent projects.	MIR-CSA, MIR-CSB, MIR-CSE, MC9.

Guidance for delivery

A variety of active teaching and learning activities should be used to engage learners in this common core. Opportunities for visits/engagement with local industry, employers and manufacturers should be provided throughout the delivery of the content – where appropriate, local employers could present details of recent projects, problems faced and how they were overcome. Learners' work placement experiences could be presented to peers detailing where knowledge and skills within the content was seen in practice.

Formative assessment for the content may include verbal Q&A, presentations to peers, observation of stock control activities etc. Reinforcement of learning can be encouraged through revisiting learning, group discussions, and the establishment of a peer support system within the cohort.

Providers must ensure content is delivered in line with current, up to date industry practices which will require:

- Current industry legislation, regulations, and technical information.
- Teaching coverage representing the type of equipment currently available and accepted for use in the UK industry.

Suggested learning resources

Books

- T F Waters, *Fundamentals of Manufacturing For Engineers*, CRC Press, 2017, ISBN: 113843485X
- Christoph Roser, *Faster, Better, Cheaper in the History of Manufacturing: From the Stone Age to Lean Manufacturing and Beyond*, Productivity Press, 2016, ISBN: 9781498756303
- Colin H Simmons, Dennis E Maguire, *Manual of Engineering Drawing: Technical Product Specification and Documentation to British and International Standards*, 3rd Edition, Butterworth-Heinemann, 2009, ISBN: 9780750689854
- Paul Clayton, *Essential Math Skills for Engineers*, John Wiley & Sons, 2009, ISBN: 9780470405024
- Millard F Beatty, *Principles of Engineering Mechanics: Volume 2 Dynamics - The Analysis of Motion (Mathematical Concepts and Methods in Science and Engineering)*, Springer, 2005, ISBN: 0387237046
- Gerardus Blokdyk, *Stock Management A Complete Guide - 2020 Edition*, 5STARCooks, 2021, ISBN: 1867301091
- Jeffrey Liker, *The Toyota Way, Second Edition: 14 Management Principles from the World's Greatest Manufacturer*, McGraw-Hill Education, 2020, ISBN: 1260468518
- David Shonnard, David Allen, *Sustainable Engineering: Concepts, Design and Case Studies*, Pearson, 2011, ISBN: 0132756544

Websites

- Engineering Industry Trends for 2020 - blog.v-hr.com/blog/engineering-industry-trends-for-2020
- Introduction to Engineering Mechanics - youtu.be/ksmsp9OzAsI
- Research Trends in Sustainable Manufacturing - link.springer.com/article/10.1007/s40684-019-00113-5
- Innovation Engineering - www.innovation-engineering.net/
- Principles of Sustainable Engineering - www.e-education.psu.edu/eme807/node/688
- ISO management standards in Engineering and Manufacturing - www.nqa.com/en-za/certification/sectors/engineering-manufacturing
- List of Environmental Laws - www.field.org.uk/list-of-environmental-laws
- Application of Newton's Laws - engineeringlibrary.org/reference/application-of-newtons-laws-doe-handbook
- Management: Drivers of Behavior - courses.lumenlearning.com/boundless-management/chapter/drivers-of-behavior

311 Maintenance engineering technologies: Mechanical

Level:	3
GLH:	680
Assessment method:	Practical assignment

What is this specialism about?

The purpose of this specialism is for learners to know and understand mechanical engineering systems commonly used in industry. Learners will have the opportunity to plan and undertake maintenance, fault finding, commissioning, testing and repair activities on mechanical systems, and complete associated documentation. Learners will plan, perform and evaluate their work whilst utilising a range of materials, tools, equipment and machinery.

Learners will develop their knowledge and understanding of, and skills in:

- Knowledge of mechanical principles and systems
- Knowledge and application of component classification, numbering and referencing systems
- Knowledge of how components are removed, replaced and repaired as part of mechanical engineering systems
- Skills to plan and prepare mechanical maintenance activities using evaluation
- Skills to select and use tools, equipment, machinery and technology safely and effectively to complete maintenance, installation and repair activities

Learners may be introduced to this specialism by asking themselves questions such as:

- How do mechanical systems operate and function?
- What components are used in mechanical systems?
- How is maintenance, installation and repair carried out within mechanical engineering?

Underpinning knowledge outcomes

On completion of this specialism, learners will understand:

1. Maintenance engineering technology - mechanical knowledge criteria

Performance outcomes

On completion of this specialism, learners will be able to:

2. Analyse requirements, specifications and technical information to enable the delivery of successful maintenance, installation, servicing and repair of mechanical plant and equipment.

3. Plan and prepare the maintenance, installation, servicing and repair of mechanical plant and equipment, taking into account the specific requirements and context.

4. Perform relevant maintenance, installation, servicing and repair of mechanical plant and equipment, using appropriate techniques and procedures to achieve the required quality outcomes and solutions.

5. Review and evaluate activities to help improve workplace systems and processes associated with maintenance, installation, servicing and repair of mechanical plant and equipment, demonstrating commercial awareness and accountability.

6. Communicate mechanical operations, maintenance, installation, servicing and repair information, proposals and solutions, producing, recording and explaining relevant technical information.

Completion of this specialism will give learners the opportunity to develop their Maths, English and Digital Skills. Details are presented at the end of the specification.

Specialism content

Outcome 1

Underpinning knowledge criteria for the performance outcomes

1.1 **Principles and techniques** for maintenance and repair.

Range:
Principles and techniques –

- removal and replacement activities – assembly and disassembly techniques, mechanical fixings/fastening
- conditions that determine repair – age of components, condition, costings, maintenance, replacement, repair, disposal, installation, downtime, productivity, quality, environmental
- maintenance and servicing strategies – reactive (condition-based monitoring, unplanned/emergency/post-fault), preventative (scheduled, planned, timed)
- disposal requirements – appropriate methods, documentation, legislation, sustainability and environmental considerations
- control documentation – schedules, specifications, method statements, authorisation, care and control procedures
- maintenance planning considerations – cost, production output, safety, skills and competency, equipment, job instructions)
- sources of information – data sheets, technical data, engineering drawings, exploded diagrams, planning sheets, workshop manuals, schematics
- types of tools – hand tools, power tools, test equipment, measuring instruments
- decommissioning considerations – down time, repair costs, environmental issues, productivity, quality, planning, lockouts, hazardous waste, risk assessments, permits, legislation.

What do learners need to learn?	**Skills**
Reasons of removal and replacement activities. Factors to be considered when determining either repair or replacement of assemblies or sub-assemblies. Types of documentation that are used to monitor, record and control maintenance activities and their typical contents. How to produce or amend appropriate technical documentation. The reasons for planning maintenance activities. Sources of information used in maintenance activities and how they are used. Types and purpose of tools and equipment used in maintenance activities. Disposal requirements appropriate to the waste and relevant legislation. Factors to be considered when decommissioning and their implications.	EC3, EC5, EC6, MC2, MC6, MC7, MC9, DC1, DC2, DC5.

Analyse requirements, specifications and technical information to enable the delivery of successful maintenance, installation, servicing and repair of mechanical plant and equipment (PO2)

1.2 Operation of **mechanical principles** and **systems**.

Range:

Mechanical principles – motions and forces (static and dynamic loading, stress, strain, tensile shear, compressive shear, moments, torque) thermal, friction, system principles (input, process and output), hydraulic, pneumatic, work done and efficiency, mechanical advantage.

Mechanical systems – pulleys, levers, gearbox, torque converters, clutches (mechanical, electronic, fluid), cooling, lubrication.

What do learners need to learn?	Skills
How the systems manage forces, power, and motion. Calculations of the specified values. Moments affecting levers and beams.	EC5, MC3, MC4.

1.3 Fundamentals of **common mechanisms** and **lifting equipment.**

Range:

Mechanisms – gears (characteristics of gears including teeth, root, pitch, meshing, backlash), gear box, gear trains, governors, levers, brakes, friction devices/clutches (mechanical, hydraulic, electromagnetic), structural components (frames, bearings, springs).

Lifting equipment – pulleys, jacks, cranes, hoists.

What do learners need to learn?	Skills
The functions of common mechanisms. The application of lifting equipment and mechanisms, and how they operate. Types of gear trains, including compound gears and the role of idler gears. Identify ties and struts in frames. Simple harmonic motion of springs. Factors of safety, including safe working loads, when working with lifting equipment.	EC5, MC6.

1.4 Key principles of **energy storage** and **transfer**.

Range:

Energy storage – heat, pressure (hydraulic, pneumatic), electrical, conversion of energy, methods of storage (batteries, capacitors, flywheels, pressure vessels).

Energy transfer – methods of energy transfer (mechanical, electrical, conduction, convection, radiation, heat, generation, co-efficient of friction), hydraulic/pneumatic systems.

What do learners need to learn?	Skills
Characteristics and methods of energy storage and transfer. The applications of energy storage and transfer methods. How energy forms are converted to enable storage.	MC4, MC6.

1.5 Mechanical **loadings** on structures and components.

Range:
Loadings – tension, compression, shear, bending and torsion (static and dynamic), torque, fatigue.

What do learners need to learn?	Skills
Calculations of mechanical loads on structures and components. Effects of mechanical loads on structures and components.	EC4, EC5, MC6, DC1, DC4.

1.6 **Construction and operation** of power transmission systems.

Range:
Construction and operation – types of gear (spur, helical, bevel, worm, rack and pinion), gear boxes, shafts, woodruff keys, cams, linkages, fluid power, drive belts, rams (pneumatic, hydraulic), lubrication systems (manual, gravity feed, forced, splash).

What do learners need to learn?	Skills
How power transmission systems work to achieve an output. Gear boxes, including compound gear trains and idlers. The characteristics of gears affecting the efficiency of transfer and changing the direction of motion. Types of drive belts and their applications. Advantages and limitations of different lubrication systems.	EC5, MC2, MC3, MC4, MC6.

1.7 **Systems**, **circuits** and **components** of electrical installations, including **properties**, **failure modes** and **protection methods**.

Range:
Systems – single phase, three phase.
Components – resistors, capacitors, diodes, transformers, motors.
Properties – voltage, current, resistance, impedance, power.
Failure modes – equipment failure, human error, environmental conditions.
Protection methods – isolation, earthing, fuses, fusible links, circuits breakers.

What do learners need to learn?	Skills
Function and operational characteristics of electrical components. The properties of electrical systems and circuits. The different types of electrical circuits. Identify common failure modes and protection methods. The reasons for the use of different protection methods.	MC2, MC3, MC4, MC6, DC1.

1.8 **Drive devices**, their purposes and applications.

Range:
Drive devices – motors, belts, shafts, gear boxes, clutches.

What do learners need to learn?	Skills
Purposes, outcomes and applications of common drive devices. The advantages and limitations of the different drive devices.	EC5, MC2, MC3, MC4, MC6, DC1.

1.9 **Sensing** and **measurement techniques**.

Range:
Sensing – temperature, vibration, linear dimensions and clearances, speed/position sensors, pressure sensors, liquid flow.
Measurement techniques – steel rule, dividers, square (engineers, combination), Vernier callipers (internal, external, digital), gauges (feeler, pressure, slip, height, thread, plug), micrometers (internal, external, depth), thermocouples, dial tester indicator (DTI), coordinate measuring machine (CMM), centre finders, laser level, comparison plates.

What do learners need to learn?	Skills
The purposes and applications of sensing equipment. The relative benefits and limitations of sensing and measurement techniques and technologies. How sensing and measurement technologies are used to measure parameters.	MC2, MC3, MC4, MC6, DC1.

1.10 **Component identification** and referencing systems.

Range:
Component identification – part numbers, identification numbers, bill of materials (BOM), proof marking, labelling, specifications, identification codes and technical data, manufacturers data sheets, manufacturers safety specifications, colour codes, schematic diagrams, BS, EN and ISO Standards.

What do learners need to learn?	Skills
The purposes and applications of numbering and referencing systems. How to interpret current BS, EN and ISO standards related to mechanical engineering, including classification, numbering and referencing.	MC2, MC3, MC4, MC6, DC1, DC5.

Perform relevant maintenance, installation, servicing and repair of mechanical plant and equipment, using appropriate techniques and procedures to achieve the required quality outcomes and solutions (PO4)

1.11 **Hand tools, power tools** and **equipment.**

Range:
Hand tools – spanners, sockets (ratchet, universal joints, extension bars), screwdrivers, torx, pry bars, punches, chisels, hacksaw, pliers, mole grips, side cutters, bolt cutters, files, hammers, mallets, crimpers, taps and dies.
Power tools – jigsaw, angle grinder, drills, multitool, reciprocating saw.
Equipment – lifts, jacks, hoist pulleys, welding (metal inert gas (MIG)/metal active gas (MAG)).

What do learners need to learn?	Skills
How to check the physical condition of tools prior to use. The suitable applications and limitations of the identified equipment. How to maintain tools and equipment and use safely, following all safety regulations relating to use. Risks and consequences of using non-authorised tools and equipment. The main differences between the welding processes. How to safely operate equipment, machinery and technology. How to follow relevant guidelines and instructions, limits of own authority and expertise, and seek advice and guidance, where necessary.	EC5, MC1, MC2, MC3, MC4, DC1, DC4.

1.12 **Effects** of **environmental conditions** on materials, components, wiring, and equipment.

Range:
Effects – failure modes, working condition, false readings, degradation, corrosion, ingress, egress, leakages, system errors, blockages, electrical faults, mechanical faults, debris, cracking, brittle, disintegration, cleanliness, clarity.
Environmental conditions – humidity, moisture, temperature, pressure, heat, pollution, dirt, debris, radiation, chemicals.

What do learners need to learn?	Skills
How environmental conditions can affect materials components, wiring and equipment, and their potential effects. Characteristics relating to material quality and condition. How materials degrade and fail, including monitoring, maintaining and preventative techniques. Appropriate methods of maintenance, management, storage, preservation and prevention for materials, tools and equipment.	EC5, MC1, MC2, DC1, DC4, DC6.

1.13 **CAD/CAM** systems and software.

Range:
CAD/CAM – features and functions (solid modelling, geometry manipulation, component drawing), programming methods (manual programming, conversational programming), data transfer**,** manufacturing simulation, operations**.**

What do learners need to learn?	Skills
The application and purpose of CAD/CAM systems and software across multiple dimensions and collaboration. The key principles of manufacturing using a CAD/CAM system.	EC5, MC2, MC4, MC5, MC6, DC1, DC4, DC5, DC6.

1.14 **Machine tools** and **machine elements**.

Range:
Machine tools – drills (pillar and bench), centre lathe, vertical milling machine, linisher, buffer/polisher, compressor.
Machine elements – manual and computer numerical control (CNC), methods of work holding (chuck, machine vice, jigs), tooling.

What do learners need to learn?	Skills
Identify machine tools, their functions and capabilities. Identify the elements of these machine tools and how these are used. How to safely operate machinery and technology. How to follow relevant guidelines and instructions, limits of own authority and expertise, and seek advice and guidance, where necessary.	EC5, MC1, MC2, MC3, MC5, DC1, DC4, DC6.

1.15 **Installation**, **configuration**, and integration of mechanical engineering systems.

Range:
Installation – client requirements, regulation requirements, requirements for service, commissioning, isolation, manufacturers specifications, tools and equipment.
Configuration – setting parameters, calibration, testing, first use, operating systems, specifications, tools and equipment.

What do learners need to learn?	Skills
Requirements, procedures and considerations for installation and configuration of engineering and manufacturing systems. How to safely use tools, equipment and technology to complete maintenance, installation and repair requirements. How to follow relevant guidelines and instructions, limits of own authority and expertise, and seek advice and guidance, where necessary.	EC5, MC1, MC2, MC3, MC4, MC5, MC7, DC1, DC4, DC6.

1.16 **Fault detection**, **diagnosis**, **resolution** and **isolation methods.**

Range:
Fault detection – self-diagnostic, unit substitution, input output, half split technique, end to end, operator experience, tools and equipment.
Fault diagnosis – sensory checks, collection of fault data, self-diagnosis, inspection, material testing, tools and equipment.

Resolution methods – replace, repair, adjust, modify.
Isolation methods – electrical isolation, lock out tag out (LOTO), release of stored energy.

What do learners need to learn?	Skills
Identifying faults utilising fault detection and diagnosis methods. Material testing methods and techniques. How to safely use tools, equipment and technology to detect and diagnose faults within assemblies and sub-assemblies. How to use resolution methods based on the fault diagnosis. Identify different isolation methods. The advantages and limitations of detection methods and isolation systems. How to apply safe isolation methods to complete resolution and rectification methods. How to follow relevant guidelines and instructions, limits of own authority and expertise, and seek advice and guidance, where necessary.	EC5, MC1, MC2, MC3, MC5, DC1, DC4, DC6.

1.17 Techniques for **disassembly**, modification and **re-assembly**.

Range:
Disassembly – removal of stored energy, isolation, removal of housing and components, proof marking, disposal requirements, documentation.
Re-assembly – sub-assemblies, replacement of lifed items, tightening techniques, QR codes, barcodes, adjustments, powering up, documentation.

What do learners need to learn?	Skills
Methods and procedures for the disassembly and re-assembly according to guidance and regulations. How to safely use tools, equipment and technology to disassemble, modify and re-assemble mechanical assemblies and sub-assemblies. Tightening techniques for different operations. The application and recording of different modification techniques. Types of lifed items. How to follow relevant guidelines and instructions, limits of own authority and expertise, and seek advice and guidance, where necessary.	EC5, MC1, MC2, MC3, MC4, MC5, MC7, DC1, DC4, DC6.

1.18 **Joining techniques**.

Range:
Joining techniques – permanent (welded, soldered, adhesive bonded, brazed, expansion fittings), semi-permanent (riveted, rivet nuts, folded, compression fittings), temporary (mechanical fastenings including screws, bolts, nuts, washers, shims, anti-rattle), interference fit.

What do learners need to learn?	Skills
The characteristics of the different joining techniques and their applications.	EC5, MC1, MC2, MC3, MC5.

Review and evaluate activities to help improve workplace systems and processes associated with maintenance, installation, servicing and repair of mechanical plant and equipment, demonstrating commercial awareness and accountability (PO5)

1.19 **Quality inspection**, **testing and recording methods**.

Range:

Quality inspection and testing methods – policies, procedures, guidance, second line verifications, organisational systems and requirements, sensory checks, checklists, maintenance instructions, data, reports, measurement, analysis of systems, test operation, communication, prior maintenance history, maintenance requirements, preventative measures.

Recording methods – maintenance logs, defect logs, reports, statements, checklists, equipment, digital technologies, amending documentation.

What do learners need to learn?	Skills
The purpose of quality inspection, testing and recording. Factors that can affect quality in mechanical engineering and quality assurance processes. How variations and defects in engineering products and components are managed. Application of methods and techniques used within quality inspection and testing. The reasons for quality inspection and testing and the impact of inadequate quality inspection and testing. How to complete and record quality processes as part of quality control, assurance and improvement.	EC3, EC4, EC5, EC6, MC2, MC5, MC6, MC10, DC1, DC2, DC4.

Communicate mechanical operations, maintenance, installation, servicing and repair information, proposals and solutions, producing, recording and explaining relevant technical information (PO6)

1.20 **Communicating technical information and data**.

Range:

Communicating – record, manage, store, amend, upload data, collaborative technologies (shared drives, email, conferencing, software and programs, forums).

Technical information and data – test data, test results, maintenance results and findings, fault information, inspection sheets, maintenance logs, repair methods.

What do learners need to learn?	Skills
How to communicate information effectively in written and verbal methods. The importance of technical documentation for communication. How to create technical reports for maintenance, installation and repair activities. How collaborative technology is used to communicate technical information and data. Current legislation including GDPR and organisational procedures that are used to manage data and increase confidentiality of sensitive information.	EC1, EC2, EC3, EC4, EC5, MC5, MC7, MC10, DC1, DC2, DC3, DC4, DC5.

1.21 Digital, information and communication technology (**ICT**).

Range:
ICT – data systems, recording systems, electronic document and management systems.

What do learners need to learn?	**Skills**
How technology and systems are used to manage engineering data and documentation. Application of software and ICT systems and techniques to record, manage, store and amend engineering information. Advantages and limitations of using ICT to record information.	EC4, EC5, MC5, MC10, DC1, DC3, DC4, DC5.

Practical criteria for performance outcomes

Outcome 2

2. Analyse requirements, specifications and technical information to enable the delivery of successful maintenance, installation, servicing and repair of mechanical plant and equipment.

2.1 Confirm the **type**, **scope** and **requirements** of the activity, task or problem.

Range:

Type – installation, re-installation, position, configuration, assembly, disassembly, modification**,** fault finding (electrical, electronic, data, system, operational, temperature), resolution methods, preventative measures, repairs, upgrade, downgrade.

Scope – tasks, features, costing, goals, deliverables, functions, requirements, outcomes, end product, depth, detail, time scales, sensory checks, maintenance records and schedules, agreed processes, evidence and data gathering, specifications, repair information, schematics, component diagrams, safety and recall instructions.

Requirements – expectations and desired output, performance requirements, client requirements, reliability, integration of information, health and safety legislation and regulations.

What do learners need to demonstrate?	**Skills**
Gather, analyse and interpret technical information, data and evidence to confirm type, scope and requirements for the task, considering performance, quality and compliance. Use information to identify and confirm issues, problems, faults and areas for investigations. Analyse and identify likely causes, agreed processes, methods, expectations and outcomes. Interrogate technical documentation considering the accuracy, relevance, currency and completion to understand issues and appropriate methods for resolution or further investigation. Use and respond effectively to specifications, repair information, observed evidence, recall instructions, maintenance tables and technical bulletins. Interpret and confirm all health and safety requirements of maintenance, installation and repair activities.	EC4, EC5, EC6, MC2, MC3, MC5, MC6, MC7, MC9, MC10, DC1, DC4.

2.2 Evaluate the **condition**, quality and **performance** of **components**, systems, **materials** and **resources.**

Range:

Condition – working condition, serviceability (degradation, deterioration, damage, corrosion, disintegration), safety.

Performance – efficiency, accuracy, effectiveness, tolerance, outputs, sustainability.

Components – mechanical, electro-mechanical.

Materials – non-ferrous (titanium and alloys), ferrous, thermosetting, thermoplastics, composites, smart materials.

Resources – maintenance instructions, maintenance manuals, data sheets, material safety data sheets (MSDS), recording forms, maintenance logs, test certificates, permit to work, health and safety regulations, environmental requirements, organisational procedures, client information, requirements, performance data and diagnostic information.

What do learners need to demonstrate?	Skills
Evaluate the condition of materials and components to ensure quality standards and requirements are met. Make effective decisions based on observation and information gathered to proceed with a task. Use diagnostic information and other evidence to determine mechanical system and component serviceability and feasibility for maintenance and repair activities.	EC4, EC5, MC2, MC5, MC6, MC10, DC4.

2.3 Interpret mechanical **representations**.

Range:
Representations – manuals, specifications, instructions, diagrams, schematics, working drawings, symbols, annotations, conventions, standards, commissioning reports, results, bulletins.

What do learners need to demonstrate?	Skills
Interpret mechanical representations to communicate and confirm details and requirements of the mechanical systems to support maintenance, installation and repair activities.	EC3, EC4, EC5, MC5, MC6, MC7, MC10, DC1, DC4.

Outcome 3

3. Plan and prepare the maintenance, installation, servicing and repair of mechanical plant and equipment, taking into account the specific requirements and context.

3.1 **Plan** and prepare **processes**, **resources**, **scope**, **technology**, **tools and equipment** to complete client expectations.

Range:
Plan – method statements, Standard Operating Procedures (SOPs), risk assessments, preparatory checks.
Processes – organisational, regulatory, maintenance, rectification, reporting, recording.
Resources – maintenance instructions, maintenance manuals, data sheets, MSDS, recording forms, maintenance logs, test certificates, permit to work, health and safety regulations, environmental requirements, organisational procedures, client information, requirements, performance data and diagnostic information.
Scope – tasks, features, costing, time constraints, goals, deliverables, functions, requirements, outcomes, end product, depth, detail, time scales, sensory checks, maintenance records and schedules, agreed processes, evidence and data gathering, specifications, repair information, schematics, recall instructions.
Technology, tools and equipment – drills, pliers, spanners, screwdrivers, torx, files, hammers, Allen keys, test equipment (CMM, multimeters, diagnostic testers), measuring tools (micrometers (internal, external, depth), Vernier callipers), pressure source, slip gauges, comparison plates.

What do learners need to demonstrate?	Skills
Produce plans using information gathered to meet client requirements, including human resources and service impact, following SOPs. Confirm technology, tools and equipment availability to complete client requirements with consideration of prior maintenance history. Identify components and parts that are required. Review, confirm and record stock levels, ordering processes, and lead-in times to complete the required task or activity. Evaluate and plan for wastage, disposal, recyclability and sustainability in maintenance, service and repair tasks and activities.	EC1, EC2, EC3, EC4, EC5, EC6, MC2, MC3, MC4, MC7, MC8, MC9, DC5.

3.2 **Risk assessment**.

Range:
Risk assessment – assessments of hazards (health and safety considerations, pneumatics, hydraulics, mechanical, electro-mechanical, temperature, abrasive wheels, hazardous substances, pressurised fluids, equipment, moving under suspended loads, risk of slips, trips and falls, working in restricted spaces), evaluation of risk (severity, impact), control measures (permits to work, SOPs, PPE), documentation.

What do learners need to demonstrate?	Skills
Complete risk assessments and implement control measures for maintenance, installation and repair activities, communicating risks according to policies and procedures. Complete risk management for maintenance and repair activities of mechanical systems. Confirm processes, outcomes and mitigations used to reduce potential risks and issues.	EC1, EC2, EC3, EC4, EC5, DC1, DC2, DC4.

3.3 Quality, accuracy and completeness of **information** and **resources**.

Range:
Information – identification codes and technical data, manufacturers data sheets, manufacturers safety specifications, MSDS, colour codes, component numbering, schematics, bill of materials, sensory checks, fault data, checklists, reports, measurements, test results, inspection sheets, technical bulletins, repair method statements (issue dates, amendments).
Resources – policies, procedures, regulations, guidance, second line verifications, organisational systems and requirements, maintenance logs, defect logs, reports, equipment, data systems, electronic document and management systems.

What do learners need to demonstrate?	Skills
Application of information and resources to ensure components are correct, complete, free of fault, and conform to specifications, grades, and dimensions. Application of calibration requirements of components and equipment prior to commencing and procedures for out-of-date calibrations.	EC4, EC5, MC2, MC3, MC4, MC6, MC7, MC8, MC9, DC1, DC2, DC4, DC5.

3.4 **Preparatory checks** for compliance, quality and functionality.

Range:
Preparatory checks – tools, equipment, calibration, isolation, work area, sensory.

What do learners need to demonstrate?	Skills
Carry out of preparatory checks on materials, resources, tools, equipment, and other technologies. The advantages and limitations of preparatory checks for compliance, quality and functionality. Application of safe isolation and calibration checks on tools and equipment.	EC5, MC2, DC1.

3.5 **Plan and prepare** work areas for mechanical engineering processes.

Range:
Plan and prepare – tools, equipment, materials, technical data, schematics, health and safety, workflow process.

What do learners need to demonstrate?	Skills
Plan and prepare the work area for mechanical engineering processes. Application of adjustments to tools and equipment according to specifications and parameters in preparation for the task to be completed.	EC5, EC6, MC2, DC1.

Outcome 4

4. Perform relevant maintenance, installation, servicing and repair of mechanical plant and equipment, using appropriate techniques and procedures to achieve the required quality outcomes and solutions.

4.1 **Maintain**, install and repair mechanical engineering systems, equipment, and components.

Range:
Maintain – total preventative, reactive, planned (timed, annual, bi-annual, shutdown), corrective, condition-based monitoring.

What do learners need to demonstrate?	Skills
Complete maintenance, installation and repair activities of mechanical engineering systems within agreed specifications, timeframes and standards of quality. Safely operate equipment, machinery and technology when completing maintenance, installation and repair tasks. Follow relevant guidelines and instructions, and seek advice and guidance, where necessary. Responsibilities of working individually and collaboratively to meet task, client and organisational standards, policies and expectations, in accordance with working practices. Follow and comply with all health and safety requirements of maintenance, installation and repair activities.	EC5, EC6. MC1, MC2, MC3, MC4, MC5, MC7, DC1, DC4, DC6.

4.2 **Diagnostic** and measurement techniques, **tools and equipment**

Range:
Diagnostic tools and equipment – test equipment (CMM, multimeters, diagnostic testers), measuring tools (micrometers (internal, external, depth), Vernier callipers, DTI gauge, feeler gauges), pressure source, hydraulic simulators, slip gauges, comparison plates.

What do learners need to demonstrate?	Skills
Follow manufacturer's instructions when using diagnostic and measuring equipment. Application of diagnostic and measurement techniques, tools and equipment to obtain accurate information and results on performance, condition and compliance. Use fault detection techniques, tools and equipment to identify and locate faults and their causes on mechanical assemblies, sub-assemblies, systems and equipment. Interpret and evaluate built in tests and self-diagnostic results.	EC5, EC6, MC1, MC2, MC3, MC4, MC5, MC6, MC7, DC1, DC4, DC6.

4.3 **Reactive** and **preventative** maintenance procedures.

Range:
Reactive – condition-based monitoring, unplanned/emergency/post-fault.
Preventative – scheduled, planned, timed.

What do learners need to demonstrate?	**Skills**
Determine schedule of tasks (remove, replace, repair) from diagnostic and measurement findings. Follow procedures to complete reactive maintenance tasks. Complete preventative maintenance procedures to reduce further failure or downtime, including recommending amendments to the maintenance schedule where appropriate.	EC5, MC1, MC2, MC3, MC4, MC5, MC6, DC4.

4.4 **Disassemble**, **assemble** and **install** mechanical components, devices and systems.

Range:
Disassemble – removal of stored energy, isolation, powering down, removal of components, proof marking, disposal requirements, documentation.
Assemble – sub-assemblies, replacement of lifed items, attachments, fixings, tightening techniques, powering up, testing, documentation.
Install – client requirements, regulation requirements, commissioning, isolation, manufacturers specifications, replacement parts, testing.

What do learners need to demonstrate?	**Skills**
Processes to be followed when assembling and disassembling components, devices and systems. Apply requirements and specifications to ensure correct assembly and disassembly, considering technical data and instructions. Accurately position, install, calibrate and configure devices and equipment to agreed requirements and specifications. Consider and follow regulatory requirements throughout.	EC5, MC1, MC2, MC3, MC4, MC5, MC7, DC1, DC4, DC6.

4.5 **Commissioning** and **return to service** of mechanical engineering systems and technology.

Range:
Commissioning – design, construct, test, integration, set parameters, check tolerances, live testing, test before first use, confirm performance and accuracy, alterations, wiring.
Return to service – power up, confirm functionality, reliability, serviceability, handover.

What do learners need to demonstrate?	**Skills**
Commission and return to service mechanical devices, systems, and technology to fully operational condition. Application and purpose of testing the system is operating correctly, adjusting where necessary. Carry out commissioning procedures safely and checking the safety of mechanical systems.	EC5, EC6, MC1, MC2, MC3, MC5, DC1, DC4, DC6.

4.6 Planned maintenance, **servicing** and repair **tasks**.

Range:
Servicing – fluid maintenance, component change, calibration, condition checks, functional checks, fitting replacement.
Tasks – measuring, cutting, drilling, filing, removing and replacing bolts, screws and clips, replacing seals, extracting and replacing damaged fasteners, applying surface treatments.

What do learners need to demonstrate?	Skills
Perform planned maintenance, servicing and repair tasks to mechanical engineering systems according to schedules. Review and analyse outputs, data and readings.	EC5, MC1, MC2, MC3, MC5, MC7, DC3, DC4.

4.7 **Re-instate** work areas.

Range:
Re-instate – equipment is functioning to specification, fluids and lubricants renewed and refilled, material removal, work area is back to original condition, returning of tools and equipment, correct disposal requirements followed, housekeeping.

What do learners need to demonstrate?	Skills
Reinstate work areas back to original condition upon completion of tasks. Manage the area ensuring the area is left in safe condition. Check and return all tools and equipment back to storage facilities. Follow disposal requirements appropriate to the waste and relevant legislation.	EC5, MC2.

Outcome 5

5. Review and evaluate activities to help improve workplace systems and processes associated with maintenance, installation, servicing and repair of mechanical plant and equipment, demonstrating commercial awareness and accountability.

5.1 **Safe systems of work** and legal compliance.

Range:
Safe systems of work – procedures, safe working practices, risk assessment and management, recording and documentation.

What do learners need to demonstrate?	Skills
Anticipate and identify potential risks and actual risks. Apply safe systems of work, following policies and procedures relevant to the task. Complete documentation of activities and reflect on outcomes. Follow and comply with safe working practices and legal requirements.	EC4, EC5, EC6, MC1, MC2, MC4, MC5, MC6, MC10, DC1, DC2, DC4.

5.2 Work area **practices**.

Range:
Practices – safe working, guidance, regulatory requirements, organisational requirements, scope, responsibility, documentation, reporting procedures.

What do learners need to demonstrate?	Skills
Monitor working area practices to prevent, resolve, manage, and mitigate issues arising during tasks. Identify potential issues, following correct procedures to report and record. Implement practices to manage stock levels, materials, and availability of resources.	EC4, EC5, MC1, MC2, MC5, MC6, MC7, MC10, DC4, DC5.

5.3 Deal promptly and effectively with **issues**.

Range:
Issues – health and safety, age related use/wear, not meeting required standards or regulations, decommissioning, inappropriate use/lack of training, time constraints, cost implications, documentation discrepancies, tool and equipment failure.

What do learners need to demonstrate?	Skills
Deal with issues encountered throughout mechanical engineering tasks in a timely manner. Apply problem solving techniques to resolve issues within the limits of own authority. Follow reporting procedures to ensure issues are communicated. Report and escalate issues where falling outside the limits of own authority.	EC3, EC4, EC5, EC6, MC2, MC6, MC9, MC10, DC1.

5.4 Carry out **quality monitoring** and **assurance checks** to review processes.

Range:

Quality monitoring – inspections, reviewing (self, peer to peer, supervisory), amending, supervisory checks, checking of quality.

Assurance checks – checking and validating reliability and durability, post-repair performance and functional tests.

What do learners need to demonstrate?	**Skills**
Conduct quality monitoring and assurance checks as part of a team's maintenance, servicing and repair operations and processes. Review efficiency of processes, practices and outcomes to improve quality. Consistently check validity, accuracy and relevance of documentation. Communicate technical information, advice and suggestions for improvements. Suggest strategies to increase efficiency of quality monitoring processes, with consideration of performance and potential improvements.	EC4, EC5, EC6, MC4, MC5, MC6, MC10, DC1, DC2, DC3, DC4.

5.5 Make positive **contributions** for mechanical maintenance and operations whilst working effectively with others.

Range:

Contributions – communicate solutions, improvements, ideas, findings, designs, technical information, recommendations, research, facts, methods, operational changes, maintenance requirements.

What do learners need to demonstrate?	**Skills**
Recommend improvements, methods and other technical information as part of a team. Contribute effectively to maintenance, operations and team discussions. Working effectively with others and be willing to assist where necessary and appropriate.	EC2, EC3, EC4, EC5, EC6, MC2, MC9, MC10.

5.6 Respond constructively to **feedback** and identify opportunities for personal and **organisational** improvement.

Range:

Feedback – reviews (self, peer to peer, supervisory), appraisals, reports, progress reviews, evaluation, client.

Organisational – commercial, productivity, safety, growth, activities, services, quality, technology, continuing professional development (CPD).

What do learners need to demonstrate?	**Skills**
Reflect and respond constructively to feedback provided throughout tasks and activities. Make suggestions for organisational improvements for commercial, productivity, and safety. Review feedback, identifying and implementing opportunities, personally and professionally within the organisation.	EC2, EC6, MC2, MC9, MC10, DC2, DC3.

Outcome 6

6. Communicate mechanical operations, maintenance, installation, servicing and repair information, proposals and solutions, producing, recording and explaining relevant technical information.

6.1 **Record and amend** technical information, data, risks, and issues.

Range:
Record and amend – diagrams, working drawings, reports, results, maintenance logs, defect logs, statements, checklists, test certificates.

What do learners need to demonstrate?	**Skills**
Record findings, data, risks, and issues from the task accurately to support mechanical maintenance, servicing and repair work. Create technical reports to communicate maintenance, installation and repair information. Make amendments and recommendations at relevant stages, within the limits of own authority. Use records, information, and data to inform improved practices, recommendations, and continuous improvement.	EC3, EC4, MC2, MC5, DC1, DC3, DC4, DC5, DC6.

6.2 Complete **handover procedures**.

Range:
Handover – complete work, incomplete work, modifications, faults, further investigation, suggested updates and improvements to maintenance schedules, demonstration of system functionality, confirmation (completion, responsibility, quality standards, specific requirements and outcomes, agreement), due date of next maintenance activity, technical documentation.
Procedures – communication methods (verbal, written, digital), de-brief, technical documentation (test results and certificates, calibration certificates, appropriate calculations, maintenance schedules, drawings and diagrams, software update information, maintenance records), signatures and date.

What do learners need to demonstrate?	**Skills**
Accurately communicate handover information following organisational procedures The functionality of the system following maintenance, installation and repair activities. Communicate the reasons for non or partial functionality following maintenance, installation and repair activities, including any outstanding faults, defects or issues, and suggestions for future improvements. Follow and implement document version control for relevant paperwork and technical documentation where updates are made, including maintenance schedules and representations. Follow organisational handover procedures. Apply organisational policies (brief, meetings, documentation) to the handover procedures.	EC1, EC4, MC2, MC7, MC8, MC10, DC1, DC4.

6.3 Team-working, inter-personal skills and communication with **technical** and **non-technical audiences**.

Range:
Technical audiences – supervisors, engineers, colleagues, skilled technicians, apprentices.
Non-technical audiences – stakeholders, customers, clients, investors, colleagues (sales/service advisers, in house health and safety advisor).

What do learners need to demonstrate?	**Skills**
Communicate technical information as part of a team. Work as part of a team to obtain desired outcomes, maintaining positive and professional working relationships. Interact using inter-personal skills to contribute to team success. Adapt technical language appropriately to communicate with non-technical client/customers and colleagues.	EC1, EC2, EC3, EC4, EC5, EC6, DC3, DC4.

6.4 Communication methods, including **written, verbal** and **media.**

Range:
Written – note taking (lists, mind mapping/flow diagrams), writing style (business letter, memo writing, report styles and format, email), proofreading and amending text, use of logbook for planning and prioritising work schedules, graphical presentation techniques (graphs, charts and diagrams).
Verbal – speaking (with peers, supervisors, use of appropriate technical language, tone and manner), listening (use of paraphrasing and note taking to clarify meaning), impact and use of body language in verbal communication.
Media – inter/intranet (manuals, data, analytical software, manufacturers' catalogues), spreadsheets, databases, fault diagnostic software.

What do learners need to demonstrate?	**Skills**
Communicate information, requirements, expectations, plans, performance, and outcomes using different communication methods to convey and confirm maintenance, installation and repair information.	EC1, EC2, EC3, EC4, EC5, EC6, MC7, MC8, MC10, DC1, DC2, DC3, DC4, DC5.

Guidance for delivery

Opportunities for visits/engagement with local industry, employers and manufacturers should be provided throughout the delivery of the content within this specialism – where appropriate local employers could present details of recent projects including a variety of mechanical engineering maintenance activities, problems faced and how they were overcome. Learners work placement experiences could be presented to peers detailing where knowledge and skills within the content was seen in practice.

Formative assessment for the content may include oral Q&A, presentations to peers, observation of measuring activities etc. Reinforcement of learning can be encouraged through revisiting learning, group discussions, and the establishment of a peer support system within the cohort.

Providers must ensure content is delivered in line with current, up-to-date industry practice which will require;

- Provision of appropriate tools, equipment and test instrumentation for demonstration and practical training purposes
- Teaching coverage representing the type of equipment currently available and accepted for use in the UK industry

Suggested learning resources

Books

- E. Avallone, T. Baumeister, A. Sadeh. *Marks' Standard Handbook for Mechanical Engineers*, 11th edition, McGraw-Hill. 2006. ISBN 978-0071428675.
- C. McCauley. *Machinery's Handbook,* 30th edition, Industrial Press Inc. 2016. ISBN 978-0831130916.
- N. J. Smith, *Engineering Project Management,* 3rd edition, Wiley-Blackwell Publishing, 2007, ISBN 9781405168021

Websites

- Institution of Mechanical Engineers **www.imeche.org**
- Health and Safety Executive www.hse.gov.uk

Scheme of Assessment – Maintenance engineering technologies: Mechanical

The Maintenance engineering technologies: Mechanical Occupational Specialism is assessed by one practical assignment. The duration of the assessment is 22 hours. Learners will be assessed against the following assessment themes:

- Health and safety
- Planning and preparation
- Systems and components
- Working with faults
- Reviewing and reporting

By completing the following tasks:

Task	Typical Knowledge and skills
Task 1 – Plan and prepare	Displays a breadth of knowledge and practical skills that enables them to plan and prepare for carrying out maintenance, installation and repair activities on mechanical systems. Candidates will need to produce documents and complete risk assessments that clearly details how they plan to complete the maintenance, servicing, installation and repair activities to meet the requirements of the brief.
Task 2 – Perform maintenance	Applies a breadth of knowledge, understanding and practical skills that enables them to carry out maintenance, servicing, installation and repair activities on a variety of mechanical systems and machines. The task is carried out in a clear and logical sequence. Works in a safe manner, able to carry out fault detection, diagnosis, isolation and resolution methods effectively Tools, materials and equipment are selected and used correctly.
Task 3 – Review and report	Displays a breadth of knowledge and understanding in the evaluation of their maintenance, installation and repair activities, recommending personal and organisational improvements to the process. Justifications for diagnosis, isolation and resolution methods used. Justifications for how peer review feedback was considered and implemented.
Task 4 - Handover	Displays breath of knowledge and skills in communicating technical information to a variety of audience types and how to complete handover procedures effectively. Candidates will need to demonstrate critical thinking skills when responding to peer review feedback.

The information provided in the following tables demonstrates to approved providers the weightings of each performance outcome and how each performance outcome is assessed.

Performance outcome and weighting (%)	***High level tasks*** *Provide specific instructions for candidates to provide evidence for and are the same for every version of the assessment*	**Assessment Theme**	***Typical evidence***
PO2 Analyse requirements, specifications and technical information to enable the delivery of successful maintenance, installation, servicing and repair of mechanical plant and equipment. (10%)	T1- Plan and prepare	Planning and preparation	List of requirements and resources, and method statement.
PO3 Plan and prepare the maintenance, installation, servicing and repair of mechanical plant and equipment, taking into account the specific requirements and context (20%)	T1- Plan and prepare T2 – Perform	Health and safety Planning and preparation Systems and components Health and safety Planning and preparation Systems and components	List of requirements and resources, and method statement. Risk assessment. Work area preparation

PO4 Perform relevant maintenance, installation, servicing and repair of mechanical plant and equipment, using appropriate techniques and procedures to achieve the required quality outcomes and solutions (40%)	T1- Plan and prepare T2 – Perform T3 – Review and report T4 - Handover	Health and safety Health and safety Systems and components Working with faults Health and safety Systems and components Reviewing and reporting Health and safety Reviewing and reporting	List of requirements and resources, and method statement. Risk assessment. Completed test records, updated maintenance records and control documents Annotated method statement. Maintenance activities and work area re-instatement Technical report Technical report and maintenance schedule. Handover meeting.
PO5 Review and evaluate activities to help improve workplace systems and processes associated with maintenance, installation, servicing and repair of mechanical plant and equipment, demonstrating commercial awareness and accountability (20%)	T2 – Perform T3 – Review and report T4 - Handover	Systems and components Reviewing and reporting Health and safety Reports and information	Completed test records, updated maintenance records and control documents Annotated method statement. Technical report and maintenance schedule. Handover meeting.

PO6 Communicate mechanical operations, maintenance, installation, servicing and repair information, proposals and solutions, producing, recording and explaining relevant technical information (10%)	T3 – Review and report T4 - Handover	Reports and information Reports and information	Technical report and maintenance schedule. Handover meeting

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Level:	3
GLH:	680
Assessment method:	Practical assignment

What is this specialism about?

The purpose of this specialism is for learners to know and understand mechatronic engineering systems and undertake key procedures for maintenance, installation and repair. Learners will have the opportunity to plan, perform and evaluate their work whilst utilising a range of materials, tools, equipment and machinery.

Learners will develop their knowledge and understanding of, and skills in:

- Knowledge of common mechanisms and controllers
- Knowledge and application of component classification, numbering and referencing systems
- Knowledge of how components are removed, replaced and repaired as part of mechatronic systems
- Skills to plan and prepare mechatronic maintenance activities using evaluation
- Skills to select and use tools, equipment, machinery and technology safely and effectively to complete maintenance, installation and repair activities

Learners may be introduced to this specialism by asking themselves questions such as:

- How do mechatronic systems operate and function?
- What components are used in mechatronic systems?
- How is maintenance, installation and repair carried out within mechatronic engineering?

Underpinning knowledge outcomes

On completion of this specialism, learners will understand:

1. Maintenance engineering technology - mechatronics knowledge criteria

Performance outcomes

On completion of this specialism, learners will be able to:

2. Analyse requirements, specifications, and technical information to enable the delivery of successful maintenance, installation, servicing and repair of mechatronic technology, systems, and equipment.

3. Plan and prepare the maintenance, installation, servicing and repair of mechatronic technology, systems, and equipment, considering the specific requirements and context.

4. Perform relevant maintenance, installation, servicing and repair of mechatronic technology, systems, and equipment, using appropriate techniques and procedures to achieve the required quality outcomes and solutions.

5. Review and evaluate activities to help improve workplace systems and processes associated with maintenance, installation, servicing and repair of mechatronic technology, systems, and equipment, demonstrating commercial awareness and accountability.

6. Communicate mechatronic maintenance, installation, servicing and repair information, proposals, and solutions, producing, recording, and explaining relevant technical information.

Completion of this specialism will give learners the opportunity to develop their Maths, English, and Digital Skills. Details are presented at the end of the specification.

Specialism content

Outcome 1

Underpinning knowledge criteria for the performance outcomes

1.1 **Principles and techniques** for maintenance and repair.

Range:

Principles and techniques –

- removal and replacement activities – assembly and disassembly techniques, mechanical fixings/fastening
- conditions that determine repair – age of components, condition, costings, maintenance, replacement, repair, disposal, installation, downtime, productivity, quality, environmental
- maintenance and servicing strategies – reactive (condition-based monitoring, unplanned/emergency/post-fault), preventative (scheduled, planned, timed)
- disposal requirements – appropriate methods, documentation, legislation, sustainability and environmental considerations
- control documentation – schedules, specifications, method statements, authorisation, care and control procedures
- maintenance planning considerations – cost, production output, safety, skills and competency, equipment, job instructions)
- sources of information – data sheets, technical data, engineering drawings, exploded diagrams, planning sheets, workshop manuals, schematics
- types of tools – hand tools, power tools, test equipment, measuring instruments
- decommissioning considerations – down time, repair costs, environmental issues, productivity, quality, planning, lockouts, hazardous waste, risk assessments, permits, legislation.

What do learners need to learn?	**Skills**
Reasons of removal and replacement activities. Factors to be considered when determining either repair or replacement of assemblies or sub-assemblies. Types of documentation that are used to monitor, record and control maintenance activities and their typical contents. How to produce or amend appropriate technical documentation. The reasons for planning maintenance activities. Sources of information used in maintenance activities and how they are used Types and purpose of tools and equipment used in maintenance activities. Disposal requirements appropriate to the waste and relevant legislation. Factors to be considered when decommissioning and their implications.	EC3, EC5, EC6, MC2, MC6, MC7, MC9, DC1, DC2, DC5.

Analyse requirements, specifications, and technical information to enable the delivery of successful maintenance, installation, servicing and repair of mechatronic technology, systems, and equipment (PO2)

1.2 Operation of **mechanical systems** and **principles.**

Range:

Mechanical systems – gearbox, cams and followers, pulleys, levers, actuation, cooling, lubrication, integrated systems (hydraulic, pneumatic, electronic).

Mechanical principles – motions and forces (static and dynamic loading, stress, strain, tensile shear, compressive shear, moments, torque), thermal, friction, system principles (input, process and output), hydraulic, pneumatic, work done and efficiency, mechanical advantage.

What do learners need to learn?	Skills
How the systems manage forces, power, and motion. The principles and applications of mechatronics and the systems that use them. The operation of systems that uses mechatronics by representation of block diagrams. Calculations of the specified values. Moments affecting levers and beams. Calculations of mechanical loads on structures and components. Effects of mechanical loads on structures and components.	EC5, MC3, MC4.

1.3 Fundamentals of common **mechanisms** and **controllers**.

Range:

Mechanisms – levers, rams, valve blocks, gears (characteristics of gears including teeth, root, pitch, meshing, backlash), gear trains, gearbox, governors, pulleys, cylinders, cams and followers, friction devices/clutches (mechanical, hydraulic, electromagnetic), structural components (frames, bearings, springs, bushes), overhead cranes, hoists.

Controllers – microprocessors, microcontrollers, sensors (displacement, position, proximity, velocity and motion, force, pressure, flow, viscosity, level, temperature, light sensors and switches), actuators, motors (electric, stepper, control, flow control), automation, artificial intelligence (AI).

What do learners need to learn?	Skills
The functions of common mechanisms used in mechatronics. The operation and application of sensors and actuators. Types of gear trains, including compound gears and the role of idler gears. How controllers maintain and control performance.	EC5, MC6.

1.4 Key principles of **energy storage** and **transfer**.

Range:
Energy storage – heat, chemical, kinetic, potential, electrical, conversion of energy, pressure.
Energy transfer – methods of energy transfer (conduction, convection, radiation, mechanical, electrical, heating) energy efficiencies, circuits, transmissions, drive trains, torque converters, belts, hydraulic/pneumatic systems, automation, robotics, AI.

What do learners need to learn?	Skills
Characteristics and methods of energy storage and transfer. The applications of energy storage and transfer methods. How energy forms are converted to enable storage.	MC4, MC6.

1.5 **Construction** and **operation** of power conversion systems.

Range:
Construction – electrical devices (transformers, regulators, invertors), electro-mechanical devices (motor-generators), control panels, rectifiers, rotary convertors, hydraulic, pneumatic, surface mount circuitry, through-hole technology, fluid power.
Operation – frequency control, diodes, converting alternating current (AC) to direct current (DC) and back, DC-DC, DC-AC convertors, efficiencies of systems, power flow.

What do learners need to learn?	Skills
Functions and operation of power conversion systems, and the components required to construct them. Principles of power conversion systems and how they work to achieve an output. Power flow analysis techniques and their applications.	EC5, MC2, MC3, MC4, MC6.

1.6 **Components** of electrical installations, including **failure modes** and **protection methods**.

Range:
Components – passive components (resistors, capacitors, inductors, transformers, circuit board, wire harness, connectors), active components (voltage and current sources), generators, transistors, operational amplifiers, diodes (Zener, photodiodes, light emitting diodes (LED`s)), residual current devices (RCD), wiring (standards, earth leakage).
Failure modes – equipment failure (human error, environmental conditions), circuit faults (symmetrical and unsymmetrical faults, short circuit and open circuit connections, high resistance connections, connections to earth), power supply faults (components out of specification, intermittent faults, fault and tolerance testing), digital faults (input, output, logic).
Protection methods – relays, earthing and bonding, fuses, circuit breakers, solenoids, diodes.

What do learners need to learn?	Skills
Function and operational characteristics of electrical components, cabling and wiring. Identify common failure modes and protection methods. The advantages and limitations of protection methods. How to interpret and apply the latest edition IET wiring regulations HSE directive.	MC2, MC3, MC4, MC6, DC1.

1.7 **Properties** and applications of electrical and electronic **systems, circuits** and **components**.

Range:

Properties – voltage, current, resistance, impedance, power.

Systems – mechatronic, mechanical, electro-mechanical, electrical, power electronics, microelectronics, digital electronics, integrated circuits, Wheatstone bridge, amplifiers, power supplies, sequential, asynchronous/synchronous logic, programmable systems, data logging and measurement systems, automation, AI.

Circuits – series, parallel, series-parallel, open and closed circuits, control, latching, power, timer, auxiliary, printed circuit board (PCB), surface mount technology (SMT).

Components – switches, sensors (temperature, flow, level, pressure, light, proximity, position), diodes, transistors, rectifiers, capacitors, RCD's, resistors, inductors, relays, actuators, motors (electric, stepper, control, flow control), visual display units (VDU), human machine interface (HMI), transformers, operational amplifiers, potentiometers.

What do learners need to learn?	Skills
The nature and behaviour of electricity in systems. The properties and characteristics of electrical and electronic systems, circuits and components within mechatronic engineering. Different types of electrical circuits (series and parallel) and their applications in mechatronic engineering. The application of different types of systems and their components. Application of electrical and electronic laws and theorems.	MC3, MC4, MC6, DC1.

1.8 **Drive devices,** their purposes, **parameters,** and applications.

Range:

Drive devices – basic input/output system (BIOS), hardware, motherboard, adjustable drive devices, motors, pumps, belts, rams, gear trains, gearboxes, clutches, modulators, control units, sensing units, AC and DC units, microprocessors, microcontrollers, output devices, robotics, AI.

Parameters – inputs, process and outputs, memory, peripherals, hardware specifications, software and programming languages, logic operators (AND, OR, NOT).

What do learners need to learn?	Skills
Fundamentals, application and purpose of drive devices. The advantages and limitations of drive units. The purpose and outcomes of drive device parameters and how they contribute to the operation of the system. How programmable logic controllers (PLC's) operate and their applications in mechatronics. Purpose and outcomes of system testing.	EC5, MC2, MC3, MC4, MC6, DC1.

1.9 **Sensing** and **measurement techniques and technologies**.

Range:

Sensing – temperature, acceleration, position, pressure, displacement, vibration, proximity, velocity/motion, force, flow (gas, liquid), viscosity, level, photo electric, switches.

Sensing technologies – inductive, capacitive, hall effect, operational amplifiers, Wheatstone bridge, filtering, transformers, piezoelectric transducers.

Measurement techniques and technologies – multimeters, oscilloscopes, signal generators, thermocouples, residual temperature devices (RTD's), data logging, analysers (logic, dewpoint, hygrometers, hydrometers, thermometer).

What do learners need to learn?	**Skills**
The purposes and applications of electronic systems that measure performance. The relative benefits and limitations of sensing and measurement techniques and technologies. How programming, sensing and measurement technologies are used to measure parameters and signals.	MC2, MC3, MC4, MC6, DC1.

1.10 **Component classification**, **numbering** and **referencing systems**.

Range:

Component classification – passive, active, electromechanics, manufacturers specifications.

Numbering – part numbers, manufacturers specifications, bill of materials (BOM), labelling, specifications.

Referencing systems – wiring identification, identification codes and technical data, standard reference designations for electrical and electronic parts and equipment (IEEE standards), colour codes, component numbering, QR codes, barcodes, CE marking, IET wiring regulations (British Standard 7671), BS3939, EMC Directive, BS, IEC, EN and ISO Standards.

What do learners need to learn?	**Skills**
The purposes and applications of component classification, numbering and referencing. Standardised component numbering and referencing systems. How to interpret current IET, BS, IEC, EN and ISO standards related to mechatronic systems including classification, numbering and referencing. Classification, numbering and referencing related to engineering documents.	MC2, MC3, MC4, MC6, DC1, DC5.

Perform relevant maintenance, installation, servicing and repair of mechatronic technology, systems, and equipment, using appropriate techniques and procedures to achieve the required quality outcomes and solutions. (PO4)

1.11 **Hand** and **power tools,** and **equipment.**

Range:

Hand tools – spanners, sockets (ratchet, universal joints, extension bars), screwdrivers, torx, pry bars, punches, chisels, hacksaw, pliers wire strippers, soldering iron, de-soldering tool, mole grips, stilsons, side cutters, bolt cutters, files, hammers, mallets, crimpers, drills, jig saws, riveter, rivet nut gun.

Power tools – jigsaw, angle grinder, multitool, reciprocating saw, cutters, grinders, drills, electrical, pneumatic, hydraulic.

Equipment – test equipment (multimeters, electronic control unit (ECU) diagnostic testers), measuring tools (micrometers, Vernier callipers, flow meter, pressure gauges), oscilloscopes, signal generators, logic probes, data logger, lifts, jacks, hoist pulleys, overhead crane, welding (TIG, MIG/MAG, MMA), forging, isolation kit, digital technologies (laptops, tablets, mobile applications, handheld PC (H/PC), personal digital assistant (PDA)).

What do learners need to learn?	Skills
How to check the physical condition of tools prior to use. The suitable applications and limitations of the identified equipment. The main differences between the welding processes The application of computerised monitoring systems using digital technologies. How to maintain tools and equipment and use safely, following all safety regulations relating to use. How to safely operate equipment, machinery and technology. How to follow relevant guidelines and instructions, limits of own authority and expertise, and seek advice and guidance, where necessary.	EC5, MC1, MC2, MC3, MC4, DC1, DC4.

1.12 **Effects** of **environmental conditions** on materials, components, wiring, and equipment.

Range:

Effects – failure modes, working condition, false readings, degradation, corrosion, ingress, egress, leakages, system errors, blockages, electrical faults, mechanical faults, debris, cracking, brittle, disintegration, cleanliness, clarity.

Environmental conditions – humidity, moisture, temperature, pressure, heat, pollution, dirt, debris, radiation, chemicals.

What do learners need to learn?	Skills
How environmental conditions can affect materials components, wiring and equipment, and their potential effects. Characteristics relating to material quality and condition. How materials degrade and fail, including monitoring, maintaining and preventative techniques. Appropriate methods of maintenance, management, storage, preservation and prevention for materials, tools and equipment.	EC5, MC1, MC2, DC1, DC4, DC6.

1.13 Electro-static sensitive devices and components (**ESD's**), and **measures of protection**.

Range:
ESDs – metal oxide semiconductor field effect transistors (MOSFETs), complementary metal oxide semiconductor (CMOS) integrated circuits, micro-controllers.
Measures for protection – ESD-safe bags and foam, grounding mats, straps and tools, anti-static garments, wrist straps.

What do learners need to learn?	Skills
Static electricity and the effect it has on semi-conductors. The importance of anti-static practices during transport, storage, maintenance, servicing, and repair work, and the implications of not following these practices.	MC2, MC6, DC1, DC6.

1.14 **CAD/CAM** systems and software.

Range:
CAD/CAM – features and functions (solid modelling, geometry manipulation, component drawing), programming methods (manual programming, conversational programming), data transfer**,** manufacturing simulation, operations, 3D CAD**.**

What do learners need to learn?	Skills
The application and purpose of CAD/CAM systems and software across multiple dimensions and collaboration. The key principles of manufacturing using a CAD/CAM system.	EC5, MC2, MC4, MC5, MC6, DC1, DC4, DC5, DC6.

1.15 **Machine tools** and **machine elements**.

Range:
Machine tools – drills, lathes, milling machines, threading machines, grinders, polishers.
Machine elements – manual and computer numerical control (CNC), chucks, tooling (end mills, fluted cutters, facing cutters, boring bars, drills, centre-drills, taps, reamers).

What do learners need to learn?	Skills
Identify machine tools and machine elements. The characteristics and functions of machine tools and elements used in mechatronics. How to safely operate machinery and technology. How to follow relevant guidelines and instructions, limits of own authority and expertise, and seek advice and guidance, where necessary.	EC5, MC1, MC2, MC3, MC5, DC1, DC4, DC6.

1.16 **Installation**, **configuration**, and **integration** of mechatronic engineering systems.

Range:

Installation – client requirements, regulation requirements, requirements for service, 1st fix, 2nd fix of components, commissioning, isolation, manufacturers specifications, schematic diagrams, tools and equipment.

Configuration – setting parameters, calibration, testing, first use, operating systems, specifications, tools and equipment.

Integration – combining of systems, functions, designs, planning, processes, tools and equipment.

What do learners need to learn?	**Skills**
Application of installation techniques, configuration and integration using the correct tools, following regulations. Requirements and procedures for installation and configuration of mechatronic systems. How to safely use tools, equipment and technology to complete maintenance, installation and repair requirements. How to follow relevant guidelines and instructions, limits of own authority and expertise, and seek advice and guidance, where necessary.	EC5, MC1, MC2, MC3, MC4, MC5, MC7, DC1, DC4, DC6.

1.17 **Fault detection**, **diagnosis**, **isolation** and **resolution methods**.

Range:

Fault detection – self-diagnostic, unit substitution, input output, half split technique, 6 point technique, component isolation, operational experience, end to end, top-down techniques, timed test run, sensory checks, HMI, reported faults, fault history, tools and equipment.

Fault diagnosis – sensory checks, collection of fault data (mean time between failures (MTBF), mean time to repair (MTTR)), self-diagnosis, inspection, digital systems, material testing, tools and equipment.

Isolation methods – electrical isolation, supply, testing for dead, keys, lock out, electrical, temperature, pressure, residual current device (RCD), tools and equipment.

Resolution methods – replace, repair, adjust, modification, preventative measures, reporting, recording, informing, amendments.

What do learners need to learn?	**Skills**
Identifying faults utilising fault detection and diagnosis methods. Material testing methods and techniques. How to safely use tools, equipment and technology to detect and diagnose faults within assemblies and sub-assemblies. How to use resolution methods based on the fault diagnosis. Identify different isolation methods and carry out safe and effective isolation. The advantages and limitations of detection and diagnosis methods How to interpret and comply with relevant legislation. How to apply safe isolation methods to complete resolution and rectification methods. How to follow relevant guidelines and instructions, limits of own authority and expertise, and seek advice and guidance, where necessary.	EC5, MC1, MC2, MC3, MC5, DC1, DC4, DC6.

1.18 Techniques for **disassembly**, **modification and re-assembly**.

Range:

Disassembly – powering down, isolation, removal of housing and components, disposal requirements, documentation, tools and equipment.

Modification – changing of parameters, wiring, adjustments, process change, tools and equipment, re-calibration, reporting and recording, housing and components.

Re-assembly – structures, removal, powering up, documentation, attachments, fixings, QR codes, barcodes, tightening techniques, tools and equipment.

What do learners need to learn?	Skills
Methods and procedures for the disassembly and re-assembly according to guidance and regulations. How to safely use tools, equipment and technology to disassembly, modify and re-assemble mechanical assemblies and sub-assemblies. Tightening techniques for different operations. The application and recording of different modification techniques. How to follow relevant guidelines and instructions, limits of own authority and expertise, and seek advice and guidance, where necessary.	EC5, MC1, MC2, MC3, MC4, MC5, MC7, DC1, DC2, DC4, DC6.

1.19 **Joining techniques**.

Range:

Joining techniques – permanent (welded, soldered, adhesive bonded, brazed, expansion fittings), semi-permanent (riveted, folded, compression fittings), temporary (mechanical fastenings including screws and bolts), interference fit.

What do learners need to learn?	Skills
The characteristics of the different joining techniques and their applications.	EC5, MC1, MC2, MC3, MC5.

Review and evaluate activities to help improve workplace systems and processes associated with maintenance, installation, servicing and repair of mechatronic technology, systems, and equipment, demonstrating commercial awareness and accountability (PO5)

1.20 **Quality inspection**, **testing and recording methods**.

Range:

Quality inspection and testing methods – policies, procedures, guidance, organisational systems and requirements, sensory checks, checklists, maintenance instructions, data, reports, measurement, analysis of systems, communication, prior maintenance history, maintenance requirements, preventative measures.

Recording methods – maintenance logs, defect logs, reports, statements, checklists, equipment, digital technologies, amending documentation.

What do learners need to learn?	Skills
The purpose of quality inspection, testing and recording. Factors that can affect quality in mechatronic engineering and quality assurance processes. How variations and defects in engineering products and components are managed. Application of methods and techniques used within quality inspection and testing. The importance of using the correct quality inspection and testing techniques. The impact of inadequate quality inspection and testing. How to complete and record quality processes as part of quality control, assurance and improvement.	EC3, EC4, EC5, EC6, MC2, MC5, MC6, MC10, DC1, DC2, DC4.

Communicate mechatronic maintenance, installation, servicing and repair information, proposals, and solutions, producing, recording, and explaining relevant technical information. (PO6)

1.21 **Communicating technical information and data**.

Range:

Communicating – record, manage, store, amend, upload data, collaborative technologies (shared drives, email, conferencing, software and programs, forums).

Technical information and data – test data, test results, maintenance results and findings, fault information, inspection sheets, maintenance logs, repair methods.

What do learners need to learn?	Skills
How to communicate information effectively in written and verbal methods. The importance of technical documentation for communication. How to create technical reports for maintenance, installation and repair activities. How collaborative technology is used to communicate technical information and data. Current legislation including GDPR and organisational procedures that are used to manage data and increase confidentiality of sensitive information.	EC1, EC2, EC3, EC4, EC5, MC5, MC7, MC10, DC1, DC2, DC3, DC4, DC5.

1.22 Digital, information and communication technology (**ICT**).

Range:

ICT – data systems, recording systems, electronic document and management systems.

What do learners need to learn?	Skills
How technology and systems are used to manage engineering data and documentation. Application of software and ICT techniques to record, manage, store and amend engineering information. Advantages and limitations of using ICT to record information.	EC4, EC5, MC5, MC10, DC1, DC3, DC4, DC5.

Practical criteria for performance outcomes

Outcome 2

2. Analyse requirements, specifications, and technical information to enable the delivery of successful maintenance, installation, servicing and repair of mechatronic technology, systems, and equipment.

2.1 Confirm the **type**, **scope** and **requirements** of the activity, task or problem.

Range:

Type – installation, re-installation, position, configuration, assembly, disassembly, modification**,** fault finding (mechanical, electrical, data, system, pressure, operational, temperature), resolution methods, preventative measures, repairs, upgrade, downgrade.

Scope – tasks, features, costing, goals, deliverables, functions, requirements, outcomes, end product, depth, detail, time scales, sensory checks, maintenance records and schedules, agreed processes, evidence and data gathering, specifications, repair information, wiring diagrams, recall instructions.

Requirements – expectations and desired output, performance requirements, customer requirements, reliability, integrate information, health and safety legislation and regulations.

What do learners need to demonstrate?	**Skills**
Gather, analyse and interpret technical information, data and evidence to confirm type, scope and requirements for the task, considering performance, quality and compliance. Use information to identify and confirm issues, problems, faults and areas for investigations. Analyse and identify likely causes, agreed processes, methods, expectations and outcomes. Interrogate technical documentation considering the accuracy, relevance, currency and completion to understand issues and appropriate methods for resolution or further investigation. Use and respond effectively to specifications, repair information, observed evidence, recall instructions, maintenance tables and technical bulletins. Interpret and confirm all health and safety requirements of maintenance, installation and repair activities.	EC4, EC5, EC6, MC2, MC3, MC5, MC6, MC7, MC9, MC10, DC1, DC4.

2.2 Evaluate the **condition**, quality and **performance** of **components**, systems, **materials** and **resources**.

Range:

Condition – working condition, serviceability (degradation, deterioration, damage, corrosion, disintegration), safety.

Performance – efficiency, accuracy, effectiveness, tolerance, outputs, reliability, sustainability.

Components – transmitters, displays, gauges, wiring, pipes, circuit boards, cable trays, sensors, switches, breakers, fuses, transistors, rectifiers, transformers.

Materials – non-ferrous, ferrous, thermosetting, thermoplastics, composites, smart materials.

Resources – maintenance instructions, maintenance manuals, data sheets, material safety data sheets (MSDS), recording forms, maintenance logs, test certificates, work permits, health and safety regulations, environmental requirements, organisational procedures.

What do learners need to demonstrate?	Skills
Evaluate condition of components to ensure quality standards and requirements are met. Make effective decisions based on observation and information gathered to proceed with a task. Use diagnostic information and other evidence to determine mechatronic system and component serviceability and feasibility for maintenance and repair activities.	EC4, EC5, MC2, MC5, MC6, MC10, DC4.

2.3 Interpret mechatronic **representations**.

Range:
Representations – manuals, specifications, instructions, diagrams (block, circuit, schematic, wiring), drawings, symbols, annotations, conventions, standards, reports, results, statements, signage, tags, labels.

What do learners need to demonstrate?	Skills
Interpret representations to communicate and confirm details and requirements of the mechatronic systems to support maintenance, installation and repair processes.	EC3, EC4, EC5, MC5, MC6, MC7, MC10, DC1, DC4.

Outcome 3

3. Plan and prepare the maintenance, installation, servicing and repair of mechatronic technology, systems, and equipment, considering the specific requirements and context.

3.1 **Plan** and prepare **processes**, resources, **scope**, **technology, tools and equipment** to complete client expectations.

Range:
Plan – method statements, Standard Operating Procedures (SOPs), risk assessments, preparatory checks.
Processes – organisational, regulatory, maintenance, rectification, reporting, recording.
Resources – maintenance instructions, maintenance manuals, data sheets, MSDS, recording forms, maintenance logs, test certificates, work permits, health and safety regulations, environmental requirements, organisational procedures.
Scope – tasks, features, costing, goals, deliverables, functions, requirements, outcomes, end product, depth, detail, time scales, sensory checks, maintenance records and schedules, agreed processes, evidence and data gathering, specifications, repair information, wiring diagrams, recall instructions.
Technology, tools and equipment – drills, pliers, wire cutters, wire strippers, de-soldering tool, spanners, screwdrivers, files, hammers, torx, Allen keys, crimping tool, test equipment (clamp meters, electronic control unit (ECU), diagnostic testers), measuring tools (micrometers, Vernier callipers), oscilloscopes, signal generators, logic probes, data logger, soldering iron, multimeters.

What do learners need to demonstrate?	Skills
Produce plans using information gathered to meet client requirements, including human resources and service impact, following SOPs. Check technology, tools and equipment availability to complete client requirements with consideration of history. Review, confirm and record stock levels, ordering processes, and lead-in times to complete the required task or activity. Evaluate and plan for wastage, disposal, recyclability and sustainability in maintenance, service and repair tasks and activities.	EC1, EC2, EC3, EC4, EC5, EC6, MC2, MC3, MC4, MC7, MC8, MC9, DC5, DC6.

3.2 **Risk assessment**.

Range:
Risk assessment – assessments of hazards (health and safety considerations, pneumatics, hydraulics, mechanical, electro-mechanical, temperature, abrasive wheels, hazardous substances, pressurised fluids, equipment, moving under suspended loads, risk of slips, trips and falls, working in restricted spaces), evaluation of risk (severity, impact), control measures (permits to work, SOPs, PPE), documentation.

What do learners need to demonstrate?	Skills
Complete risk assessments and implement control measures for maintenance, installation and repair activities, communicating risks according to policies and procedures. Complete risk management for maintenance and repair activities of mechatronic systems. Confirm processes, outcomes and mitigations used to reduce potential risks and issues.	EC1, EC2, EC3, EC4, EC5, DC1, DC2, DC4.

3.3 Quality, accuracy and completeness of **information** and **resources**.

Range:
Information – identification codes and technical data, manufacturers data sheets, manufacturers safety specifications, MSDS, colour codes, component numbering, schematics, material lists, sensory checks, fault data, checklists, reports, measurement, test results, inspection sheets, repair method statements (issue dates, amendments).
Resources – policies, procedures, regulations, guidance, second line verifications, organisational systems and requirements, maintenance logs, defect logs, reports, equipment, data systems, electronic document and management systems.

What do learners need to demonstrate?	Skills
Application of information and resources to ensure components are correct, complete, free of fault, and conform to specifications, grades, and dimensions. Application of calibration dates and requirements of components and equipment prior to commencing, the procedures for out-of-date calibrations and electrical safety checks.	EC4, EC5, MC2, MC3, MC4, MC6, MC7, MC8, MC9, DC1, DC2, DC4, DC5.

3.4 **Preparatory checks** for compliance, quality and functionality.

Range:
Preparatory checks – tools, equipment, calibration, isolation requirements, work area, sensory, specifications, bill of materials (BOM), test dates (PAT test, calibration, electrical safety).

What do learners need to demonstrate?	Skills
Carry out preparatory checks on materials, resources, tools, equipment, and other technologies. The advantages and limitations of preparatory checks for compliance, quality and functionality. Application of safe isolation and calibration checks on tools and equipment.	EC5, MC2, DC1.

3.5 **Plan and prepare** work areas for mechatronic processes and outcomes.

Range:
Plan and prepare – tools, equipment, materials, technical data, specifications, health and safety, workflow process, procedures, requirements, communication methods (verbal, digital), housekeeping, signage, barriers, training.

What do learners need to demonstrate?	Skills
Plan and prepare the work area for mechatronic processes and outcomes. Application of adjustments to tools and equipment according to specifications and parameters in preparation for the task to be completed.	EC5, EC6, MC2, DC1.

Outcome 4

4. Perform relevant maintenance, installation, servicing and repair of mechatronic technology, systems, and equipment, using appropriate techniques and procedures to achieve the required quality outcomes and solutions.

4.1 **Maintain**, install and repair mechatronic systems, equipment, and components.

Range:
Maintain – total preventative, reactive, planned (timed, annual, bi-annual, shutdown), corrective, condition-based monitoring.

What do learners need to demonstrate?	Skills
Complete maintenance installation and repair activities of mechatronic systems, equipment and components within agreed specifications, timeframes and standards of quality. Safely operate equipment, machinery and technology when completing maintenance, installation and repair tasks. Follow relevant guidelines and instructions, and seek advice and guidance, where necessary. Responsibilities of working individually and collaboratively to meet task, client and organisational standards, policies and expectations, in accordance with working practices. Application of electrical and electronic laws and theorems in maintenance, installation and repair activities. Follow and comply with all health and safety requirements of maintenance, installation and repair activities.	EC5, EC6, MC1, MC2, MC3, MC4, MC5, MC7, DC1, DC4, DC6.

4.2 **Diagnostic** and measurement techniques, **tools and equipment**.

Range:
Diagnostic tools and equipment – test equipment (multimeters, diagnostic testers, CMM), measuring tools (micrometers, Vernier callipers, rule), oscilloscopes, signal generators, logic probes, data logger, flow meter, pressure gauges, pressure sources, calibrators.

What do learners need to demonstrate?	Skills
Follow manufacturer's instructions when using diagnostic and measuring equipment. Application of diagnostic and measurement techniques, tools and equipment to obtain accurate diagnostic information and measurements. Use fault detection techniques, tools and equipment to identify and locate faults and their causes in electrical and electronic devices, systems and equipment. Interpret and evaluate built in tests and self-diagnostic results.	EC5, EC6, MC1, MC2, MC3, MC4, MC5, MC6, MC7, DC1, DC4, DC6.

4.3 **Reactive** and **preventative** maintenance procedures.

Range:
Reactive – control monitoring, condition-based monitoring, unplanned, emergency, post-fault.
Preventative – scheduled, planned, timed.

What do learners need to demonstrate?	Skills
Determine schedule of tasks (remove, replace, repair) from diagnostic and measurement findings, according to the life cycle of components and systems. Follow procedures to complete reactive maintenance tasks. Complete preventative maintenance procedures to reduce further failure or downtime, including recommending amendments to the maintenance schedule where appropriate.	EC5, MC1, MC2, MC3, MC4, MC5, MC6, DC4.

4.4 **Disassemble**, **assemble** and **install** mechatronic components, devices and systems.

Range:
Disassemble – powering down, isolation, functional safety (safety instrumented systems (SIS), safety integrity level (SIL)), removal of components, disposal requirements, documentation, de-solder, tools and equipment.
Assemble – structures, removal, powering up, documentation, attachments, fixings, tightening techniques.
Install – client requirements, regulation requirements, 1st fix, 2nd fix of components, commissioning, isolation, manufacturers specifications, replacement parts, pipework, fasteners, functional safety checks.

What do learners need to demonstrate?	Skills
Processes to be followed when assembling and disassembling components, devices and systems. Apply requirements and specifications to ensure correct assembly and disassembly, considering technical data and instructions. Accurately position, install, calibrate and configure devices and equipment to agreed requirements and specifications. Consider and follow regulatory requirements throughout.	EC5, MC1, MC2, MC3, MC4, MC5, MC7, DC1, DC4, DC6.

4.5 **Commissioning** and **return to service** mechatronic devices, systems and technologies.

Range:
Commissioning – design, construct, test, integration, set parameters, check tolerances, offload testing, live testing, test before first use, confirm performance and accuracy, alterations, wiring.
Return to service – power up, confirm functionality, reliability, serviceability, handover.

What do learners need to demonstrate?	Skills
Commission and return to service mechatronic devices, systems, and technology to fully operational condition. Application and purpose of testing the system is operating correctly, adjusting where necessary. Carry out commissioning procedures safely and checking the safety of mechatronic systems.	EC5, EC6, MC1, MC2, MC3, MC5, DC1, DC4, DC6.

4.6 Planned maintenance, **servicing** and repair tasks.

Range:

Servicing – fluid maintenance, component and circuit replacement, calibration, condition checks, functional checks.

Tasks – measuring, cutting, drilling, filing, removing and replacing bolts, screws and clips, replacing seals, extracting and replacing damaged fasteners, soldering and brazing, applying surface treatments.

What do learners need to demonstrate?	Skills
Perform planned essential maintenance, servicing and repair tasks for maintenance of mechatronics according to schedules. Review and analyse outputs, data and readings.	EC5, MC1, MC2, MC3, MC5, MC7, DC3, DC4.

4.7 **Re-instate** work areas.

Range:

Re-instate – equipment is functioning to specification, work area is back to original condition, returning of tools and equipment, correct disposal requirements followed, housekeeping.

What do learners need to demonstrate?	Skills
Reinstate work areas back to original condition upon completion of tasks. Manage the area ensuring the area is left in safe condition. Check and return all tools and equipment back to storage facilities. Follow disposal requirements appropriate to the waste and relevant legislation.	EC5, MC2.

Outcome 5

5. Review and evaluate activities to help improve workplace systems and processes associated with maintenance, installation, servicing and repair of mechatronic technology, systems, and equipment, demonstrating commercial awareness and accountability.

5.1 **Safe systems of work** and legal compliance.

Range:
Safe systems of work – procedures, safe working practices, risk assessment and management, recording and documentation.

What do learners need to demonstrate?	Skills
Anticipate and identify potential risks and actual risks. Apply safe systems of work, following policies and procedures relevant to the task. Complete documentation of activities and reflect on outcomes. Follow and comply with safe working practices and legal compliance.	EC4, EC5, EC6, MC1, MC2, MC4, MC5, MC6, MC10, DC1, DC2, DC4.

5.2 Work area **practices**.

Range:
Practices – safe working, guidance, regulatory requirements, organisational requirements, scope, responsibility, documentation, reporting procedures.

What do learners need to demonstrate?	Skills
Monitor working area practices to prevent, resolve, manage, and mitigate issues arising during tasks. Implement practices to manage stock levels, materials and availability of resources.	EC4, EC5, MC1, MC2, MC5, MC6, MC7, MC10, DC4, DC5.

5.3 Deal promptly and effectively with **issues**.

Range:
Issues – health and safety, age related use/wear, not meeting required standards or regulations, decommissioning, inappropriate use/lack of training, time constraints, cost implications, documentation discrepancies, tool and equipment failure.

What do learners need to demonstrate?	Skills
Deal with issues encountered throughout engineering tasks in a timely manner. Apply problem solving techniques to resolve issues within limits of own authority, seeking guidance where necessary. Follow reporting policies and procedures to ensure issues and problems are communicated. Report and escalate issues and problems where falling outside the limits of own authority.	EC3, EC4, EC5, EC6, MC2, MC6, MC9, MC10, DC1.

5.4 Carry out **quality monitoring** and **assurance checks** to review processes.

Range:

Quality monitoring – inspections, reviewing (self, peer to peer, supervisory), amending, supervisory checks, second line, sampling and checking of quality.

Assurance checks – checking and validating reliability and durability, currency, accuracy, relevance, post-repair performance and functional tests.

What do learners need to demonstrate?	Skills
Conduct quality monitoring and assurance checks as part of a team's maintenance, servicing and repair operations and processes. Review efficiency of processes, practices and outcomes to improve quality. Consistently check validity, accuracy and relevance of documentation. Communicate technical information, advice and suggestions for improvements. Suggest strategies to increase efficiency of quality monitoring processes, with consideration of performance and potential improvements.	EC4, EC5, EC6, MC4, MC5, MC6, MC10, DC1, DC2, DC3, DC4.

5.5 Make positive **contributions** for maintenance and operations whilst working effectively with others.

Range:

Contributions – communicate solutions, improvements, ideas, findings, designs, technical information, recommendations, research, facts, methods, operational changes, maintenance requirements.

What do learners need to demonstrate?	Skills
Recommend improvements, methods and other technical information as part of a team. Contribute effectively to maintenance, operations and team discussions. Working effectively with others and willing to assist where necessary and appropriate.	EC2, EC3, EC4, EC5, EC6, MC2, MC9, MC10.

5.6 Respond constructively to **feedback** and identify opportunities for personal and **organisational** improvement.

Range:

Feedback – reviews (self, peer to peer, supervisory), appraisals, reports, progress reviews, evaluation, client.

Organisational – commercial, productivity, safety, growth, activities, services, quality, technology, continuing professional development (CPD).

What do learners need to demonstrate?	Skills
Reflect and respond constructively to feedback provided throughout tasks and activities. Make suggestions for organisational improvements for commercial, productivity, and safety. Review feedback, identifying and implementing opportunities, personally and professionally within organisation.	EC2, EC6, MC2, MC9, MC10, DC2, DC3.

Outcome 6

6. Communicate mechatronic maintenance, installation, servicing and repair information, proposals, and solutions, producing, recording, and explaining relevant technical information.

6.1 **Record and amend** technical information, data, risks and issues.

Range:
Record and amend – diagrams, drawings, reports, results, maintenance logs, defect logs, statements, checklists.

What do learners need to demonstrate?	Skills
Record findings, data, risks and issues from the task accurately to support mechatronic maintenance, servicing and repair work. Create technical reports to communicate maintenance, installation and repair information. Make amendments and recommendations at relevant stages, within the limits of own authority and expertise. Use records, information, and data to inform improved practices, recommendations, and continuous improvement.	EC3, EC4, MC2, MC5, DC1, DC3, DC4, DC5, DC6.

6.2 Complete **handover procedures**.

Range:
Handover – complete work, incomplete work, modifications, faults, further investigation, suggested updates and improvements to maintenance schedules, demonstration of system functionality, confirmation (completion, responsibility, quality standards, specific requirements and outcomes, agreement), due date of next maintenance activity, technical documentation.
Procedures – communication methods (verbal, written, digital), de-brief, technical documentation (test results and certificates, calibration certificates, appropriate calculations, maintenance schedules, drawings and diagrams, software update information, maintenance records), signatures and date.

What do learners need to demonstrate?	Skills
Accurately communicate handover information following organisational procedures. The functionality of the system following maintenance, installation and repair activities. Communicate the reasons for non or partial functionality following maintenance, installation and repair activities, including any outstanding faults, defects or issues, and suggestions for future improvements. Follow and implement document version control for relevant paperwork and technical documentation where updates are made, including maintenance schedules and representations. Follow organisational handover procedures. Apply organisational policies (brief, meetings, documentation) to the handover procedures.	EC1, EC4, MC2, MC7, MC8, MC10, DC1, DC4.

6.3 Team-working, inter-personal skills and communication with **technical** and **non-technical audiences**.

Range:
Technical audiences – supervisors, engineers, colleagues, skilled technicians, apprentices.
Non-technical audiences – stakeholders, customers, clients, investors, colleagues (sales/service advisers, in house health and safety advisor).

What do learners need to demonstrate?	**Skills**
Communicate technical information as part of a team. Work as part of a team to obtain desired outcomes, maintaining positive and professional working relationships. Interact using inter-personal skills to contribute to team success. Adapt technical language appropriately to communicate with non-technical client/customers and colleagues.	EC1, EC2, EC3, EC4, EC5, EC6, DC3, DC4.

6.4 Communication methods, including **written**, **verbal** and **media**.

Range:
Written – note taking (lists, mind mapping/flow diagrams), writing style (business letter, memo writing, report styles and format, email), proofreading and amending text, use of logbook for planning and prioritising work schedules, graphical presentation techniques (graphs, charts and diagrams).
Verbal – speaking (with peers, supervisors, use of appropriate technical language, tone and manner), listening (use of paraphrasing and note taking to clarify meaning), impact and use of body language in verbal communication.
Media – inter/intranet (manuals, data, analytical software, manufacturers' catalogues), spreadsheets, databases, fault diagnostic software.

What do learners need to demonstrate?	**Skills**
Communicate information, requirements, expectations, plans, performance, and outcomes using different communication methods to convey and confirm maintenance, installation and repair information.	EC1, EC2, EC3, EC4, EC5, EC6, MC7, MC8, MC10, DC1, DC2, DC3, DC4, DC5.

Guidance for delivery

Opportunities for visits/engagement with local industry, employers and manufacturers should be provided throughout the delivery of the content within this specialism – where appropriate local employers could present details of recent projects including a variety of mechatronic maintenance activities, problems faced and how they were overcome. Learners work placement experiences could be presented to peers detailing where knowledge and skills within the content was seen in practice.

Formative assessment for the content may include oral Q&A, presentations to peers, observation of measuring activities etc. Reinforcement of learning can be encouraged through revisiting learning, group discussions, and the establishment of a peer support system within the cohort.

Providers must ensure content is delivered in line with current, up-to-date industry practice which will require;

- Provision of appropriate tools, equipment and test instrumentation for demonstration and practical training purposes
- Teaching coverage representing the type of equipment currently available and accepted for use in the UK industry

Suggested learning resources

Books

- W.Bolton, *Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering,* 7th edition, Pearson Education, 2018, ISBN-13 : 978-1292250977
- **C.W. de Silva,** *Mechatronics: A Foundation Course Hardcover,* 1st edition, CRC Press, 2010, ISBN-13 : 978-1420082111
- **P. Božek, Y. Nikitin, T. Krenicky,** *Diagnostics of Mechatronic Systems (Studies in Systems, Decision and Control),* 1st edition, Springer, 2021, ISBN-13 : 978-3030670542
- **B. Wilamowski, J. D. Irwin,** *Control and Mechatronics (The Electrical Engineering Handbook),* 1st edition, CRC Press, 2017, ISBN-13 : 978-1138073593
- N. J. Smith, *Engineering Project Management,* 3rd edition, Wiley-Blackwell Publishing, 2007, ISBN 9781405168021

Websites

- Science Direct Topics **https://www.sciencedirect.com/topics/engineering/mechatronics**
- Institute for apprenticeships and technical education **https://www.instituteforapprenticeships.org/**
- Institute of Engineering and Technology (IET) **https://electrical.theiet.org/bs-7671/**
- Health and Safety Executive **https://www.hse.gov.uk/electricity/**
- Fire & Security matters - **https://www.fsmatters.com/Home**
- International Society of Mechatronic Engineering **http://ismetek.org/**
- The institution of engineering and technology **https://communities.theiet.org/**

Scheme of Assessment – Maintenance engineering technologies: Mechatronic Occupational Specialism

The Maintenance engineering technologies: Mechatronic Occupational Specialism is assessed by one practical assignment. The duration of the assessment is 22 hours. Learners will be assessed against the following assessment themes:

- Health and safety
- Planning and preparation
- Systems and components
- Working with faults
- Reviewing and reporting

By completing the following tasks:

Task	Typical Knowledge and skills
Task 1 – Plan and prepare	Displays a breadth of knowledge and practical skills that enables them to plan and prepare for carrying out maintenance, installation and repair activities on mechatronic systems. Candidates will need to produce documents and complete risk assessments that clearly details how they plan to complete the maintenance, servicing, installation and repair activities to meet the requirements of the brief.
Task 2 – Perform maintenance	Applies a breadth of knowledge, understanding and practical skills that enables them to carry out maintenance, servicing, installation and repair activities on a variety of mechatronic systems and machines. The task is carried out in a clear and logical sequence. Works in a safe manner, able to carry out fault detection, diagnosis, isolation and resolution methods effectively Tools, materials and equipment are selected and used correctly.
Task 3 – Review and report	Displays a breadth of knowledge and understanding in the evaluation of their maintenance, installation and repair activities, recommending personal and organisational improvements to the process. Justifications for diagnosis, isolation and resolution methods used. Justifications for how peer review feedback was considered and implemented.
Task 4 - Handover	Displays breath of knowledge and skills in communicating technical information to a variety of audience types and how to complete handover procedures effectively. Candidates will need to demonstrate critical thinking skills when responding to peer review feedback.

The information provided in the following tables demonstrates to approved providers the weightings of each performance outcome and how each performance outcome is assessed.

Performance outcome and weighting (%)	***High level tasks*** *Provide specific instructions for candidates to provide evidence for and are the same for every version of the assessment*	**Assessment Theme**	***Typical evidence***
PO2 Analyse requirements, specifications and technical information to enable the delivery of successful maintenance, installation, servicing and repair of mechatronic technology, systems, and equipment. (10%)	T1- Plan and prepare	Planning and preparation	List of requirements and resources, and method statement.

PO3 Plan and prepare the maintenance, installation, servicing and repair of mechatronic technology, systems, and equipment, taking into account the specific requirements and context. (20%)	T1- Plan and prepare T2 – Perform	Health and safety Planning and preparation Systems and components Health and safety Planning and preparation Systems and components	List of requirements and resources, and method statement. Risk assessment. Work area preparation

PO4 Perform relevant maintenance, installation, servicing and repair of mechatronic technology, systems, and equipment, using appropriate techniques and procedures to achieve the required quality outcomes and solutions. (40%)	T1- Plan and prepare T2 – Perform T3 – Review and report T4 - Handover	Health and safety Health and safety Systems and components Working with faults Health and safety Systems and components Reviewing and reporting Health and safety Reviewing and reporting	List of requirements and resources, and method statement. Risk assessment. Completed test records, updated maintenance records and control documents Annotated method statement. Maintenance activities and work area re-instatement Technical report Technical report and maintenance schedule. Handover meeting.
PO5 Review and evaluate activities to help improve workplace systems and processes associated with maintenance, installation, servicing and repair of mechatronic technology, systems, and equipment, demonstrating commercial awareness and accountability. (20%)	T2 – Perform T3 – Review and report T4 - Handover	Systems and components Reviewing and reporting Health and safety Reports and information	Completed test records, updated maintenance records and control documents Annotated method statement. Technical report and maintenance schedule. Handover meeting.

PO6 Communicate mechatronic maintenance, installation, servicing and repair information, proposals and solutions, producing, recording and explaining relevant technical information. (10%)	T3 – Review and report T4 - Handover	Reports and information Reports and information	Technical report and maintenance schedule. Handover meeting

313 Maintenance engineering technologies: Electrical and electronic

Level:	3
GLH:	680
Assessment method:	Practical assignment

What is this specialism about?

The purpose of this specialism is for learners to know and understand electrical and electronic components and systems, and undertake key procedures for maintenance, installation and repair. Learners will have the opportunity to plan, perform and evaluate their work whilst utilising a range of materials, tools and equipment.

Learners will develop their knowledge and understanding of, and skills in:

- Knowledge of the construction and operation of standard power conversion systems
- Knowledge and application of component classification, numbering and referencing systems
- Knowledge of how components are removed, replaced and repaired as part of electrical and electronic systems
- Skills to plan and prepare electrical and electronic maintenance activities using analysis and evaluation
- Skills to select and use tools, equipment, machinery and technology safely and effectively to complete maintenance, installation and repair activities

Learners may be introduced to this specialism by asking themselves questions such as:

- How do electrical and electronic systems operate and function?
- What are the components used in electrical and electronic?
- How is maintenance, installation and repair to electrical and electronic systems carried out?

Underpinning knowledge outcomes

On completion of this specialism, learners will understand:

1. Maintenance engineering technology - electrical and electronic knowledge criteria

Performance outcomes

On completion of this specialism, learners will be able to:

2. Analyse requirements, specifications and technical information to enable the delivery of successful maintenance, installation, servicing and repair of electrical and electronic technology, systems and equipment.

3. Plan and prepare the maintenance, installation, servicing and repair of electrical and electronic technology, systems and equipment, taking into account the specific requirements and context.

4. Perform relevant maintenance, installation, servicing and repair of electrical and electronic technology, systems, and equipment, using appropriate techniques and procedures to achieve the required quality outcomes and solutions.

5. Review and evaluate activities to help improve workplace systems and processes associated with maintenance, installation, servicing and repair of electrical and electronic technology, systems, and equipment, demonstrating commercial awareness and accountability.

6. Communicate electrical and electronic maintenance, installation, servicing and repair information, proposals and solutions, producing, recording and explaining relevant technical information.

Completion of this specialism will give learners the opportunity to develop their Maths, English and Digital Skills. Details are presented at the end of the specification.

Specialism content

Outcome 1

Underpinning knowledge criteria for the performance outcomes

1.1 **Principles and techniques** for maintenance and repair.

Range:
Principles and techniques –

- removal and replacement activities – assembly and disassembly techniques, mechanical fixings/fastening
- conditions that determine repair – age of components, condition, costings, maintenance, replacement, repair, disposal, installation, downtime, productivity, quality, environmental
- maintenance and servicing strategies – reactive (condition-based monitoring, unplanned/emergency/post-fault), preventative (scheduled, planned, timed)
- disposal requirements – appropriate methods, documentation, legislation, sustainability and environmental considerations
- control documentation – schedules, specifications, method statements, authorisation, care and control procedures
- maintenance planning considerations – cost, production output, safety, skills and competency, equipment, job instructions)
- sources of information – data sheets, technical data, engineering drawings, exploded diagrams, planning sheets, workshop manuals, schematics
- types of tools – hand tools, power tools, test equipment, measuring instruments
- decommissioning considerations – down time, repair costs, environmental issues, productivity, quality, planning, lockouts, hazardous waste, risk assessments, permits, legislation.

What do learners need to learn?	**Skills**
Reasons of removal and replacement activities. Factors to be considered when determining either repair or replacement of assemblies or sub-assemblies. Types of documentation that are used to monitor, record and control maintenance activities and their typical contents. How to produce or amend appropriate technical documentation. The reasons for planning maintenance activities. Sources of information used in maintenance activities and how they are used. Types and purpose of tools and equipment used in maintenance activities. Disposal requirements appropriate to the waste and relevant legislation. Factors to be considered when decommissioning and their implications.	EC3, EC5, EC6, MC2, MC6, MC7, MC9, DC1, DC2, DC5.

Analyse requirements, specifications and technical information to enable the delivery of successful maintenance, installation, servicing and repair of electrical and electronic technology, systems and equipment (PO2)

1.2 **Construction** and **operation** of power conversion systems.

Range:
Construction – electrical devices, electro-mechanical devices, inverters, transformers, control panels, regulators, rectifiers, motor-generators, rotary convertors.
Operation – frequency control, diodes convert alternating current (AC) to direct current (DC) and back, DC-DC convertors, efficiencies of systems.

What do learners need to learn?	Skills
Functions and operation of power conversion systems, and the components required to construct them. How power conversion systems work to achieve an output. The working principles behind power conversion systems. Power flow analysis techniques and their applications.	EC5, MC2, MC3, MC4, MC6.

1.3 **Components** of electrical installations, including **failure modes** and **protection methods**.

Components – passive components (resistors, capacitors (polarised, non-polarised, supercapacitor), inductors, transformers), active components (voltage and current sources), generators, transistors (bipolar, field effect), operational amplifiers, diodes (P-N junction, Zener, photodiodes, light emitting diodes (LED)), cables (single core, multicore, armoured, fire resistant, flexible, non-flexible), wiring (single strand, multi strand), residual current device (RCD), photovoltaic cells, electrical power outlets (three pin plug outlets, USB charging points, indoor, outdoor).
Failure modes – equipment failure (human error, environmental conditions), circuit faults (symmetrical and unsymmetrical faults, short circuit and open circuit connections, high resistance connections, connections to earth), supply faults (components out of specification, intermittent, fault and tolerance testing, power supply spikes and drops), digital faults (input, output, logic), interference.
Protection methods – relays, earthing, bonding, fuses, immobilisers, circuit breakers, isolators, ingress protection rating (IP).

What do learners need to learn?	Skills
Function and operational characteristics of electrical components, cabling and wiring. Identify common failure modes and protection methods. The advantages and limitations of protection methods used in electrical and electronic engineering. How to interpret and apply the latest edition IET wiring regulations HSE directive.	MC2, MC3, MC4, MC6, DC1.

1.4 **Properties** and applications of **electrical** and **electronic systems, circuits** and **components**

Range:
Properties – voltage, current, resistance, impedance, power.
Systems – electrical, electronic, electro-mechanical, circuit types, amplifiers, power supplies, DC networks.
Circuits – series, parallel, series-parallel, closed, open circuits, power, timer, latching, auxiliary, pulse generation circuits, integrated circuits (IC).
Electrical components – switches (single pole single throw (SPST), single pole double throw (SPDT), double pole single throw (DPST), double pole double throw (DPDT)), diodes (P-N junction, Zener), rectifiers, capacitors, RCD, resistors, inductors, relays, transformers, potentiometers.
Electronic components – transistors (bipolar (NPN, PNP), field effect (MOSFET, JFET)), thyristors, operational amplifiers, microcontrollers, logic gates (AND, OR, NOT, NAND, NOR, XOR), counter, timer.

What do learners need to learn?	**Skills**
The nature and behaviour of electricity in systems. The properties and characteristics of electrical and electronic systems, and their components. Different types of electrical circuits (series and parallel) and their applications in electrical and electronic engineering. The characteristics of electronic components used in equipment, including basic circuits, using electronic equipment and their uses. The application of different types of systems and their components. Application of electrical and electronic laws and theorems.	MC3, MC4, MC6, DC1, DC6.

1.5 **Drive devices**, their purposes, **parameters** and applications.

Range:
Drive devices – electrical motors, modulators, control units, sensing units, AC and DC units.
Parameters – inputs, process and outputs, hardware specifications, peripherals.

What do learners need to learn?	**Skills**
The purpose and applications of drive devices and motors. The advantages and limitations of drive units. The purpose and outcomes of drive device parameters and how they contribute to the operation of the system.	EC5, MC2, MC3, MC4, MC6, DC1.

1.6 **Sensing** and **measurement techniques** and **technologies.**

Range:
Sensing – temperature, infrared, speed/position, pressure, displacement, proximity, force, light, linear dimensions and clearances, and liquid flow.
Sensing technologies – inductive, capacitive, hall effect, operational amplifiers (seismic sensors), Wheatstone bridge, filtering, transformers, variable resistors, piezoelectric transducers.
Measurement techniques and technologies – multimeters, oscilloscopes, signal and function generators, insulation resistance tester, data logging, logic probes, frequency meter.

What do learners need to learn?	**Skills**
The purposes and applications of electronic systems that measure performance.	MC2, MC3, MC4, MC6,

The relative benefits, functions and limitations of sensing and measurement techniques and technologies. How sensing and measurement technologies are used to measure electrical and electronic parameters and signals.	DC1.

1.7 **Component classification**, **numbering** and **referencing systems**.

Range:
Component classification – passive, active.
Numbering – part numbers, identification numbers, material lists, labelling, specifications.
Referencing systems – wiring identification, identification codes and technical data, standard reference designations for electrical and electronic parts and equipment (IEEE standards), manufacturers data sheets, manufacturers safety specifications, technical manuals, colour codes, tags, component numbering, QR codes, barcodes, CE marking, schematic diagrams, wiring diagrams, IET wiring regulations (British Standard 7671), BS3939, EMC Directive, BS, IEC, EN and ISO Standards.

What do learners need to learn?	**Skills**
The purposes and applications of component classification, numbering and referencing systems. How to interpret current IET, BS, IEC, EN and ISO standards related to electrical and electronic systems including classification, numbering and referencing. Classification, numbering and referencing related to engineering documents.	MC2, MC3, MC4, MC6, DC1, DC5.

1.8 Key principles of **energy storage** and **transfer**.

Range:
Energy storage – current, electricity, static electricity, heat (conduction, convection, radiation), kinetic, batteries, capacitors, compressed air, hydroelectricity, flywheel, pressurised tanks.
Energy transfer – methods of energy transfer (mechanical, electrical, radiation, heating) energy efficiencies, conduction, circuits.

What do learners need to learn?	**Skills**
Characteristics and methods of energy storage and transfer. Application of energy storage and transfer methods. How energy forms are converted to enable storage.	MC4, MC6.

Perform relevant maintenance, installation, servicing and repair of electrical and electronic technology, systems, and equipment, using appropriate techniques and procedures to achieve the required quality outcomes and solutions (PO4)

1.9 Hand and power **tools,** and **equipment.**

Range:
Tools – drills, pliers, wire cutters, wire strippers, de-soldering tool, spanners, screwdrivers, torx, files, hammers, Allen keys, crimping tool, soldering iron, potentiometer trimmer.
Equipment – test equipment (multimeters, clamp meters, electronic control unit (ECU), diagnostic testers), measuring tools (micrometers, Vernier callipers), oscilloscopes, signal generators, logic probes, data logger.

What do learners need to learn?	Skills
How to check the physical condition of tools prior to use. The suitable applications and limitations of the identified equipment. How to maintain tools and equipment and use safely, following all safety regulations relating to use. Risks and consequences of using non-authorised tools and equipment. How to safely operate equipment, machinery and technology. How to follow relevant guidelines and instructions, limits of own authority and expertise, and seek advice and guidance, where necessary.	EC5, MC1, MC2, MC3, MC4, DC1, DC4.

1.10 **Effects** of **environmental conditions** on materials, components, wiring, and equipment.

Range:
Effects – failure modes, working condition, false readings, degradation, corrosion, ingress, egress, leakages, system errors, blockages, electrical faults, mechanical faults, debris, cracking, brittle, disintegration, cleanliness, clarity.
Environmental conditions – humidity, moisture, temperature, pressure, heat, pollution, dirt, debris, radiation, chemicals.

What do learners need to learn?	Skills
How environmental conditions can affect materials components, wiring and equipment, and their potential effects. Characteristics relating to material quality and condition. How materials degrade and fail, including monitoring, maintaining and preventative techniques. Appropriate methods of maintenance, management, storage, preservation and prevention for materials, tools and equipment.	EC5, MC1, MC2, DC1, DC4, DC6.

1.11 Electro-static sensitive devices **(ESDs)** and components, and **measures of protection**.

Range:
ESDs – metal oxide semiconductor field effect transistors (MOSFETs), complementary metal oxide semiconductor (CMOS) integrated circuits, micro-controllers.
Measures of protection – ESD-safe bags and foam, grounding mats, straps and tools, anti-static garments, wrist straps.

What do learners need to learn?	Skills
Static electricity and the effect it has on semi-conductors. The importance of anti-static practices during transport, storage, maintenance, servicing, and repair work, and the implications of not following these practices.	MC2, MC6, DC1, DC6.

1.12 **Installation**, **configuration**, and **integration** of electrical and electronic engineering systems.

Range:
Installation – client requirements, regulation requirements, commissioning, isolation, manufacturers specifications, tools and equipment.
Configuration – setting parameters, calibration, testing, handover, operating systems, specifications, tools and equipment.
Integration – combining of systems, networking, functions, designs, planning, processes, tools and equipment.

What do learners need to learn?	Skills
Application of installation techniques, configuration and integration using the correct tools and following regulations. Requirements and procedures for installation and configuration of electrical and electronic systems. Installation and integration of wireless technologies and systems. How to safely use tools, equipment and technology to complete maintenance, installation and repair requirements. How to follow relevant guidelines and instructions, limits of own authority and expertise, and seek advice and guidance, where necessary.	EC5, MC1, MC2, MC3, MC4, MC5, MC7, DC1, DC4, DC6.

1.13 **Fault detection**, **diagnosis**, **resolution** and **isolation methods.**

Range:
Fault detection – equipment, self-diagnostic, unit substitution, input output, half split technique, end to end, top-down technique, component isolation, tools and equipment.
Fault diagnosis – sensory checks, collection of fault data, self-diagnosis, inspection, material testing, tools and equipment.
Resolution methods – replace, repair, adjust, modification.
Isolation methods – supply, testing for dead, keys, lock out, electrical, temperature, pressure, RCD, tools and equipment.

What do learners need to learn?	Skills
Identifying faults utilising fault detection and diagnosis methods. Material testing methods and techniques. How to safely use tools, equipment and technology to detect and diagnose faults within assemblies and sub-assemblies.	EC5, MC1, MC2, MC3, MC5, DC1, DC2, DC4,

How to use resolution methods based on the fault diagnosis. Identify different isolation methods and carry out safe and effective isolation. The advantages and limitations of detection methods and isolation systems. How to interpret and comply with relevant legislation. How to apply safe isolation methods to complete resolution and rectification methods. How to follow relevant guidelines and instructions, limits of own authority and expertise, and seek advice and guidance, where necessary.	DC6.

1.14 Techniques for **disassembly, modification and re-assembly.**

Range:
Disassembly – powering down, isolation, removal of housing and components, disposal requirements, documentation, tools and equipment.
Modification – changing of parameters, wiring, adjustments, process change, tools and equipment, re-calibration, reporting and recording, housing and components.
Re-assembly – structures, removal, powering up, documentation, QR codes, barcodes, attachments, fixings, tightening techniques, tools and equipment.

What do learners need to learn?	**Skills**
Methods and procedures for the assembly and disassembly according to guidance and regulations. How to safely use tools, equipment and technology to disassembly, modify and re-assemble mechanical assemblies and sub-assemblies. Tightening techniques for different operations. The application and recording of different modification techniques. How to follow relevant guidelines and instructions, limits of own authority and expertise, and seek advice and guidance, where necessary.	EC5, MC1, MC2, MC3, MC4, MC5, MC7, DC1, DC4, DC6.

1.15 **Joining techniques**.

Range:
Joining techniques – permanent, semi-permanent, soldering, crimping, use of block connectors, interference fit.

What do learners need to learn?	**Skills**
The different methods and applications of joining techniques. How joining techniques ensure electrical and electronic systems are effective.	EC5, MC1, MC2, MC3, MC5.

Review and evaluate activities to help improve workplace systems and processes associated with maintenance, installation, servicing and repair of electrical and electronic technology, systems, and equipment, demonstrating commercial awareness and accountability (PO5)

1.16 **Quality inspection**, **testing and recording methods**.

Range:
Quality inspection and testing methods – policies, procedures, guidance, organisational systems and requirements, sensory checks, checklists, maintenance instructions, data, reports, measurement, analysis of systems, communication, prior maintenance history, maintenance requirements, preventative measures.
Recording methods – maintenance logs, defect logs, reports, statements, checklists, equipment, digital technologies, amending documentation.

What do learners need to learn?	Skills
The purpose of quality inspection, testing and recording. Factors that can affect quality in electrical and electronic engineering and quality assurance processes. How variations and defects in engineering products and components are managed. Application of methods and techniques used within quality inspection and testing. The importance of using the correct quality inspection and testing techniques. The impact of inadequate quality inspection and testing. How to complete and record quality processes as part of quality control, assurance and improvement.	EC3, EC4, EC5, EC6, MC2, MC5, MC6, MC10, DC1, DC2, DC4.

Communicate electrical and electronic maintenance, installation, servicing and repair information, proposals and solutions, producing, recording and explaining relevant technical information (PO6)

1.17 **Communicating technical information and data**.

Range:
Communicating – record, manage, store, amend, upload data, collaborative technologies (shared drives, email, conferencing, software and programs, forums).
Technical information and data – test data, test results, maintenance results and findings, fault information, inspection sheets, maintenance logs, repair methods.

What do learners need to learn?	Skills
How to communicate information effectively in written and verbal methods. The importance of technical documentation for communication. How to create technical reports for maintenance, installation and repair activities. How collaborative technology is used to communicate technical information and data. Current legislation including GDPR and organisational procedures that are used to manage data and increase confidentiality of sensitive information.	EC1, EC2, EC3, EC4, EC5, MC5, MC7, MC10, DC1, DC2, DC3, DC4, DC5.

1.18 Digital, information and communication technology (**ICT**).

Range:
ICT – data systems, recording systems, electronic document and management systems.

What do learners need to learn?	**Skills**
How technology and systems are used to manage engineering data and documentation. Application of software and ICT systems and techniques to record, manage, store and amend engineering information. Advantages and limitations of using ICT to record information.	EC4, EC5, MC5, MC10, DC1, DC3, DC4, DC5.

Practical criteria for performance outcomes

Outcome 2

2. Analyse require complaint details; maintenance records and schedules) to develop an understanding of issues and appropriate methods for resolution.

2.1 Confirm the **type**, **scope** and **requirements** of the activity, task or problem.

Range:
Type – installation, re-installation, position, configuration, assembly, disassembly, modification**,** fault finding (electrical, electronic, data, system, operational, temperature), resolution methods, preventative measures, repairs, upgrade, downgrade.
Scope – tasks, features, costing, goals, deliverables, functions, requirements, outcomes, end product, depth, detail, time scales, sensory checks, maintenance records and schedules, agreed processes, evidence and data gathering, specifications, repair information, wiring diagrams, recall instructions.
Requirements – expectations and desired output, performance requirements, client requirements, access, reliability, integration of information, health and safety legislation and regulations.

What do learners need to demonstrate?	**Skills**
Gather, analyse and interpret technical information, data and evidence to confirm type, scope and requirements for the task, considering performance, quality and compliance. Use information to identify and confirm issues, problems, faults and areas for investigations. Analyse and identify likely causes, agreed processes, methods, expectations and outcomes. Interrogate technical documentation considering the accuracy, relevance, currency and completion to understand issues and appropriate methods for resolution or further investigation. Use and respond effectively to specifications, repair information, observed evidence, recall instructions, maintenance tables and technical bulletins. Interpret and confirm all health and safety requirements of maintenance, installation and repair activities.	EC4, EC5, EC6, MC2, MC3, MC5, MC6, MC7, MC9, MC10, DC1, DC4.

2.2 Evaluate the **condition**, quality and **performance** of **components**, systems, **materials** and **resources**.

Range:
Condition – working condition, serviceability (degradation, deterioration, damage, corrosion, disintegration), safety.
Performance – efficiency, accuracy, effectiveness, tolerance, outputs, sustainability.
Components – electrical, electronic, electro-mechanical, mechanical.
Materials – non-ferrous, ferrous, thermosetting, thermoplastics, composites, smart materials.
Resources – maintenance instructions, maintenance manuals, data sheets, material safety data sheets (MSDS), recording forms, maintenance logs, test certificates, work permits, health and safety regulations, environmental requirements, organisational procedures.

What do learners need to demonstrate?	**Skills**
Evaluate condition of components to ensure quality standards and requirements are met.	EC4, EC5,

Make effective decisions based on observation and information gathered to proceed with a task. Use diagnostic information and other evidence to determine electrical and electronic system and component serviceability and feasibility for maintenance and repair activities.	MC2, MC5, MC6, MC10, DC4.

2.3 Interpret electrical and electronic **representations**.

Range:
Representations – manuals, specifications, instructions, diagrams (circuit, schematic, wiring, block), drawings, symbols, annotations, conventions, standards, reports, results, statements.

What do learners need to demonstrate?	**Skills**
Interpret representations to communicate and confirm details and requirements of the electrical and electronic systems to support maintenance, installation and repair activities.	EC3, EC4, EC5, MC5, MC6, MC7, MC10, DC1, DC4.

Outcome 3

3. Plan and prepare the maintenance, installation, servicing and repair of electrical and electronic technology, systems and equipment, taking into account the specific requirements and context.

3.1. **Plan** and prepare **processes**, **resources**, **scope**, **technology, tools and equipment** to complete client expectations.

Range:
Plan – method statements, Standard Operating Procedures (SOPs), risk assessments, preparatory checks.
Processes – organisational, regulatory, maintenance, rectification, reporting, recording.
Resources – maintenance instructions, maintenance manuals, data sheets, MSDS, recording forms, maintenance logs, test certificates, work permits, health and safety regulations, environmental requirements, organisational procedures.
Scope – tasks, features, costing, goals, deliverables, functions, requirements, outcomes, end product, depth, detail, time scales, sensory checks, maintenance records and schedules, agreed processes, evidence and data gathering, specifications, repair information, wiring diagrams, recall instructions.
Technology, tools and equipment – drills, insulated tools (wire cutters, wire strippers, pliers, screwdrivers), torx, soldering iron, de-soldering tool, spanners, files, hammers, Allen keys, crimping tool, test equipment (clamp meters, electronic control unit (ECU), diagnostic testers), oscilloscopes, signal generators, logic probes, data logger, multimeters, wire gauge.

What do learners need to demonstrate?	Skills
Produce plans using information gathered to meet client requirements, including human resources and service impact, following SOPs. Confirm technology, tools and equipment availability to complete client requirements with consideration of prior maintenance history. Identify components and parts that are required. Review, confirm and record stock levels, ordering processes, and lead-in times to complete the required task or activity. Evaluate and plan for wastage, disposal, recyclability and sustainability in maintenance, service and repair tasks and activities.	EC1, EC2, EC3, EC4, EC5, EC6, MC2, MC3, MC4, MC7, MC8, MC9, DC5.

3.2 **Risk assessment.**

Range:
Risk assessment – assessments of hazards (health and safety considerations, pneumatics, hydraulics, mechanical, electro-mechanical, temperature, abrasive wheels, hazardous substances, pressurised fluids, equipment, moving under suspended loads, risk of slips, trips and falls, working in restricted spaces), evaluation of risk (severity, impact), control measures (permits to work, SOPs, PPE), documentation.

What do learners need to demonstrate?	Skills
Complete risk assessments and implement control measures for maintenance, installation and repair activities, communicating risks according to policies and procedures. Complete risk management for maintenance and repair activities of electrical and electronic systems. Confirm processes, outcomes and mitigations used to reduce potential risks and issues.	EC1, EC2, EC3, EC4, EC5, DC1, DC2, DC4.

3.3 Quality, accuracy and completeness of **information** and **resources**.

Range:
Information – identification codes and technical data, manufacturers data sheets, manufacturers safety specifications, MSDS, regulations, colour codes, component numbering, schematics, material lists, sensory checks, fault data, checklists, reports, measurements, test results, inspection sheets, repair method statements (issue dates, amendments).
Resources – policies, procedures, regulations, guidance, second line verifications, organisational systems and requirements, maintenance logs, defect logs, reports, equipment, data systems, electronic document and management systems.

What do learners need to demonstrate?	Skills
Application of information and resources to ensure components are correct, complete, free of fault, and conform to specifications and dimensions. Application of calibration requirements of components and equipment prior to commencing, procedures for out-of-date calibrations and electrical safety checks.	EC4, EC5, MC2, MC3, MC4, MC6, MC7, MC8, MC9, DC1, DC2, DC4, DC5, DC6.

3.4 **Preparatory checks** for compliance, quality and functionality.

Range:
Preparatory checks – tools, equipment, calibration, isolation requirements, work area, sensory.

What do learners need to demonstrate?	Skills
Carry out preparatory checks on materials, resources, tools, equipment, and other technologies. The advantages and limitations of preparatory checks for compliance, quality and functionality. Application of safe isolation and calibration checks on tools and equipment.	EC5, MC2, DC1, DC6.

3.5 **Plan and prepare** work areas for electrical and electronic engineering processes.

Range:
Plan and prepare – tools, equipment, materials, components, technical data, diagrams, schematics, regulations, workflow process, environment.

What do learners need to demonstrate?	Skills
Plan and prepare the work area for electrical and electronic engineering processes. Application of adjustments to tools and equipment according to specifications and parameters in preparation for the task to be completed.	EC5, EC6, MC2, DC1, DC6.

Outcome 4

4. Perform relevant maintenance, installation, servicing and repair of electrical and electronic technology, systems, and equipment, using appropriate techniques and procedures to achieve the required quality outcomes and solutions.

4.1 **Maintain**, install and repair electrical and electronic systems, equipment, and components.

Range:
Maintain – total preventative, reactive, planned (timed, annual, bi-annual), corrective, condition-based monitoring.

What do learners need to demonstrate?	**Skills**
Complete maintenance, installation and repair activities of electrical and electronic systems, equipment and components within agreed specifications, timeframes and standards of quality. Safely operate equipment, machinery and technology when completing maintenance, installation and repair tasks. Follow relevant guidelines and instructions, and seek advice and guidance, where necessary. Responsibilities of working individually and collaboratively to meet task, client and organisational standards, policies and expectations, in accordance with working practices. Application of electrical and electronic laws and theorems in maintenance, installation and repair activities Follow and comply with all health and safety requirements of maintenance, installation and repair activities.	EC5, EC6. MC1, MC2, MC3, MC4, MC5, MC7, DC1, DC4, DC6.

4.2 **Diagnostic** and measurement techniques, **tools and equipment**.

Range:
Diagnostic tools and equipment – test equipment (clamp meters, electronic control unit (ECU), diagnostic testers), measuring tools, oscilloscopes, signal generators, logic probes, data logger, multimeters.

What do learners need to demonstrate?	**Skills**
Follow manufacturer's instructions when using diagnostic and measuring equipment. Application of diagnostic and measurement techniques, tools and equipment to obtain accurate information and results on performance, condition and compliance. Use fault detection techniques, tools and equipment to identify and locate faults and their causes in electrical and electronic devices, systems and equipment. Interpret and evaluate built in tests and self-diagnostic results.	EC5, EC6, MC1, MC2, MC3, MC4, MC5, MC6, MC7, DC1, DC4, DC6.

4.3 **Reactive** and **preventative** maintenance procedures.

Range:
Reactive – control monitoring, condition-based monitoring, unplanned, emergency, post-fault.
Preventative – scheduled, planned, timed.

What do learners need to demonstrate?	**Skills**
Determine schedule of tasks (remove, replace, repair) from diagnostic and measurement findings. Follow procedures to complete reactive maintenance tasks. Complete preventative maintenance procedures to reduce further failure or downtime, including recommending amendments to the maintenance schedule where appropriate.	EC5, MC1, MC2, MC3, MC4, MC5, MC6, DC4.

4.4 **Disassemble**, **assemble** and **install** electrical and electronic components, devices and systems.

Range:
Disassemble – powering down, isolation, removal of components, functional safety (safety instrumented systems (SIS), safety integrity level (SIL)), disposal requirements, tools and equipment, documentation.
Assemble – structures, removal, powering up, documentation, attachments, fixings, tightening techniques, tools and equipment.
Install – client requirements, regulation requirements, commissioning, isolation, manufacturers specifications, replacement parts, 1st fix, 2nd fix of components, functional safety checks.

What do learners need to demonstrate?	**Skills**
Follow all relevant processes when assembling and disassembling components, devices and systems. Application of requirements and specifications to ensure correct assembly and disassembly, considering technical data and instructions. Accurately position, install, calibrate and configure devices and equipment to agreed requirements and specifications. Consider and follow regulatory requirements throughout.	EC5, MC1, MC2, MC3, MC4, MC5, MC7, DC1, DC4, DC6.

4.5 **Commissioning** and **return to service** of electrical and electronic devices, systems and technology.

Range:
Commissioning – design, construct, test, integration, set parameters, check tolerances, offload testing, live testing, test before first use, confirm performance and accuracy, alterations, wiring.
Return to service – power up, confirm functionality, reliability, serviceability, handover.

What do learners need to demonstrate?	**Skills**
Commission and return to service electrical and electronic devices and systems to fully operational condition. Application and purpose of testing the system is operating correctly, adjusting where necessary. Carry out commissioning procedures safely and checking the safety of electrical and electronic devices and systems.	EC5, EC6, MC1, MC2, MC3, MC5, DC1, DC4, DC6.

4.6 Planned maintenance, **servicing** and repair **tasks**.

Range:
Servicing – component and circuit replacement, calibration, condition checks, functional checks.
Tasks – wiring, crimping, measuring, cutting, soldering, stripping, removing and replacing circuits.

What do learners need to demonstrate?	**Skills**
Perform planned maintenance, servicing and repair tasks to electrical and electronic systems according to schedules. Review and analyse outputs, data and readings.	EC5, MC1, MC2, MC3, MC5, MC7, DC3, DC4.

4.7 **Re-instate** work areas.

Range:
Re-instate – equipment is functioning to specification, work area is back to original condition, returning of tools and equipment, correct disposal requirements followed, housekeeping.

What do learners need to demonstrate?	**Skills**
Reinstate work areas back to original condition upon completion of tasks. Manage the area ensuring the area is left in safe condition. Check and return all tools and equipment back to storage facilities. Follow disposal requirements appropriate to the waste and relevant legislation.	EC5, MC2.

Outcome 5

5. Review and evaluate activities to help improve workplace systems and processes associated with maintenance, installation, servicing and repair of electrical and electronic technology, systems, and equipment, demonstrating commercial awareness and accountability.

5.1 **Safe systems of work** and legal compliance.

Range:
Safe systems of work – procedures, safe working practices, risk assessment and management.

What do learners need to demonstrate?	Skills
Anticipate and identify potential risks and actual risks. Apply safe systems of work, following policies and procedures relevant to the task. Complete documentation of activities and reflect on outcomes. Follow and comply with safe working practices and legal compliance.	EC4, EC5, EC6, MC1, MC2, MC4, MC5, MC6, MC10, DC1, DC2, DC4.

5.2 Work area **practices**.

Range:
Practices – safe working, guidance, regulatory requirements, organisational requirements, scope, responsibility, documentation, reporting procedures.

What do learners need to demonstrate?	Skills
Monitor working area practices to prevent, resolve, manage, and mitigate issues arising during tasks. Identify potential issues, following correct procedures to report and record. Implement practices to manage stock levels, materials and availability of resources.	EC4, EC5, MC1, MC2, MC5, MC6, MC7, MC10, DC4, DC5.

5.3 Deal promptly and effectively with **issues**.

Issues – health and safety, age related use/wear, not meeting required standards or regulations, decommissioning, inappropriate use/lack of training, time constraints, cost implications, documentation discrepancies, tool and equipment failure.

What do learners need to demonstrate?	Skills
Deal with issues encountered throughout engineering tasks in a timely manner. Apply problem solving techniques to resolve issues within the limits of own authority and expertise. Follow reporting procedures to ensure issues and problems are communicated. Report and escalate issues and problems where falling outside the limits of own authority.	EC3, EC4, EC5, EC6, MC2, MC6, MC9, MC10, DC1.

5.4 Carry out **quality monitoring** and **assurance checks** to review processes.

Range:
Quality monitoring – inspections, reviewing (self, peer to peer, supervisory), amending, supervisory checks, checking of quality.
Assurance checks – checking and validating reliability and durability, post-repair performance and functional tests.

What do learners need to demonstrate?	**Skills**
Conduct quality monitoring and assurance checks as part of a team's electrical and electronic maintenance, servicing and repair operations and processes. Review efficiency of processes, practices and outcomes to improve quality. Consistently check validity, accuracy and relevance of documentation. Communicate technical information, advice and suggestions for improvements. Suggest strategies to increase efficiency of quality monitoring processes, with consideration of performance and potential improvements.	EC4, EC5, EC6, MC4, MC5, MC6, MC10, DC1, DC2, DC3, DC4.

5.5 Make positive **contributions** for maintenance and operations whilst working effectively with others.

Range:
Contributions – communicate solutions, improvements, ideas, findings, designs, technical information, recommendations, research, facts, methods, operational changes, maintenance requirements.

What do learners need to demonstrate?	**Skills**
Recommend improvements, methods and other technical information as part of a team. Contribute effectively to maintenance, operations and team discussions. Working effectively with others and willing to assist where necessary and appropriate.	EC2, EC3, EC4, EC5, EC6, MC2, MC9, MC10.

5.6 Respond constructively to **feedback** and identify opportunities for personal and **organisational** improvement.

Range:
Feedback- reviews (self, peer to peer, supervisory), appraisals, reports, progress reviews, evaluation, witness statements, observational records.
Organisational – commercial, productivity, safety, growth, activities, services, quality, technology, continuing professional development (CPD).

What do learners need to demonstrate?	**Skills**
Reflect and respond constructively to feedback provided throughout tasks and activities. Make suggestions for organisational improvement. Review feedback, identifying and implementing opportunities, personally and within the organisation.	EC2, EC6, MC2, MC9, MC10, DC2, DC3.

Outcome 6

6. Communicate electrical and electronic maintenance, installation, servicing and repair information, proposals and solutions, producing, recording and explaining relevant technical information.

6.1 **Record and amend** technical information, data, risks and issues.

Range:
Record and amend – diagrams, drawings, reports, results, maintenance logs, defect logs, statements, checklists.

What do learners need to demonstrate?	Skills
Accurately record findings, data, risks and issues from tasks to support electrical and electronic maintenance, servicing and repair work. Create technical reports to communicate maintenance, installation and repair information. Make amendments and recommendations at relevant stages, within the limits of own authority. Use records, information, and data to inform improved practices, recommendations, and continuous improvement.	EC3, EC4, MC2, MC5, DC1, DC3, DC4, DC5, DC6.

6.2 Complete **handover procedures**.

Range:
Handover – complete work, incomplete work, modifications, faults, further investigation, suggested updates and improvements to maintenance schedules, demonstration of system functionality, confirmation (completion, responsibility, quality standards, specific requirements and outcomes, agreement), due date of next maintenance activity, technical documentation.
Procedures – communication methods (verbal, written, digital), de-brief, technical documentation (test results and certificates, calibration certificates, appropriate calculations, maintenance schedules, drawings and diagrams, software update information, maintenance records), signatures and date.

What do learners need to demonstrate?	Skills
Accurately communicate handover information following organisational procedures The functionality of the system following maintenance, installation and repair activities. Communicate the reasons for non or partial functionality following maintenance, installation and repair activities, including any outstanding faults, defects or issues, and suggestions for future improvements. Follow and implement document version control for relevant paperwork and technical documentation where updates are made, including maintenance schedules and representations. Follow organisational handover procedures. Apply organisational policies (brief, meetings, documentation) to the handover procedures.	EC1, EC4, MC2, MC7, MC8, MC10, DC1, DC4.

6.3 Team-working, inter-personal skills and communication with **technical** and **non-technical audiences**.

Range:
Technical audiences – supervisors, engineers, colleagues, skilled technicians, apprentices.
Non-technical audiences – stakeholders, customers, clients, investors, colleagues (sales/service advisers, in house health and safety advisor).

What do learners need to demonstrate?	**Skills**
Communicate technical information as part of a team. Work as part of a team to obtain desired outcomes, maintaining positive and professional working relationships. Interact using inter-personal skills to contribute to team success. Adapt technical language appropriately to communicate with non-technical client/customers and colleagues.	EC1, EC2, EC3, EC4, EC5, EC6, DC3, DC4.

6.4 Communication methods, including **written**, **verbal** and **media**.

Range:
Written – note taking (lists, mind mapping/flow diagrams), writing style (business letter, memo writing, report styles and format, email), proofreading and amending text, use of logbook for planning and prioritising work schedules, graphical presentation techniques (graphs, charts and diagrams).
Verbal – speaking (with peers, supervisors, use of appropriate technical language, tone and manner), listening (use of paraphrasing and note taking to clarify meaning), impact and use of body language in verbal communication.
Media – inter/intranet (manuals, data, analytical software, manufacturers' catalogues), spreadsheets, databases, fault diagnostic software.

What do learners need to demonstrate?	**Skills**
Communicate information, requirements, expectations, plans, performance, and outcomes using different communication methods to convey and confirm maintenance, installation and repair information.	EC1, EC2, EC3, EC4, EC5, EC6, MC7, MC8, MC10, DC1, DC2, DC3, DC4, DC5.

Guidance for delivery

Opportunities for visits/engagement with local industry, employers and manufacturers should be provided throughout the delivery of the content within this specialism – where appropriate local employers could present details of recent projects including a variety of electrical and electronic engineering maintenance activities, problems faced and how they were overcome. Learners work placement experiences could be presented to peers detailing where knowledge and skills within the content was seen in practice.

Formative assessment for the content may include oral Q&A, presentations to peers, observation of measuring activities etc. Reinforcement of learning can be encouraged through revisiting learning, group discussions, and the establishment of a peer support system within the cohort.

Providers must ensure content is delivered in line with current, up-to-date industry practice which will require;

- Provision of appropriate tools, equipment and test instrumentation for demonstration and practical training purposes
- Teaching coverage representing the type of equipment currently available and accepted for use in the UK industry

Suggested learning resources

Books

- L.S. Bobrow, *Fundamentals of Electrical Engineering*. 2nd edition, Oxford University Press, 1996, ISBN 978-0195105094
- WK Chen, *The Electrical Engineering Handbook*. 1st edition, Academic Press. 2004, ISBN 978-0080477480.
- N. J. Smith, *Engineering Project Management,* 3rd edition, Wiley-Blackwell Publishing, 2007, ISBN 9781405168021

Websites

- Institution of Engineering and Technology www.theiet.org
- Health and Safety Executive www.hse.gov.uk

Scheme of Assessment – Maintenance engineering technologies: Electrical and Electronic

The Maintenance engineering technologies: Electrical and Electronic is assessed by one practical assignment. The duration of the assessment is 22 hours. Learners will be assessed against the following assessment themes:

- Health and safety
- Planning and preparation
- Systems and components
- Working with faults
- Reviewing and reporting

By completing the following tasks:

Task	Typical Knowledge and skills
Task 1 – Plan and prepare	Displays a breadth of knowledge and practical skills that enables them to plan and prepare for carrying out maintenance, installation and repair activities on electrical and electronic systems. Candidates will need to produce documents and complete risk assessments that clearly details how they plan to complete the maintenance, servicing, installation and repair activities to meet the requirements of the with the brief.
Task 2 – Perform maintenance	Applies a breadth of knowledge, understanding and practical skills that enables them to carry out maintenance, servicing, installation and repair activities on a variety of electrical and electronic systems. The task is carried out in a clear and logical sequence. Works in a safe manner, able to carry out fault detection, diagnosis, isolation and resolution methods effectively Tools, materials and equipment are selected and used correctly.
Task 3 – Review and report	Displays a breadth of knowledge and understanding in the evaluation of their maintenance, installation and repair activities, recommending personal and organisational improvements to the process. Justifications for diagnosis, isolation and resolution methods used. Justifications for how peer review feedback was considered and implemented.
Task 4 - Handover	Displays breath of knowledge and skills in communicating technical information to a variety of audience types and how to complete handover procedures effectively. Candidates will need to demonstrate critical thinking skills when responding to peer review feedback.

The information provided in the following tables demonstrates to approved providers the weightings of each performance outcome and how each performance outcome is assessed.

Performance outcome and weighting (%)	***High level tasks*** *Provide specific instructions for candidates to provide evidence for and are the same for every version of the assessment*	**Assessment Theme**	***Typical evidence***
PO2 Analyse requirements, specifications and technical information to enable the delivery of successful maintenance, installation, servicing and repair of electrical and electronic technology, systems and equipment. (10%)	T1- Plan and prepare	Planning and preparation	List of requirements and resources, and method statement.

PO3 Plan and prepare the maintenance, installation, servicing and repair of electrical and electronic technology, systems and equipment, taking into account the specific requirements and context. (20%)	T1- Plan and prepare T2 – Perform	Health and safety Planning and preparation Systems and components Health and safety Planning and preparation Systems and components	List of requirements and resources, and method statement. Risk assessment. Work area preparation

PO4 Perform relevant maintenance, installation, servicing and repair of electrical and electronic technology, systems, and equipment, using appropriate techniques and procedures to achieve the required quality outcomes and solutions. (40%)	T1- Plan and prepare T2 – Perform T3 – Review and report T4 - Handover	Health and safety Health and safety Systems and components Working with faults Health and safety Systems and components Reviewing and reporting Health and safety Reviewing and reporting	List of requirements and resources, and method statement. Risk assessment. Completed test records, updated maintenance records and control documents Annotated method statement. Maintenance activities and work area re-instatement Technical report Technical report and maintenance schedule. Handover meeting.

PO5 Review and evaluate activities to help improve workplace systems and processes associated with maintenance, installation, servicing and repair of electrical and electronic technology, systems, and equipment, demonstrating commercial awareness and accountability. (20%)	T2 – Perform T3 – Review and report T4 - Handover	Systems and components Reviewing and reporting Health and safety Reports and information	Completed test records, updated maintenance records and control documents Annotated method statement. Technical report and maintenance schedule. Handover meeting.
PO6 Communicate electrical and electronic maintenance, installation, servicing and repair information, proposals and solutions, producing, recording and explaining relevant technical information. (10%)	T3 – Review and report T4 - Handover	Reports and information Reports and information	Technical report and maintenance schedule. Handover meeting

314 Maintenance engineering technologies: Control and instrumentation

Level:	3
GLH:	680
Assessment method:	Practical assignment

What is this specialism about?

The purpose of this specialism is for learners to know and understand control and instrumentation systems commonly used in industry. Learners will have the opportunity to plan and undertake maintenance, fault finding, commissioning, testing and repair activities on control and instrumentation systems and devices, and complete associated documentation.

Learners will develop their knowledge and understanding of, and skills in:

- Knowledge of electronic sensing and measurement techniques and technologies used in control and instrumentation systems
- Knowledge and application of component classification, numbering and referencing systems
- Knowledge of how components are removed, replaced and repaired as part of control and instrumentation systems
- Skills to plan and prepare control and instrumentation maintenance activities using analysis and evaluation
- Skills to select and use tools, equipment, machinery and technology safely and effectively to complete control and instrumentation maintenance, installation and repair activities

Learners may be introduced to this specialism by asking themselves questions such as:

- How do control and instrumentation systems operate and function?
- Why is control required as part of an engineering system?
- What is the importance of accurate calibration and maintenance of control and instrumentation components and equipment?

Underpinning knowledge outcomes

On completion of this specialism, learners will understand:

1. Control and instrumentation knowledge criteria

Performance outcomes

On completion of this specialism, learners will be able to:

2. Analyse requirements, specifications and technical information to enable the delivery of successful maintenance, installation, servicing and repair of control and instrumentation technology, systems, and equipment.

3. Plan and prepare the maintenance, installation, servicing and repair of control and instrumentation technology, systems and equipment, taking into account the specific requirements and context.

4. Perform relevant maintenance, installation, servicing and repair of control and instrumentation technology, systems, and equipment, using appropriate techniques and procedures to achieve the required quality outcomes and solutions.

5. Review and evaluate activities to help improve workplace systems and processes associated with maintenance, installation, servicing and repair of control and instrumentation technology, systems, and equipment, demonstrating commercial awareness and accountability.

6. Communicate control and instrumentation maintenance, installation, servicing and repair information, proposals and solutions, producing, recording and explaining relevant technical information.

Completion of this specialism will give learners the opportunity to develop their Maths, English and Digital Skills. Details are presented at the end of the specification.

Specialism content

Outcome 1

Underpinning knowledge criteria for the performance outcomes

1.1 **Principles and techniques** for maintenance and repair.

Range:
Principles and techniques –

- removal and replacement activities – assembly and disassembly techniques, mechanical fixings/fastening
- conditions that determine repair – age of components, condition, costings, maintenance, replacement, repair, disposal, installation, downtime, productivity, quality, environmental
- maintenance and servicing strategies – reactive (condition-based monitoring, unplanned/emergency/post-fault), preventative (scheduled, planned, timed)
- disposal requirements – appropriate methods, documentation, legislation, sustainability and environmental considerations
- control documentation – schedules, specifications, method statements, authorisation, care and control procedures
- maintenance planning considerations – cost, production output, safety, skills and competency, equipment, job instructions)
- sources of information – data sheets, technical data, engineering drawings, exploded diagrams, planning sheets, workshop manuals, schematics
- types of tools – hand tools, power tools, test equipment, measuring instruments
- decommissioning considerations – down time, repair costs, environmental issues, productivity, quality, planning, lockouts, hazardous waste, risk assessments, permits, legislation.

What do learners need to learn?	**Skills**
Reasons of removal and replacement activities. Factors to be considered when determining either repair or replacement of assemblies or sub-assemblies. Types of documentation that are used to monitor, record and control maintenance activities and their typical contents. How to produce or amend appropriate technical documentation. The reasons for planning maintenance activities. Sources of information used in maintenance activities and how they are used. Types and purpose of tools and equipment used in maintenance activities. Disposal requirements appropriate to the waste and relevant legislation. Factors to be considered when decommissioning and their implications.	EC3, EC5, EC6, MC2, MC6, MC7, MC9, DC1, DC2, DC5.

Analyse requirements, specifications and technical information to enable the delivery of successful maintenance, installation, servicing and repair of control and instrumentation technology, systems, and equipment (PO2)

1.2 **Construction** and **operation** of power conversion systems.

Range:
Construction – electrical devices, electro-mechanical devices, inverters, transformers, control panels, regulators, rectifiers, motor-generators, rotary convertors.
Operation – frequency control, diodes convert alternating current (AC) to direct current (DC) and back, DC-DC convertors, efficiencies of systems.

What do learners need to learn?	Skills
Functions and operation of power conversion systems, and the components required to construct them. How power conversion systems work to achieve an output from an input. The working principles behind power conversion systems. Power flow analysis techniques and their applications.	EC5, MC2, MC3, MC4, MC6.

1.3 **Components** of electrical installations, including **failure modes** and **protection methods.**

Range:
Components – passive components (resistors, capacitors, inductors, transformers), active components (voltage and current sources), generators, transistors, operational amplifiers, diodes (Zener, photodiodes, light emitting diodes (LED)), residual current device (RCD).
Failure modes – equipment failure (human error, environmental conditions), circuit faults (symmetrical and unsymmetrical faults, short circuit and open circuit connections, high resistance connections, connections to earth), power supply faults (components out of specification, calibration of components, intermittent faults, tolerance testing), digital faults (input side, output side), program errors and codes, interference.
Protection methods – relays, earthing, bonding, fuse lock-off, immobilisers, circuit breakers, fail-safe mode.

What do learners need to learn?	Skills
Function and operational characteristics of electrical components. Identify common failure modes and protection methods. The advantages and limitations of different protection methods used in control and instrumentation. How to interpret and apply the latest edition IET wiring regulations HSE directive.	MC2, MC3, MC4, MC6, DC1.

1.4 **Properties** and **applications** of electrical and electronic **systems, circuits and components.**

Range:
Properties – voltage, current, resistance, impedance, power.
Systems – power electronics, microelectronics, digital electronics, integrated circuits, Wheatstone bridge, amplifiers, power supplies, sequential, asynchronous/synchronous logic, programmable systems, data logging and measurement systems, DC networks.
Circuits – series, parallel, series-parallel, open and closed circuits, control, latching, power, timer, auxiliary, printed circuit board (PCB), surface mount technology (SMT).
Components – switches, sensors (temperature, flow, level, pressure, light, proximity, position), diodes, transistors, rectifiers, capacitors, RCDs, resistors, inductors, relays, actuators, motors (electric, stepper, invertor, servo, induction, brushed, brushless, AC, DC, three phase, single phase), visual display units (VDU), human machine interface (HMI), transformers, operational amplifiers, potentiometers, power supply units.

What do learners need to learn?	Skills
The nature and behaviour of electricity in systems. The properties and operating principles of electrical and electronic circuits within control and instrumentation. The application of electrical and electronic circuits in instrumentation systems to control, measure and monitor processes. How components of electrical and electronic systems are used in control and instrumentation. Application of electrical and electronic laws and theorems.	MC3, MC4, MC6, DC1.

1.5 **Drive devices,** their purposes, **parameters** and applications.

Range:
Drive devices – basic input/output system (BIOS), hardware, adjustable drive devices, motors, pumps, belts, rams, gear trains, gearboxes, clutches, modulators, control units, sensing units, AC and DC units, microprocessors, microcontrollers, output devices, robotics, AI.
Parameters – inputs, process and outputs, memory, peripherals, hardware specifications, software and programming languages, logic operators (AND, OR, NOT).

What do learners need to learn?	Skills
Application and purpose of drive devices within control and instrumentation systems. The advantages and limitations of drive units. The purpose and outcomes of drive device parameters and how they contribute to the operation of the system. How programmable logic controllers (PLC's) operate and their applications in control and instrumentation. Purpose and outcomes of system testing.	EC5, MC2, MC3, MC4, MC6, DC1.

1.6 **Sensing** and **measurement techniques and technologies**.

Range:
Sensing – temperature, acceleration, position, pressure, displacement, vibration, proximity, force, flow (gas, liquid), viscosity, velocity, clarity, level, photo electric, switches, linear dimensions, clearances.
Sensing technologies – inductive, capacitive, hall effect, operational amplifiers, Wheatstone bridge, filtering, transformers, piezoelectric transducers, automatic, proximity.
Measurements – hysteresis, measuring of accuracy, reliability, static error, lag, responsiveness, reproductivity, dynamic error, fidelity.
Measurement techniques and technologies – multimeters, oscilloscopes, signal generators, thermocouples, thermal cameras, residual temperature devices (RTDs), turbidity, data logging, analysers (logic, dewpoint, hygrometers, hydrometers, thermometer), automatic, proximity.

What do learners need to learn?	Skills
The purposes and applications of electronic systems that measure and monitor performance. The relative benefits and limitations of sensing and measurement techniques and technologies. How sensing and measurement technologies are used to measure parameters and signals.	MC2, MC3, MC4, MC6, DC1.

1.7 **Component classification**, **numbering** and **referencing systems**.

Range:
Component classification – passive, active, electromechanical, manufacturers specifications.
Numbering – part numbers, identification numbers, manufacturers specifications, bill of materials (BOM), labelling, specifications, QR codes, barcodes.
Referencing systems – wiring identification, identification codes and technical data, data tables, colour codes, manufacturers data sheets, technical manuals, serial numbers, tags, component numbering, QR codes, barcodes, CE marking, standard reference designations for electrical and electronic parts and equipment (IEEE standards) colour codes, component numbering, IET wiring regulations (British Standard 7671), BS3939, EMC Directive, BS, IEC, EN and ISO Standards.

What do learners need to learn?	Skills
Component classifications including working principles. Standardised component numbering and referencing systems. How to interpret current IET, BS, IEC, EN and ISO standards related to control and instrumentation systems, including classification, numbering and referencing. Classification, numbering and referencing systems related to engineering documents.	MC2, MC3, MC4, MC6, DC1, DC5.

1.8 Key principles of **energy storage and transfer**.

Range:
Energy storage – current, electricity, static electricity, heat, kinetic, batteries, capacitors, compressed air, hydroelectricity, flywheel, pressurised tanks.
Energy transfer – methods of energy transfer (conduction, convection, radiation, kinetic, heat, electrical, circuits), energy efficiencies/inefficiencies, conversion systems (transmitters, transducers, 4-20ma loops).

What do learners need to learn?	Skills
Characteristics and methods of energy storage and transfer. The applications of energy storage and transfer methods. How energy forms are converted to enable storage.	MC4, MC6.

Plan and prepare the maintenance, installation, servicing and repair of control and instrumentation technology, systems and equipment, taking into account the specific requirements and context (PO3)

1.9 **Requirements** for **networked systems** in industry.

Range:
Requirements – communication, control modules, devices, network, bridges, bus interface, control loop, internet connection, cables (RS485, RS422, RS232, ribbon, USB), adaptors, electrical interface.
Networked systems – supervisory control and data acquisition (SCADA), distributed control system (DCS), process control system (PCS), electronic software distribution (ESD), safety instrumented systems (SIS), fibre glass systems (FGS), proportional integral derivative controller (PID), programmable logic controller (PLC), controller area network (CAN) bus, process field bus (Profibus), process field net (Profinet), foundation fieldbus (FF), Modbus (485, remote terminal unit (RTU)), device net, fibre optic networks, wireless systems, network LAN, ethernet, Bluetooth connectivity.

What do learners need to learn?	Skills
The principles and functions of networked systems. Requirements and applications for networked systems.	EC5, MC2, MC6, MC10, DC1, DC4, DC6.

Perform relevant maintenance, installation, servicing and repair of control and instrumentation technology, systems, and equipment, using appropriate techniques and procedures to achieve the required quality outcomes and solutions. (PO4)

1.10 **Hand tools**, **power tools** and **equipment.**

Range:
Hand tools – screwdrivers, torx, spanners, Allen keys, wrenches, micrometers, Vernier callipers, pliers, files, mole grips, side cutters, wire strippers, crimping tool, potentiometer trimmer.
Power tools – drills, pillar drills, air compressors.
Equipment – soldering and de-soldering equipment, multi-function calibrators, highway addressable remote transducer (HART), pressure sources, temperature baths, multimeters, oscilloscopes, clamp meters, loop calibrator, digital technologies (laptops, tablets, mobile applications, handheld PC (H/PC), personal digital assistant (PDA)).

What do learners need to learn?	Skills
How to check the physical condition and calibration dates of tools and equipment prior to use. The application of computerised monitoring systems using digital technologies. The suitable applications and limitations of the identified equipment. How to maintain tools and equipment and use safely, following all safety regulations relating to use. Risks and consequences of using non-authorised tools and equipment. How to safely operate equipment, machinery and technology. How to follow relevant guidelines and instructions, limits of own authority and expertise, and seek advice and guidance, where necessary.	EC5, MC1, MC2, MC3, MC4, DC1, DC4.

1.11 **Effects** of **environmental conditions** on materials, components, wiring, and equipment.

Range:
Effects – failure modes, working condition, drifting, false readings, degradation, corrosion, ingress, egress, leakages, system errors, blockages, electrical faults, mechanical faults, debris, cracking, brittle, disintegration, cleanliness, clarity.
Environmental conditions – humidity, moisture, temperature, pressure, heat, pollution, dirt, debris, radiation, chemicals.

What do learners need to learn?	Skills
How environmental conditions can affect materials components, wiring and equipment, and their potential effects. Characteristics relating to material quality and condition. How materials degrade and fail, including monitoring, maintaining and preventative techniques. Appropriate methods of maintenance, management, storage, preservation and prevention for materials, tools and equipment.	EC5, MC1, MC2, DC1, DC4, DC6.

1.12 **Network topologies** and **data transmission**.

Range:
Network topologies – elements as part of communication networks (star, bus, ring, mesh, tree, data transmission), equipment, communication devices.
Data transmission – digital data, analogue data, signals, multiplexing, communication devices (hub, switch, router, bridge, gateway), methods (serial data transmission, parallel data transmission).

What do learners need to learn?	Skills
Common arrangements and applications of network topologies. Different types of data used in network topologies. Computer software and platforms used to measure data transmission speeds. Data transmission methods and devices.	EC5, MC2, MC3, MC4, MC5, MC6, DC1, DC4, DC6.

1.13 **Parts** and **system elements**.

Range:
Parts – transducers, transmitters, displays, gauges, wiring, pipes, circuit boards, cable trays, sensors, switches, breakers, fuses, transistors, rectifiers, transformers, solenoids, thermocouples, RCDs, relays, output devices, luminaires, push buttons, measurement devices, (venturi tubes, orifice plates, resistance temperature devices (RTDs), thermocouples, ultrasonic sensors), circuit boards, isolators, guards, panels, interfaces, pipework, valves, manifolds, fastenings, supplies (power supplies, air supplies, fluid supplies)**,** communication equipment, HMI, PLC.
System elements – alarms, trips, temperature, flow, pressure, level, emergency, shutdown, control, feedback.

What do learners need to learn?	Skills
Identify control and instrumentation parts and system elements. The characteristics and functions of parts and system elements as part of an integrated system. Recognition of manufacturers service manuals in their use and application. How to safely operate machinery and technology. How to follow relevant guidelines and instructions, limits of own authority and expertise, and seek advice and guidance, where necessary.	EC5, MC1, MC2, MC3, MC5, DC1, DC4, DC6.

1.14 **Installation**, **configuration**, and **integration** of control and instrumentation systems.

Range:
Installation – client requirements, regulatory requirements, requirements for service, commissioning, isolation, manufacturers specifications, tools and equipment.
Configuration – setting parameters, calibration, testing, first use, operating systems, specifications, tools and equipment.
Integration – combining of system, functions, designs, planning, processes, tools and equipment.

What do learners need to learn?	Skills
Application of installation techniques, configuration and integration using the correct tools and following regulations.	EC5, MC1, MC2, MC3, MC4, MC5,

Requirements and procedures for installation and configuration of control and instrumentation systems. Installation and integration of wireless technologies and systems. How to safely operate machinery and technology for installation, configuration and integration of control and instrumentation systems. How to follow relevant guidelines and instructions, limits of own authority and expertise, and seek advice and guidance, where necessary.	MC6, DC1, DC4, DC6.

1.15 **Fault detection**, **diagnosis, isolation** and **resolution methods**.

Range:
Fault detection – self-diagnostic, unit substitution, input output, half split technique, 6 point technique, component isolation, operational experience, device diagnostics (HART, FF, Profibus, Profinet, HMI), sensory checks, reported faults, fault history, tools and equipment.
Fault diagnosis – sensory checks, collection of fault data (mean time between failures (MTBF), mean time to repair (MTTR)), self-diagnosis, inspection, digital systems, material testing, tools and equipment.
Isolation methods –lock out tag out (LOTO), release of stored energy, testing for dead (prove-test-prove), communication.
Resolution methods – replace, repair, adjust, modify, preventative measures, reporting, recording, informing, amendments.

What do learners need to learn?	**Skills**
Identifying faults utilising fault detection and diagnosis methods. Material testing methods and techniques. How to safely use tools, equipment and technology to detect and diagnose faults within assemblies and sub-assemblies. How to use resolution methods based on the fault diagnosis. Identify different isolation methods. The advantages and limitations of detection and diagnostic methods. How to interpret and comply with relevant legislation. How to apply safe isolation methods to complete resolution and rectification methods. How to follow relevant guidelines and instructions, limits of own authority and expertise, and seek advice and guidance, where necessary.	EC5, MC1, MC2, MC3, MC5, DC1, DC4, DC6.

1.16 Techniques for **disassembly, modification and re-assembly**.

Range:
Disassembly – safe release of stored energy, isolation, removal of housing and components, proof marking, disposal requirements, documentation, tools and equipment.
Modification – changing of parameters, wiring, adjustments, process change, removing and replacing components, housing and equipment, re-calibration, reporting and recording, tools and equipment.
Re-assembly – sub-assemblies, replacement of lifed items, attachments, fixings, tightening techniques, adjustments, powering up, documentation, QR codes, barcodes, tools and equipment.

What do learners need to learn?	Skills
Methods and procedures for the disassembly and re-assembly according to guidance and regulations. How to safely use tools, equipment and technology to disassembly, modify and re-assemble mechanical assemblies and sub-assemblies. Tightening techniques for different operations. The application and recording of different modification techniques. Types of lifed items. How to follow relevant guidelines and instructions, limits of own authority and expertise, and seek advice and guidance, where necessary.	EC5, MC1, MC2, MC3, MC4, MC5, MC7, DC1, DC4, DC6.

1.17 **Joining techniques**.

Range:
Joining techniques – permanent (soldering, adhesive bonding, heat shrink, crimping, conduit), semi-permanent (compression fittings, use of block connectors).

What do learners need to learn?	Skills
The characteristics of the different joining techniques and their applications.	EC5, MC1, MC2, MC3, MC5.

1.18 Control and **control loops**, positive, integral and derivative tuning **(P&ID tuning**) and feedback.

Range:
Control loops – 4-20 mA current loops, process variables, physical components, automation, adjustments, values, control functions.
P&ID tuning – positive, integral and derivative, current output, set gain, errors, summing, drifting, reliability, accuracy.

What do learners need to learn?	Skills
Principles and applications of control loops, P&ID tuning and feedback loops. The use of summing points in block diagrams. How adjustments can be applied for required system outputs.	EC5, MC1, MC2, MC3, MC4, MC5, MC7, DC1, DC4, DC6.

Review and evaluate activities to help improve workplace systems and processes associated with maintenance, installation, servicing and repair of control and instrumentation technology, systems, and equipment, demonstrating commercial awareness and accountability (PO5)

1.19 **Quality inspection, testing and recording methods.**

Range:
Quality inspection and testing methods – policies, procedures, guidance, organisational systems and requirements, sensory checks, checklists, maintenance instructions, data, reports, measurement, analysis of systems, communication, prior maintenance history, maintenance requirements, preventative measures.
Recording methods – maintenance logs, defect logs, reports, statements, checklists, equipment, digital technologies, amending documentation.

What do learners need to learn?	Skills
The purpose of quality inspection, testing and recording. Factors that can affect quality in control and instrumentation engineering and quality assurance processes. How variations and defects in engineering products and components are managed. Application of methods and techniques used within quality inspection and testing. The importance of using the correct quality inspection and testing techniques. The impact of inadequate quality inspection and testing. How to complete and record quality processes as part of quality control, assurance and improvement.	EC3, EC4, EC5, EC6, MC2, MC5, MC6, MC10, DC1, DC2, DC4.

Communicate control and instrumentation maintenance, installation, servicing and repair information, proposals and solutions, producing, recording and explaining relevant technical information (PO6)

1.20 **Communicating technical information and data**.

Range:
Communicating – record, manage, store, amend, upload data, collaborative technologies (shared drives, email, conferencing, software and programs, forums).
Technical information and data – test data, test results, maintenance results and findings, fault information, inspection sheets, maintenance logs, repair methods, instructions.

What do learners need to learn?	Skills
How to communicate information effectively in written and verbal methods. The importance of technical documentation for communication. How to create technical reports for maintenance, installation and repair activities. How collaborative technology is used to communicate technical information and data. Current legislation including GDPR and organisational procedures that are used to manage data and increase confidentiality of sensitive information.	EC1, EC2, EC3, EC4, EC5, MC5, MC7, MC10, DC1, DC2, DC3, DC4, DC5.

1.21 Digital, information and communication technology (**ICT**).

Range:
ICT – data systems, recording systems, electronic document and management systems.

What do learners need to learn?	**Skills**
How technology and systems are used to manage engineering data and documentation. Application of software and ICT techniques to record, manage, store and amend engineering information. Advantages and limitations of using ICT to record information.	EC4, EC5, MC5, MC10, DC1, DC3, DC4, DC5.

Practical criteria for performance outcomes

Outcome 2

2. Analyse requirements, specifications and technical information to enable the delivery of successful maintenance, installation, servicing and repair of control and instrumentation technology, systems, and equipment.

2.1 Confirm the **type**, **scope** and **requirements** of the activity, task or problem.

Range:
Type – installation, re-installation, position, configuration, assembly, disassembly, modification**,** fault finding (mechanical, electrical, data, system, pressure, operational, temperature), resolution methods, preventative measures, repairs, upgrade, downgrade.
Scope – tasks, features, costing, goals, deliverables, functions, requirements, outcomes, end product, depth, detail, time scales, sensory checks, maintenance records and schedules, agreed processes, evidence and data gathering, specifications, repair information, wiring diagrams, recall instructions.
Requirements – expectations and desired output, performance requirements, client requirements, reliability, integrate information, health and safety legislation and regulations.

What do learners need to demonstrate?	**Skills**
Gather, analyse and interpret technical information, data and evidence to confirm type, scope and requirements for the task, considering performance, quality and compliance. Use information to identify and confirm issues, problems, faults and areas for investigations. Analyse and identify likely causes, agreed processes, methods, expectations and outcomes. Interrogate technical documentation considering the accuracy, relevance, currency and completion to understand issues and appropriate methods for resolution or further investigation. Use and respond effectively to specifications, repair information, observed evidence, recall instructions, maintenance tables and technical bulletins. Interpret and confirm all health and safety requirements of maintenance, installation and repair activities.	EC4, EC5, EC6, MC2, MC3, MC5, MC6, MC7, MC9, MC10, DC1, DC4.

2.2 Evaluate the **condition**, quality and **performance** of **components**, systems, **materials** and resources.

Range:
Condition – working condition, serviceability (degradation, deterioration, damage, corrosion, disintegration), safety.
Performance – efficiency, accuracy, effectiveness, tolerance, outputs, reliability, sustainability.
Components – transducers, transmitters, displays, gauges, wiring, pipes, circuit boards, cable trays, sensors, switches, breakers, fuses, transistors, rectifiers, transformers, solenoids, push buttons, isolators, safety devices.
Materials – non-ferrous, ferrous, thermosetting, thermoplastics, composites, smart materials.
Resources – maintenance instructions, maintenance manuals, data sheets, material safety data sheets (MSDS), recording forms, maintenance logs, test certificates, work permits, health and safety regulations, environmental requirements, organisational procedures.

What do learners need to demonstrate?	Skills
Evaluate condition of components to ensure quality standards and requirements are met. Make effective decisions based on observation and information gathered to proceed with a task. Use diagnostic information and other evidence to determine control and instrumentation system and component serviceability and feasibility for maintenance and repair activities.	EC4, EC5, MC2, MC5, MC6, MC10, DC4.

2.3 Interpret control and instrumentation **representations**.

Range:
Representations – manuals, specifications, instructions, diagrams (block, circuit, schematic, wiring), drawings, symbols, annotations, conventions, standards, reports, results, statements, signage, tags, labels, data plates.

What do learners need to demonstrate?	Skills
Interpret representations to communicate and confirm details, processes and requirements of the control and instrumentation systems to support maintenance, installation and repair activities.	EC3, EC4, EC5, MC5, MC6, MC7, MC10, DC1, DC4, DC5.

Outcome 3

3. Plan and prepare the maintenance, installation, servicing and repair of control and instrumentation technology, systems and equipment, taking into account the specific requirements and context.

3.1 **Plan** and prepare **processes**, **resources**, **scope**, **technology, tools and equipment** to complete client expectations.

Range:
Plan – method statements, Standard Operating Procedures (SOPs), risk assessments, preparatory checks.
Processes – organisational, regulatory, maintenance, rectification, reporting, recording.
Resources – maintenance instructions, maintenance manuals, data sheets, MSDS, recording forms, maintenance logs, test certificates, work permits, health and safety regulations, environmental requirements, organisational procedures.
Scope – tasks, features, costing, time constraints, goals, deliverables, functions, requirements, outcomes, end product, depth, detail, time scales, sensory checks, maintenance records and schedules, agreed processes, evidence and data gathering, specifications, repair information, wiring diagrams, recall instructions.
Technology, tools and equipment – drills, pliers, wire cutters, wire strippers, de-soldering tool, spanners, screwdrivers, torx, files, hammers, Allen keys, crimping tool, test equipment (clamp meters, electronic control unit (ECU), diagnostic testers), measuring tools, oscilloscopes, signal generators, logic probes, data logger, soldering iron, multimeters, pressure source, flow meter, calibrators.

What do learners need to demonstrate?	Skills
Produce plans using information gathered to meet client requirements, including human resources and service impact, following SOPs. Confirm technology, tools and equipment availability to complete client requirements with consideration of history. Review, confirm and record stock levels, ordering processes, and lead-in times to complete the required task or activity. Evaluate and plan for wastage, disposal, recyclability and sustainability in maintenance, service and repair tasks and activities.	EC1, EC2, EC3, EC4, EC5, EC6, MC2, MC3, MC4, MC7, MC8, MC9, DC5.

3.2 **Risk assessment**.

Range:
Risk assessment – assessments of hazards (health and safety considerations, pneumatics, hydraulics, mechanical, electro-mechanical, temperature, abrasive wheels, hazardous substances, pressurised fluids, equipment, moving under suspended loads, risk of slips, trips and falls, working in restricted spaces), evaluation of risk (severity, impact), control measures (permits to work, SOPs, PPE), documentation.

What do learners need to demonstrate?	Skills
Complete risk assessments and implement control measures for maintenance, installation and repair activities, communicating risks according to policies and procedures. Complete risk management for maintenance and repair activities of control and instrumentation systems. Confirm processes, outcomes and mitigations used to reduce potential risks and issues.	EC1, EC2, EC3, EC4, EC5, DC1, DC2, DC4.

3.3 Quality, accuracy and completeness of **information** and **resources**.

Range:
Information – identification codes and technical data, manufacturers data sheets, manufacturers safety specifications, MSDS, colour codes, component numbering, schematics, material lists, sensory checks, fault data, checklists, reports, measurement, test results, inspection sheets, repair method statements (issue dates, amendments).
Resources – policies, procedures, guidance, second line verifications, organisational systems and requirements, maintenance logs, defect logs, reports, equipment, computer systems, data systems, recording systems, electronic document and management systems.

What do learners need to demonstrate?	**Skills**
Application of information and resources to ensure components are correct, complete, free of fault, and conform to specifications. Apply calibration requirements of components and equipment prior to commencing, the procedures for out-of-date calibrations and electrical safety checks.	EC4, EC5, MC2, MC3, MC4, MC6, MC7, MC8, MC9, DC1, DC2, DC4, DC5.

3.4 **Preparatory checks** for compliance, quality and functionality.

Range:
Preparatory checks – tools, equipment, calibration, isolation requirements, work area, sensory, specifications, bill of materials (BOM), test dates (PAT test, calibration, electrical safety).

What do learners need to demonstrate?	**Skills**
Carry out preparatory checks on materials, resources, tools, equipment, and other technologies. The advantages and limitations of preparatory checks for compliance, quality and functionality. Application of safe isolation and calibration checks on tools and equipment.	EC5, MC2, DC1.

3.5 **Plan and prepare** work areas for control and instrumentation processes and outcomes.

Range:
Plan and prepare – tools, equipment, materials, technical data, specifications, health and safety, workflow process, procedures, requirements, communication methods (verbal, digital), housekeeping, signage, barriers, training.

What do learners need to demonstrate?	**Skills**
Plan and prepare the work area for control and instrumentation processes and outcomes. Application of adjustments according to specifications and parameters in preparation for the task to be completed.	EC5, EC6, MC2, DC1.

Outcome 4

4. Perform relevant maintenance, installation, servicing and repair of control and instrumentation technology, systems, and equipment, using appropriate techniques and procedures to achieve the required quality outcomes and solutions.

4.1 **Maintain**, install and repair control and instrumentation systems, equipment, and components.

Range:
Maintain – total preventative, reactive, planned (timed, annual, bi-annual), corrective, condition-based monitoring.

What do learners need to demonstrate?	Skills
Complete maintenance installation and repair activities of control and instrumentation systems within agreed specifications, timeframes and standards of quality. Safely operate equipment, machinery and technology when completing maintenance, installation and repair tasks. Follow relevant guidelines and instructions, and seek advice and guidance, where necessary. Responsibilities of working individually and collaboratively to meet task, client and organisational standards, policies and expectations, in accordance with working practices. Application of electrical and electronic laws and theorems in maintenance, installation and repair activities. Follow and comply with all health and safety requirements of maintenance, installation and repair activities.	EC5, EC6, MC1, MC2, MC3, MC4, MC5, MC7, DC1, DC2, DC4, DC6.

4.2 **Diagnostic** and measurement techniques, **tools and equipment**.

Range:
Diagnostic tools and equipment – test equipment (multimeters, clamp meters, electronic control unit (ECU), diagnostic testers), measuring tools (micrometers, Vernier callipers, rule), oscilloscopes, signal generators, logic probes, data logger, flow meter, pressure gauges, pressure sources, calibrators.

What do learners need to demonstrate?	Skills
Follow manufacturer's instructions when using diagnostic and measuring equipment. Application of diagnostic and measurement techniques, tools and equipment to obtain accurate diagnostic information and measurements. Use fault detection techniques, tools and equipment to identify and locate faults and their causes in control and instrumentation devices, systems and equipment. Interpret and evaluate built in tests and self-diagnostic results.	EC5, EC6, MC1, MC2, MC3, MC4, MC5, MC6, MC7, DC1, DC4, DC6.

4.3 Operation and application of human interface technologies **(HMI)** and expert systems.

Range:
HMI – networks and drivers (SCADA, PID, PLC, CAN, Profibus, device net, microcontrollers), control, data acquisition.

What do learners need to demonstrate?	Skills
Use HMI technologies and expert systems to control and adjust system outputs. Obtain and analyse information from HMI technologies and expert systems to check for abnormal conditions.	EC5, MC1, MC2, MC3, MC4, MC5, MC6, DC1, DC4, DC5, DC6.

4.4 **Reactive** and **preventative** maintenance procedures.

Range:
Reactive – control monitoring, condition-based monitoring, unplanned, emergency, post-fault.
Preventative – scheduled, planned, timed.

What do learners need to demonstrate?	Skills
Determine schedule of tasks (remove, replace, repair) from diagnostic and measurement findings. Follow procedures to complete reactive maintenance tasks. Complete preventative maintenance procedures to reduce further failure or downtime, including recommending amendments to the maintenance schedule where appropriate.	EC5, MC1, MC2, MC3, MC4, MC5, MC6, DC4.

4.5 **Disassemble**, **assemble** and **install** control and instrumentation components, devices and systems.

Range:
Disassemble – powering down, isolation, functional safety (safety instrumented systems (SIS), safety integrity level (SIL)), removal of components, disposal requirements, documentation, de-solder, tools and equipment.
Assemble – structures, removal, powering up, documentation, attachments, fixings, tightening techniques, tools and equipment.
Install – client requirements, regulation requirements, 1st fix, 2nd fix of components, commissioning, isolation, manufacturers specifications, replacement parts, pipework, fasteners, functional safety checks.

What do learners need to demonstrate?	Skills
Follow all relevant processes when assembling and disassembling components, devices and systems. Application of requirements and specifications to ensure correct assembly and disassembly, considering technical data and instructions. Accurately position, install, calibrate and configure devices and equipment to agreed requirements and specifications. Consider and follow regulatory requirements throughout.	EC5, MC1, MC2, MC3, MC4, MC5, MC7, DC1, DC4, DC6.

4.6 **Commissioning** and **return to service** of control and instrumentation devices, systems and technology.

Range:
Commissioning – design, construct, test, integration, set parameters, check tolerances, live testing, test before first use, confirm performance and accuracy, alterations, wiring.
Return to service – power up, confirm functionality, reliability, serviceability, handover.

What do learners need to demonstrate?	**Skills**
Commission and return to service control and instrumentation devices, systems, and technology to fully operational condition. Application and purpose of testing the system is operating correctly, adjusting where necessary. Carry out commissioning procedures safely and checking the safety of control and instrumentation systems.	EC5, EC6, MC1, MC2, MC3, MC5, DC1, DC4, DC6.

4.7 Planned maintenance, **servicing** and repair **tasks**.

Range:
Servicing – fluid maintenance, component change, calibration, condition checks, functional checks, fitting replacement.
Tasks – wiring, crimping, measuring, cutting, soldering, stripping, removing and replacing circuits.

What do learners need to demonstrate?	**Skills**
Perform planned maintenance, servicing and repair tasks to control and instrumentation systems according to schedules. Review and analyse outputs, data and readings.	EC5, MC1, MC2, MC3, MC5, MC7, DC3, DC4.

4.8 **Re-instate** work areas.

Range:
Re-instate – equipment is functioning to specification, work area is back to original condition, returning of tools and equipment, correct disposal requirements followed, housekeeping.

What do learners need to demonstrate?	**Skills**
Reinstate work areas back to original condition upon completion of tasks. Manage the work area ensuring the area is left in safe condition. Check and return all tools and equipment back to storage facilities. Follow disposal requirements appropriate to the waste and relevant legislation.	EC5, MC2.

Outcome 5

5. Review and evaluate activities to help improve workplace systems and processes associated with maintenance, installation, servicing and repair of control and instrumentation technology, systems, and equipment, demonstrating commercial awareness and accountability.

5.1 **Safe systems of work** and legal compliance.

Range:
Safe systems of work – procedures, safe working practices, hazard identification, risk assessment and management, recording and documentation.

What do learners need to demonstrate?	Skills
Anticipate and identify potential risks and actual risks. Apply safe systems of work, following policies and procedures relevant to the task. Complete documentation of activities and reflect on outcomes. Follow and comply with safe working practices and legal compliance.	EC4, EC5, EC6, MC1, MC2, MC4, MC5, MC6, MC10, DC1, DC2, DC4.

5.2 Work area **practices**.

Range:
Practices – safe working, guidance, regulatory requirements, organisational requirements, scope, responsibility, documentation, reporting procedures.

What do learners need to demonstrate?	Skills
Monitor working area practices to prevent, resolve, manage, and mitigate issues arising during tasks. Identify potential issues, following correct procedures to report and record. Implement practices to manage stock levels, materials and availability of resources.	EC4, EC5, MC1, MC2, MC5, MC6, MC7, MC10, DC4, DC5.

5.3 Deal promptly and effectively with **issues**.

Range:
Issues – health and safety, age related use/wear, not meeting required standards or regulations, decommissioning, inappropriate use/lack of training, time constraints, cost implications, documentation discrepancies, tool and equipment failure.

What do learners need to demonstrate?	Skills
Deal with issues encountered throughout engineering tasks in a timely manner. Apply problem solving techniques to resolve issues within the limits of own authority and expertise. Follow reporting procedures to ensure issues and problems are communicated. Report and escalate issues and problems where falling outside the limits of own authority.	EC3, EC4, EC5, EC6, MC2, MC6, MC9, MC10, DC1, DC6.

5.4 Carry out **quality monitoring** and **assurance checks** to review processes.

Range:
Quality monitoring – inspections, reviewing (self, peer to peer, supervisory), amending, supervisory checks, second line, sampling and assessing quality.
Assurance checks – checking and validating reliability and durability, currency, accuracy, relevance, post-repair performance and functional tests.

What do learners need to demonstrate?	Skills
Conduct quality monitoring and assurance checks as part of a team's control and instrumentation maintenance, servicing and repair operations and processes. Review efficiency of processes, practices and outcomes to improve quality. Consistently check validity, accuracy and relevance of documentation. Communicate technical information, advice and suggestions for improvements. Suggest strategies to increase efficiency of quality monitoring processes, with consideration of performance and potential improvements.	EC4, EC5, EC6, MC4, MC5, MC6, MC10, DC1, DC2, DC3, DC4.

5.5 Make positive **contributions** for maintenance and operations whilst working effectively with others.

Range:
Contributions – communicate solutions, improvements, ideas, findings, designs, technical information, recommendations, research, facts, methods, operational changes, maintenance requirements.

What do learners need to demonstrate?	Skills
Recommend improvements, methods and other technical information as part of a team. Contribute effectively to maintenance, operations and team discussions. Working effectively with others and willing to assist where necessary and appropriate.	EC2, EC3, EC4, EC5, EC6, MC2, MC9, MC10.

5.6 Respond constructively to **feedback** and identify opportunities for personal and **organisational** improvement.

Range:
Feedback – reviews (self, peer to peer, supervisory), appraisals, reports, progress reviews, evaluation, statements, comments.
Organisational – commercial, productivity, safety, growth, activities, services, quality, technology, continuing professional development (CPD).

What do learners need to demonstrate?	Skills
Reflect and respond constructively to feedback provided throughout tasks and activities. Make suggestions for organisational improvement for commercial, productivity, and safety related. Review feedback, identifying and implementing opportunities, personally and within organisation.	EC2, EC6, MC2, MC9, MC10, DC2, DC3.

Outcome 6

6. Communicate control and instrumentation maintenance, installation, servicing and repair information, proposals and solutions, producing, recording and explaining relevant technical information.

6.1 **Record and amend** technical information, data, risks and issues.

Range:
Record and amend – diagrams, drawings, reports, results, maintenance logs, defect logs, reports, statements, checklists.

What do learners need to demonstrate?	**Skills**
Record findings, data, risks and issues from the task accurately to support control and instrumentation maintenance, servicing and repair work. Create technical reports to communicate maintenance, installation and repair information. Make amendments and recommendations at relevant stages, within the limits of own authority. Use records, information, and data to inform improved practices, recommendations, and continuous improvement.	EC3, EC4, MC2, MC5, DC1, DC3, DC4, DC5, DC6.

6.2 Complete **handover procedures**.

Range:
Handover – complete work, incomplete work, modifications, faults, further investigation, suggested updates and improvements to maintenance schedules, demonstration of system functionality, confirmation (completion, responsibility, quality standards, specific requirements and outcomes, agreement), due date of next maintenance activity, technical documentation.
Procedures – communication methods (verbal, written, digital), de-brief, technical documentation (test results and certificates, calibration certificates, appropriate calculations, maintenance schedules, drawings and diagrams, software update information, maintenance records), signatures and date.

What do learners need to demonstrate?	**Skills**
Accurately communicate handover information following organisational procedures The functionality of the system following maintenance, installation and repair activities. Communicate the reasons for non or partial functionality following maintenance, installation and repair activities, including any outstanding faults, defects or issues, and suggestions for future improvements. Follow and implement document version control for relevant paperwork and technical documentation where updates are made, including maintenance schedules and representations. Follow organisational handover procedures. Apply organisational policies (brief, meetings, documentation) to the handover procedures.	EC1, EC4, MC2, MC7, MC8, MC10, DC1, DC4.

6.3 Team-working, inter-personal skills and communication with **technical** and **non-technical audiences.**

Range:
Technical audiences – supervisors, engineers, colleagues, skilled technicians, apprentices.
Non-technical audiences – stakeholders, customers, clients, investors, colleagues (sales/service advisers, in house health and safety advisor).

What do learners need to demonstrate?	**Skills**
Communicate technical information as part of a team. Work as part of a team to obtain desired outcomes, maintaining positive and professional working relationships. Interact using inter-personal skills to contribute to team success. Adapt technical language appropriately to communicate with non-technical client/customers and colleagues.	EC1, EC2, EC3, EC4, EC5, EC6, DC3, DC4.

6.4 Communication methods, including **written**, **verbal** and **media**.

Range:
Written – note taking (lists, mind mapping/flow diagrams), writing style (business letter, memo writing, report styles and format, email), proofreading and amending text, use of logbook for planning and prioritising work schedules, graphical presentation techniques (graphs, charts and diagrams).
Verbal – speaking (with peers, supervisors, use of appropriate technical language, tone and manner), listening (use of paraphrasing and note taking to clarify meaning), impact and use of body language in verbal communication.
Media – inter/intranet (manuals, data, analytical software, manufacturers' catalogues), spreadsheets, databases, fault diagnostic software.

What do learners need to demonstrate?	**Skills**
Communicate information, requirements, expectations, plans, performance, and outcomes using different communication methods to convey and confirm maintenance, installation and repair information.	EC1, EC2, EC3, EC4, EC5, EC6, MC7, MC8, MC10, DC1, DC2, DC3, DC4, DC5.

Guidance for delivery

Opportunities for visits/engagement with local industry, employers and manufacturers should be provided throughout the delivery of the content within this specialism – where appropriate local employers could present details of recent projects including a variety of control and instrumentation maintenance activities, problems faced and how they were overcome. Learners work placement experiences could be presented to peers detailing where knowledge and skills within the content was seen in practice.

Formative assessment for the content may include oral Q&A, presentations to peers, observation of measuring activities etc. Reinforcement of learning can be encouraged through revisiting learning, group discussions, and the establishment of a peer support system within the cohort.

Providers must ensure content is delivered in line with current, up-to-date industry practice which will require;

- Provision of appropriate tools, equipment and test instrumentation for demonstration and practical training purposes
- Teaching coverage representing the type of equipment currently available and accepted for use in the UK industry

Suggested learning resources

Books

- B.E. Noltingk*. Instrument Systems: Jones' Instrumentation Technology,* 4th revised edition, Newnes-Butterworths, 1987, ISBN-13 978-0408012348
- N. J. Smith, *Engineering Project Management,* 3rd edition, Wiley-Blackwell Publishing, 2007, ISBN 9781405168021

Websites

- M. Hantel, G. Steindl, J. Woods, *Industrial Networking Requirements,* 2018, **https://grouper.ieee.org/groups///802/3/ad_hoc/ngrates/public/18_03/woods_nea_01_0318.pdf**
- Cisco, *What Is Network Topology?,* (n.d.), **https://www.cisco.com/c/en/us/solutions/automation/network-topology.html**
- HSE, *About Electrical, Control and Instrumentation*, (n.d.), **https://www.hse.gov.uk/eci/about.htm**.
- Gadallah, A., *Instrumentation & Control Process Control Fundamentals,* (n.d.) **https://www.academia.edu/36548458/Instrumentation_and_Control_Process_Control_Fundamentals**

Scheme of Assessment – Maintenance engineering technologies: Control and Instrumentation

The Maintenance engineering technologies: Control and Instrumentation is assessed by one practical assignment. The duration of the assessment is 22 hours. Learners will be assessed against the following assessment themes:

- Health and safety
- Planning and preparation
- Systems and components
- Working with faults
- Reviewing and reporting

By completing the following tasks:

Task	Typical Knowledge and skills
Task 1 – Plan and prepare	Displays a breadth of knowledge and practical skills that enables them to plan and prepare for carrying out maintenance, installation and repair activities on control and instrumentation systems. Candidates will need to produce documents and complete risk assessments that clearly details how they plan to complete the maintenance, servicing, installation and repair activities to meet the requirements of the with the brief.
Task 2 – Perform maintenance	Applies a breadth of knowledge, understanding and practical skills that enables them to carry out maintenance, servicing, installation and repair activities on a variety of control and instrumentation systems and machines. The task is carried out in a clear and logical sequence. Works in a safe manner, able to carry out fault detection, diagnosis, isolation and resolution methods effectively Tools, materials and equipment are selected and used correctly.
Task 3 – Review and report	Displays a breadth of knowledge and understanding in the evaluation of their maintenance, installation and repair activities, recommending personal and organisational improvements to the process. Justifications for diagnosis, isolation and resolution methods used. Justifications for how peer review feedback was considered and implemented.
Task 4 - Handover	Displays breath of knowledge and skills in communicating technical information to a variety of audience types and how to complete handover procedures effectively. Candidates will need to demonstrate critical thinking skills when responding to peer review feedback.

The information provided in the following tables demonstrates to approved providers the weightings of each performance outcome and how each performance outcome is assessed.

Performance outcome and weighting (%)	***High level tasks*** *Provide specific instructions for candidates to provide evidence for and are the same for every version of the assessment*	**Assessment Theme**	***Typical evidence***
PO2 Analyse requirements, specifications and technical information to enable the delivery of successful maintenance, installation, servicing and repair of control and instrumentation technology, systems, and equipment. (10%)	T1- Plan and prepare	Planning and preparation	List of requirements and resources, and method statement.

PO3 Plan and prepare the maintenance, installation, servicing and repair of control and instrumentation technology, systems and equipment, taking into account the specific requirements and context. (20%)	T1- Plan and prepare T2 – Perform	Health and safety Planning and preparation Systems and components Health and safety Planning and preparation Systems and components	List of requirements and resources, and method statement. Risk assessment. Work area preparation

PO4 Perform relevant maintenance, installation, servicing and repair of control and instrumentation technology, systems, and equipment, using appropriate techniques and procedures to achieve the required quality outcomes and solutions. (40%)	T1- Plan and prepare T2 – Perform T3 – Review and report T4 - Handover	Health and safety Health and safety Systems and components Working with faults Health and safety Systems and components Reviewing and reporting Health and safety Reviewing and reporting	List of requirements and resources, and method statement. Risk assessment. Completed test records, updated maintenance records and control documents Annotated method statement. Maintenance activities and work area re-instatement Technical report Technical report and maintenance schedule. Handover meeting.

PO5 Review and evaluate activities to help improve workplace systems and processes associated with maintenance, installation, servicing and repair of control and instrumentation technology, systems, and equipment, demonstrating commercial awareness and accountability. (20%)	T2 – Perform T3 – Review and report T4 - Handover	Systems and components Reviewing and reporting Health and safety Reports and information	Completed test records, updated maintenance records and control documents Annotated method statement. Technical report and maintenance schedule. Handover meeting.
PO6 Communicate control and instrumentation maintenance, installation, servicing and repair information, proposals and solutions, producing, recording and explaining relevant technical information. (10%)	T3 – Review and report T4 - Handover	Reports and information Reports and information	Technical report and maintenance schedule. Handover meeting

315 Light and electric vehicles

Level:	3
GLH:	680
Assessment method:	Practical assignment

What is this specialism about?

The purpose of this specialism is for learners to know fundamental light and electric vehicle systems and undertake key procedures for maintenance and repair. Learners will have the opportunity to plan, perform and evaluate their work whilst utilising a range of materials, tools and equipment.

Learners will develop their knowledge and understanding of, and skills in:

- Knowledge of electrical systems and components, power sources, power units, and engine types
- Knowledge and application of component classification, numbering and referencing systems
- Knowledge of how components are removed, replaced, and repaired as part of vehicle maintenance activities
- Skills to plan and prepare vehicle maintenance activities using evaluation
- Skills to select and use tools, equipment, and technology safely and effectively to complete vehicle maintenance, servicing, and repair activities

Learners may be introduced to this specialism by asking themselves questions such as:

- How do light and electric vehicle systems operate and function?
- What components are used in light and electric vehicle systems?
- How are maintenance and repair activities to light and electric vehicles planned and carried out?

Underpinning knowledge outcomes

On completion of this specialism, learners will understand:

1. Light and electric vehicles knowledge criteria

Performance outcomes

On completion of this specialism, learners will be able to:

2. Analyse requirements, specifications and technical information to enable the delivery of successful maintenance, installation, servicing and repair of vehicles.

3. Plan and prepare the maintenance, installation, servicing and repair of vehicles, taking into account the specific requirements and context.

4. Perform relevant maintenance, installation, servicing and repair of vehicles, using appropriate techniques and procedures to achieve the required quality outcomes and solutions.

5. Review and evaluate activities to help improve workplace systems and processes associated with vehicle maintenance, installation, servicing and repair, demonstrating commercial awareness and accountability.

6. Communicate vehicle maintenance, installation, servicing and repair information, proposals and solutions, producing, recording and explaining relevant technical information.

Completion of this specialism will give learners the opportunity to develop their Maths, English and Digital Skills. Details are presented at the end of the specification.

Specialism content

Outcome 1

Underpinning knowledge criteria for the performance outcomes

1.1 **Principles and techniques** for maintenance and repair.

Range:
Principles and techniques –

- removal and replacement activities – assembly and disassembly techniques, mechanical fixings/fastening
- conditions that determine repair – age of components, condition, costings, maintenance, replacement, repair, disposal, installation, downtime, productivity, quality, environmental
- maintenance and servicing strategies – reactive (condition-based monitoring, unplanned/emergency/post-fault), preventative (scheduled, planned, timed)
- disposal requirements – appropriate methods, documentation, legislation, sustainability and environmental considerations
- control documentation – schedules, specifications, method statements, authorisation, care and control procedures
- maintenance planning considerations – cost, production output, safety, skills and competency, equipment, job instructions)
- sources of information – data sheets, technical data, engineering drawings, exploded diagrams, planning sheets, workshop manuals, schematics
- types of tools – hand tools, power tools, test equipment, measuring instruments
- decommissioning considerations – down time, repair costs, environmental issues, productivity, quality, planning, lockouts, hazardous waste, risk assessments, permits, legislation.

What do learners need to learn?	**Skills**
Reasons of removal and replacement activities. Factors to be considered when determining either repair or replacement of assemblies or sub-assemblies. Types of documentation that are used to monitor, record and control maintenance activities and their typical contents. How to produce or amend appropriate technical documentation. The reasons for planning maintenance activities. Sources of information used in maintenance activities and how they are used. Types and purpose of tools and equipment used in maintenance activities. Disposal requirements appropriate to the waste and relevant legislation. Factors to be considered when decommissioning and their implications.	EC3, EC5, EC6, MC2, MC6, MC7, MC9, DC1, DC2, DC5.

Analyse requirements, specifications and technical information to enable the delivery of successful maintenance, installation, servicing and repair of vehicles (PO2)

1.2 Operation of **mechanical principles** and **systems.**

Range:
Mechanical principles – moment of a force (static and dynamic loading, stress, strain, tensile shear, compressive shear), thermal effects, friction, torque, types of levers, principle of moments, system principles (input, process and output), centre of gravity, simple gear ratios (gear train, pinion to starter ring gear), hydraulic, pneumatic, work done and efficiency, mechanical advantage.
Mechanical systems – engine (pistons, belts, chains, bearings, shafts), ancillary systems (fuel, lubrication, cooling), transmission (clutch, torque converter, drivetrain, gearboxes (manual and automatic)), axles, differential, gear reduction units, continuously variable transmission (CVT), chassis (steering, suspension, braking, wheels, tyres).

What do learners need to learn?	**Skills**
How the systems manage forces, power, and motion. The relationship between forces, power and motion found in vehicle systems. The principles and applications of vehicle mechanical systems. Calculations of the specified values.	EC5, MC3, MC4.

1.3 **Energy**, **force**, **power**, **motion,** and **mechanics**.

Range:
Energy – kinetic, potential, chemical, electrical, heat.
Force – types of forces, force and pressure, laws of friction, friction in a clutch, stress and strain (Young's modulus), forces in tension/compression.
Power – input and output speeds, input and output torque, generation.
Motion – linear, rotary, reciprocating, oscillating, acceleration/deacceleration (inertia, friction, regeneration and power).
Mechanics – calculation of gear ratios, compression ratios, brake efficiencies.

What do learners need to learn?	**Skills**
The fundamentals relating to friction in a clutch. Energy conversion that occurs in a motor vehicle. Vehicle related problems involving force, moments, gear ratios, stress and strain. Principles of motion relating to vehicles.	EC5, MC2, MC4, MC6.

1.4 Fundamentals of **common mechanisms** and **lifting equipment.**

Range:
Common mechanisms – governors, brakes, levers, gears, gear boxes, gear trains, torque converters, friction devices/clutches (mechanical, electronic, hydraulic), structural components (frames, bearings, springs, bushes).
Lifting equipment – jacks (pneumatic, hydraulic, mechanical, scissor, trolley, bottle, ramps, transmission), cranes, hoists.

What do learners need to learn?	**Skills**
The functions of common mechanisms used in vehicles. Characteristics of gears, including teeth, root, pitch, meshing, and backlash. How mechanisms maintain and control performance.	EC5, MC6.

How lifting equipment is used in vehicle maintenance and repair. Factors of safety, including safe working loads, when working with lifting equipment.	

1.5 **Power sources**, **power units**, and **engine types**, processes, functions and **performance**.

Range:
Power sources – diesel including common-rail, petroleum, hydrogen, Battery Electric Vehicle (BEV), Hybrid Electric Vehicle (HEV), Plug-In Hybrid Electric Vehicle (PHEV), Fuel Cell Electric Vehicle (FCEV), Mild Hybrid Electric Vehicle (MHEV), Mild Hybrid Variants.
Power units – volts, kilowatt, horsepower, torque.
Engine types – engine configuration (longitudinally mounted, transverse, front, mid and rear engines), cylinder arrangements, cylinder configuration (in-line, vee, W, horizontally opposed), engine cycle (four stroke, Atkinson, Otto), electric motor, hybrid layout systems, spark ignition (SI), compression ignition (CI), rotary.
Performance – swept and clearance volume, compression ratio, cubic capacity (CC), valve timing, ignition timing, port timing, pressure charging (turbocharger, supercharger).

What do learners need to learn?	**Skills**
Engine configuration and layout of given vehicles. Operating cycles of naturally aspirated and pressure charged internal combustion engines. The performance, processes and operations of different power sources. Performance advantages and limitations of different engine/power configurations and multi-cylinder arrangements. Calculations which apply to engine/power operating cycles using correct power units.	EC5, MC2, MC3, MC4, MC6, MC7, DC1.

1.6 **Primary** and **auxiliary systems**.

Range:
Primary systems – engine, transmission (single and multi-plate clutches, manual gearboxes, automatic gearboxes, direct shift gearboxes (DSG)), electrical (engine management system, ECU, motors, modulators, control units, sensors, actuators, AC and DC units), chassis (steering, suspension, brakes, wheels and tyres), gear reduction units, CVT.
Auxiliary systems – lighting, wiper, security and alarm, convenience systems (parking sensors, cameras, lane keeping), heating, ventilation and air conditioning (HVAC), satellite navigation, infotainment, phone induction charging, Bluetooth communication, USB, electric window, monitoring and instrumentation, Advanced Driver Assistance Systems (ADAS), anti-lock braking system (ABS).

What do learners need to learn?	**Skills**
Recognise key primary systems on a vehicle. Recognise auxiliary systems on a vehicle. How to check, maintain, adjust, replace, repair and test primary and auxiliary systems and components. Safety requirements of working on high voltage systems.	EC5, MC2, MC3, MC6, DC1, DC6.

1.7 Key principles of **energy storage** and **transfer.**

Range:
Energy storage – kinetic, potential, chemical, electrical, heat, pressure (hydraulic, pneumatic), conversion of energy, methods of storage (batteries, capacitors, flywheels, pressure vessels).
Energy transfer – methods of energy transfer (mechanical, electrical, induction, conduction, convection, radiation, heat, generation, co-efficient of friction, stop-start systems, regenerative braking, mild hybrid technology), energy efficiencies, transmissions, torque converters, belts, hydraulic/pneumatic systems, hardwire.

What do learners need to learn?	Skills
Characteristics and methods of energy storage and transfer. Application of energy storage and transfer methods. How energy forms are converted to enable storage.	MC4, MC6.

1.8 **Mechanical loadings** on **structures** and **components**.

Range:
Mechanical loadings – weight, torque, bending and torsion (static and dynamic), tension, compression, shear, fatigue, aerodynamics.
Structures – engine, chassis, transmission.
Components – transmission system (single and multi-plate clutches, manual gearboxes, automatic gearboxes, DSG), CVT, gear reduction systems, chassis system (steering, suspension, brakes, wheels and tyres).

What do learners need to learn?	Skills
Identify the main components of each vehicle system. Functions and calculations of mechanical loads on structures and components. Effects of mechanical loading on structures and components.	MC2, MC3, MC4, MC6, DC4.

1.9 **Construction** and **operation** of power conversion systems.

Range:
Construction – passive components (resistors, capacitors (polarised, non-polarised), inductors, transformers), active components (transistors, voltage and current sources), alternators (diodes, rectifiers, voltage regulator, stator and rotor), invertors.
Operation – frequency control, use of diodes to convert alternating current (AC) to direct current (DC) and back, intelligent battery chargers (hybrid, electric vehicle, DC-DC converters), efficiencies of systems, power flow.

What do learners need to learn?	Skills
Functions and operation of power conversion systems, and the components required to construct them. How power conversion systems work to achieve an output. Power flow analysis techniques and their applications.	EC5, MC2, MC3, MC4, MC6.

1.10 **Components** of electrical systems, including **failure modes** and **protection methods**.

Range:
Components – passive components (resistors, capacitors, inductors, diodes), active components (transistors, operational amplifiers (voltage and current sources), lighting circuits (lamps, light emitting diodes (LED`s), incandescent, halogen, xenon, high intensity discharge (HID)), batteries (lithium-ion, nickel metal hydride (NiMH), lead acid, auxiliary), battery cell modules, programmable microcontrollers, cables, wiring looms, photovoltaic cells, electrical power outlets, USB charging points.
Failure modes – circuit faults (short circuit and open circuit connections, high resistance connections, connections to earth), design and power supply faults (components out of specification, intermittent faults, tolerance testing), digital faults (input side, output side, logic stuck-at faults), equipment failure (human error, environmental conditions).
Protection methods – relays, earthing, bonding, fuses, fusible links, immobiliser, circuit breakers, diodes.

What do learners need to learn?	**Skills**
Function and operational characteristics of electrical components, cabling and wiring. Identify common failure modes and protection methods. The advantages and limitations of protection methods used in vehicle engineering. How to identify faults in circuits, power supplies and components. How to read and interpret wiring diagrams.	MC2, MC3, MC4, MC6, DC1.

1.11 **Properties** and applications of electrical and electronic **systems, circuits and components.**

Range:
Properties – voltage, current, resistance, impedance, power.
Systems – power supplies, digital electronics, starting, charging, ignition, electronic control unit (ECU), HVAC, lighting and auxiliary, control systems (mechanical, electro-mechanical, electrical, electronic, instrumentation, engine/powertrain), controller area network (CAN bus), single phase, three phase, DC networks.
Circuits – series, parallel, series-parallel, closed, open circuits latching, power, timer, auxiliary.
Components – switches, diodes, transistors (bipolar (NPN, PNP)), rectifiers, capacitors, resistors, inductors, relays, motors, transformers, potentiometers, power supply units.

What do learners need to learn?	**Skills**
The nature and behaviour of electricity in systems. The properties and applications of electrical and electronic circuits within light and electric vehicles. Characteristics of electrical and electronic systems, components and how they are used in a range of vehicle systems. Application of electrical and electronic laws and theorems.	MC3, MC4, MC6, DC1.

1.12 **Drive devices** their purposes, **parameters** and applications**.**

Range:
Drive devices – electrical (engine management system, ECU, motors, modulators, control units, sensors, actuators, AC and DC units), mechanical (transmission systems, motors, belts, shafts, clutches).
Parameters – inputs, process and outputs (IPO), memory, peripherals, tolerances.

What do learners need to learn?	**Skills**
The purpose and application of drive devices within motor vehicle maintenance and repair. The purpose and outcomes of drive device parameters and how they contribute to the operation of the system. Purpose and outcomes of system testing. The advantages and limitations of drive units.	EC5, MC2, MC3, MC4, MC6, DC1.

1.13 **Sensing** and **measurement techniques** and **technologies**.

Range:
Sensing – engine performance (engine load, temperature, air and fuel parameters, speed/position sensors, pressure sensors, seismic sensors, exhaust emissions, lambda sensor, security/warning systems, diagnostic techniques), transmission performance (speed/position sensors, pressure sensors, security/warning systems, diagnostic techniques), chassis performance (speed/position sensors, pressure sensors, security/warning systems, diagnostic techniques).
Sensing technologies – inductive sensors, Hall effect sensors, optical sensors, variable resistors, negative temperature co-efficient (NTC) and positive temperature co-efficient (PTC), piezoelectric transducers.
Measurement techniques and technologies – multimeters, oscilloscopes, diagnostic analysers, data logging/self-diagnosis equipment, dial tester indicator (DTI), emissions testers, frequency meter.

What do learners need to learn?	**Skills**
The purposes and applications of electronic systems that measure performance. The relative benefits and limitations of sensing and measurement techniques and technologies. How sensing and measurement technologies are used to measure parameters and signals.	MC2, MC3, MC4, MC6, DC1.

1.14 **Component classification**, **numbering** and **referencing systems.**

Range:
Component classification – passive, active, part numbers, engine, transmission, chassis/frame plates.
Numbering – vehicle registration number, part numbers (original equipment manufacturer (OEM), after-market), vehicle identification numbers (VIN), paint codes, tyre marking (construction, size, width, direction of rotation, aspect ratio, speed rating, load rating, ply type).
Referencing systems – wiring identification (low voltage, high voltage), vehicle layout, identification codes and technical data, manufacturers data sheets, manufacturers safety specifications, colour codes, component numbering, QR codes, barcodes, wiring/schematic diagrams, vehicle data, wheel alignment, BS3939, EMC Directive, BS, IEC, EN and ISO Standards.

What do learners need to learn?	Skills
The purposes and applications of component classification, numbering and referencing systems. How classification, numbering and referencing systems aid vehicle maintenance, service and repair. How to interpret current IET, BS, IEC, EN and ISO standards related to light and electric vehicles maintenance, service and repair, including classification, numbering and referencing. The importance of using OEM parts to validate warranty.	MC2, MC3, MC4, MC6, DC1, DC5.

Perform relevant maintenance, installation, servicing and repair of vehicles, using appropriate techniques and procedures to achieve the required quality outcomes and solutions (PO4)

1.15 **Hand tools**, **power tools** and **equipment.**

Range:
Hand tools – spanners (open ended, ring, combination), screwdrivers, Allen keys, ratchets and sockets (metric and imperial hex, bi-hex, torx, socket drive sizes (1/4,3/8 and ½ inch), universal joints, extension bars), hammers, mallets, files, cold chisels, punches, clamps, pliers, hacksaws, crimping tools, measuring tools (engineers' rule, micrometer (internal, external, depth), hydrometer, Vernier callipers), feeler gauge, angle gauges, torque wrench, tyre tread depth gauge, spark plug adaptor, hand diagnostic equipment, vehicle specific tools, refractometer, High Voltage System (HVS) tool set (insulated).
Power tools – impact wrenches, drills (compressed air/electric).
Equipment – European on-board diagnostic (EOBD2) compliant, lifting and stabilising (pneumatic/mechanical lifts, hydraulic jacks, axle/vehicle stands), pullers, chain blocks, testers (discharge, diagnostic, compression, cooling system pressure, fuel pressure, oil pressure, vacuum gauge, emission), dial test indicator (DTI), multimeters, oscilloscopes, battery chargers, compressors, welding (metal inert gas (MIG)/metal active gas (MAG)), rolling road.

What do learners need to learn?	Skills
How to check the physical condition of tools prior to use. The suitable applications and limitations of the identified equipment. How to maintain tools and equipment and use safely, following all regulations relating to use. Risks and consequences of using non-authorised tools and equipment. The applications of and main differences between the welding processes. How to safely operate equipment, machinery and technology. How to follow relevant guidelines and instructions, limits of own authority and expertise, and seek advice and guidance, where necessary.	EC5, MC1, MC2, MC3, MC4, DC1, DC4.

1.16 **Effects** of **environmental conditions** on materials, tools, and equipment.

Range:
Effects – failure modes, working condition, false readings, degradation, corrosion, ingress, egress, leakages, system errors, blockages, electrical faults, mechanical faults, debris, cracking, brittle, disintegration, cleanliness, clarity.
Environmental conditions – humidity, moisture, temperature, pressure, heat, pollution, dirt, debris, radiation, chemicals.

What do learners need to learn?	Skills
How environmental conditions can affect materials components, wiring and equipment, and their potential effects. Characteristics relating to material quality and condition. How materials degrade and fail, including monitoring, maintaining and preventative techniques. Appropriate methods of maintenance, management, storage, preservation and prevention for materials, tools and equipment.	EC5, MC1, MC2, DC1, DC4, DC6.

1.17 **Vehicle service parts** and **systems**.

Range:
Vehicle service parts – filters (pollen, air, oil, fuel, transmission, electric motor coolant), spark plugs, wiper blades, brakes, remote/intelligent key/fob battery, fluids (oil, transmission, power steering, coolant, screen wash, brake).
Systems – engine, chassis, transmission, electrical.

What do learners need to learn?	Skills
How to identify different vehicle service parts and systems in a motor vehicle. The characteristics and functions of vehicle service parts and systems used in motor vehicles. Recognition of manufacturers service manuals in their use and application. How to safely remove, repair and replace vehicle service parts when servicing light and electric vehicle systems. How to follow relevant guidelines and instructions, limits of own authority and expertise, and seek advice and guidance, where necessary.	EC5, MC1, MC2, MC3, MC5, DC1, DC4, DC6.

Maintenance, servicing, installation and repair methods and techniques:

1.18 **Configuration** and **integration** of light and electric vehicle systems.

Range:
Configuration – setting parameters, calibration, testing, first use, operating systems, specifications, tools and equipment.
Integration – combining of systems, functions, designs, planning, processes, tightening techniques, tools and equipment.

What do learners need to learn?	Skills
Methods and procedures for the disassembly and re-assembly of vehicle systems according to guidance and regulations. Application and recording of configuration and integration techniques to remove and replace components using the correct tools and following regulations. Requirements, procedures and considerations for configuration and integration of vehicle engineering systems. Tightening techniques for different operations. How to safely use tools, equipment and technology to complete maintenance, servicing and repair requirements. How to follow relevant guidelines and instructions, limits of own authority and expertise, and seek advice and guidance, where necessary.	EC5, MC1, MC2, MC3, MC4, MC5, MC7, DC1, DC4, DC6.

1.19 **Fault detection**, **diagnosis**, **resolution** and **isolation methods**.

Range:
Fault detection – self-diagnostic, input output, half split technique, end to end, top-down techniques, operator experience, component isolation, tools and equipment.
Fault diagnosis – sensory checks, collection of fault data, self-diagnosis, inspection, material testing, tools and equipment.
Resolution methods – replace, repair, adjust, modify.
Isolation methods – supply, electrical isolation, temperature, pressure.

What do learners need to learn?	**Skills**
Identifying faults utilising fault detection and diagnosis methods. Material testing methods and techniques. How to safely use tools, equipment and technology to detect and diagnose faults within assemblies and sub-assemblies. How to use resolution methods based on the fault diagnosis. Identify different isolation methods. The advantages and limitations of fault detection methods and isolation systems. How to remove, refit, replace and configure vehicle components and systems. How to apply safe isolation methods to complete resolution and rectification methods. How to follow relevant guidelines and instructions, limits of own authority and expertise, and seek advice and guidance, where necessary.	EC5, MC1, MC2, MC3, MC5, DC1, DC4, DC6.

1.20 Joining using **welding, bonding, and fastening**.

Range:
Welding – spot, metal inert gas (MIG), metal active gas (MAG), tungsten inert gas (TIG), gas (brazing, soldering), types of joint (butt, tee, lap, corner), types of weld preparation (cleaning, edge preparation, assembly, pre-heat), welding positions, standards (welding (BS EN ISO 6947, BS 4872, BS 1140, BS EN ISO 4063), vehicle damage repair (BS10125)).
Bonding - adhesive (anaerobic, cyanoacrylate, epoxy, plastisol, polyurethane, solvent rubber), friction, fusion, composites, adhesive bonding methods (heat activated, solvent activated, impact activated), preparation of surfaces, applications.
Fastening – threaded fixings (bolts, studs, set screws, self-tapping screws), non-threaded fixings (rivets (snap head, pan head, countersunk heads, pop rivets)), nuts, washers, pins, plastic, joint configurations (self-secured, lap joints, flanged joints grooved seams, double grooved seams, knocked up, panned down, slip joints, flexible joints, threaded joints).

What do learners need to learn?	**Skills**
The characteristics, functions and applications of different welding, bonding and fastening techniques used in vehicle maintenance and repair. How to safely use tools, equipment, machinery and technology to complete welding, bonding and fastening activities. How to follow relevant guidelines and instructions, limits of own authority and expertise, and seek advice and guidance, where necessary. The relevance and application of the latest vehicle damage repair and welding standards.	EC5, MC1, MC2, MC3, MC5.

Review and evaluate activities to help improve workplace systems and processes associated with vehicle maintenance, installation, servicing and repair, demonstrating commercial awareness and accountability (PO5)

1.21 **Quality inspection, testing and recording methods.**

Range:
Quality inspection and testing methods – policies, procedures, guidance, second line verifications, organisational systems and requirements, sensory checks, checklists, maintenance instructions, data, reports, measurements, analysis of systems, pre delivery inspection (PDI), used car inspection (UCI), roadworthiness test (MOT), vehicle health and seasonal checks, communication, prior maintenance history, maintenance requirements, preventative measures.
Recording methods – service information/records, recall bulletins, reports, statements, checklists (inspection, vehicle condition report, warranty claim form), job cards, digital technologies, amending documentation.

What do learners need to learn?	Skills
The purpose of quality inspection, testing and recording. Factors that can affect quality in light and electric vehicle maintenance and quality assurance processes. How variations and defects in engineering products and components are managed. Application of methods and techniques used within quality inspection and testing. The reasons for quality inspection and testing and the impact of inadequate quality inspection and testing. How to complete and record quality processes as part of quality control, assurance and improvement. The role of the Driver and Vehicle Standards Agency (DVSA) in vehicle maintenance and safety inspections.	EC3, EC4, EC5, EC6, MC2, MC5, MC6, MC10, DC1, DC2, DC4.

Communicate vehicle maintenance, installation, servicing and repair information, proposals and solutions, producing, recording and explaining relevant technical information (PO6)

1.22 **Communicating technical information and data**.

Range:
Communicating – record, manage, store, amend, upload data, collaborative technologies (shared drives, email, conferencing, software and programs, forums).
Technical information and data – test data, test results, maintenance results and findings, fault information, inspection sheets, service history, repair methods, maintenance schedules.

What do learners need to learn?	Skills
How to communicate information effectively in written and verbal methods. The importance of technical documentation for communication. How to create technical reports for light and electric vehicle maintenance, service and repair activities. How to use different types of technical information and data communication methods. How collaborative technology is used to communicate technical information and data. Current legislation including GDPR and organisational procedures that are used to manage data and increase confidentiality of sensitive information.	EC1, EC2, EC3, EC4, EC5, MC5, MC7, MC10, DC1, DC2, DC3, DC4, DC5.

1.23 Digital, information and communication technology (**ICT**).

Range:
ICT – data systems, recording systems, electronic document and management systems, collaborative technologies, electronic storage.

What do learners need to learn?	**Skills**
How technology and systems are used to manage vehicle maintenance and repair data and documentation. Application of software and ICT techniques to record, manage, store and amend vehicle maintenance and repair information. Advantages and limitations of using ICT to record information.	EC4, EC5, MC5, MC10, DC1, DC3, DC4, DC5.

Practical criteria for performance outcomes

Outcome 2

2. Analyse requirements, specifications and technical information to enable the delivery of successful maintenance, installation, servicing and repair of vehicles

2.1 Confirm the **type**, **scope** and **requirements** of the activity, task or problem.

Range:
Type – configuration, assembly, disassembly, modification**,** fault finding (mechanical, electrical, data, system, pressure, operational, temperature), resolutions methods, preventative measures, repairs, upgrade, downgrade.
Scope – tasks, features, costing, goals, deliverables, functions, requirements, outcomes, end product, depth, detail, time scales, sensory checks, maintenance records and schedules, agreed processes, evidence and data gathering, specifications, repair information, wiring diagrams, recall bulletins.
Requirements – expectations and desired output, performance requirements, customer/client requirements, reliability, integration of information, health and safety legislation and regulations.

What do learners need to demonstrate?	**Skills**
Gather, analyse and interpret technical information, data and evidence to confirm type, scope and requirements for the task, considering performance, quality and compliance. Use information to identify and confirm issues, problems, faults and areas for investigations. Analyse and identify likely causes, agreed processes, methods, expectations and outcomes. Interrogate technical documentation considering the accuracy, relevance, currency and completion to understand issues and appropriate methods for resolution or further investigation. Use and respond effectively to specifications, repair information, observed evidence, recall instructions, maintenance tables and technical bulletins. Interpret and confirm all health and safety requirements of light and electric vehicle maintenance, service and repair activities.	EC4, EC5, EC6, MC2, MC3, MC5, MC6, MC7, MC9, MC10, DC1, DC4.

2.2 Evaluate the **condition**, quality and **performance** of **components**, systems, **materials** and **resources**.

Range:
Condition – working condition, serviceability (degradation, deterioration, damage, corrosion, disintegration), safety.
Performance – efficiency, accuracy, effectiveness, tolerance, outputs, sustainability.
Components – passive components (resistors, capacitors, inductors, diodes), active components (transistors, operational amplifiers (voltage and current sources), lighting circuits (lamps, light emitting diodes (LEDs)), batteries (lead acid, auxiliary), cables, wiring looms.
Materials – non-ferrous, ferrous, thermosetting, thermoplastics, composites, smart materials.
Resources – manufacturers technical information/data, recording forms, service information/records, test results, job cards, health and safety regulations, material safety data sheets (MSDS), environmental requirements, organisational procedures, client information, requirements, performance data and diagnostic information.

What do learners need to demonstrate?	Skills
Evaluate condition of components to ensure quality standards and requirements are met. Make effective decisions based on observation and information gathered to proceed with a task. Use diagnostic information and other evidence to determine vehicle system and component serviceability and feasibility for maintenance and repair activities.	EC4, EC5, MC2, MC5, MC6, MC10, DC4.

2.3 Interpret light and electric vehicle **representations**.

Range:
Representations – manuals, specifications, instructions, diagrams (circuit, schematic, wiring), drawings, symbols, annotations, conventions, standards, reports, results, bulletins.

What do learners need to demonstrate?	Skills
Interpret representations to communicate and confirm details, processes and requirements of light and electric vehicle maintenance and repair activities.	EC3, EC4, EC5, MC5, MC6, MC7, MC10, DC1, DC4, DC5.

Outcome 3

3. Plan and prepare the maintenance, installation, servicing and repair of vehicles, taking into account the specific requirements and context

3.1 **Plan** and prepare **processes**, **resources**, **scope**, **technology, tools and equipment** to complete client expectations.

Range:
Plan – service sheets, risk assessments, preparatory checks, SOPs, toolbox talks, job cards.
Processes – organisational, regulatory, maintenance, rectification, reporting, recording.
Resources – manufacturers technical information/data, recording forms, service information/records, test results, job cards, health and safety regulations, environmental requirements, organisational procedures.
Scope – tasks, features, costing, functions, requirements, outcomes, end product, depth, detail, time scales, sensory checks, maintenance records and schedules, agreed processes, evidence and data gathering, specifications, repair information, wiring diagrams, recall bulletins.
Tools – spanners (open ended, ring, combination), screwdrivers, Allen keys, ratchets and sockets (metric hex, bi-hex, torx, socket drive sizes (1/4,3/8 and ½ inch), universal joints, extension bars), hammers, mallets, files, cold chisels, punches, clamps, pliers, hacksaws, crimping tools, measuring tools (engineers' rule, micrometer (internal, external, depth), hydrometer, Vernier callipers), feeler gauge, angle gauges, torque wrench, tyre tread depth gauge, spark plug adaptor, hand diagnostic equipment, vehicle specific tools, refractometer, insulated tool set, impact wrenches, drills.
Equipment – lifting and stabilising (pneumatic/mechanical lifts, hydraulic jacks, axle/vehicle stands), pullers, chain blocks, testers (discharge, diagnostic, compression, cooling system pressure, fuel pressure, oil pressure, vacuum gauge, emission), DTI, multimeters, oscilloscopes, data logger, battery chargers, compressors, welding (spot, metal inert gas (MIG), metal active gas (MAG), tungsten inert gas (TIG), gas (brazing, soldering), plasma cutting, beam setting, wheel alignment equipment.

What do learners need to demonstrate?	**Skills**
Produce plans using information gathered to meet client requirements, including human resources and service impact, following SOPs. Confirm technology, tools and equipment availability to complete client requirements with consideration of prior maintenance history. Identify components and parts that are required. Review, confirm and record stock levels, ordering processes, and lead-in times to complete the required task or activity. Evaluate and plan for wastage, disposal, recyclability and sustainability in maintenance, service and repair tasks and activities.	EC1, EC2, EC3, EC4, EC5, EC6, MC2, MC3, MC4, MC7, MC8, MC9, DC5.

3.2 **Risk assessment.**

Range:
Risk assessment – assessments of hazards (health and safety considerations, pneumatics, hydraulics, mechanical, electrical, electronic, electro-mechanical, temperature, hazardous substances, pressurised fluids, equipment, moving under suspended loads, risk of slips, trips and falls, working in restricted spaces, high voltage systems), evaluation of risk (severity, impact), control measures (permits to work, SOPs, PPE, Vehicle Protection Equipment (VPE)), documentation.

What do learners need to demonstrate?	Skills
Complete risk assessments and implement control measures for maintenance and repair activities, communicating risks according to policies and procedures. Complete risk management for maintenance and repair activities of vehicle systems. Confirm processes, outcomes and mitigations used to reduce potential risks and issues.	EC1, EC2, EC3, EC4, EC5, DC1, DC2, DC4.

3.3 Quality, accuracy and completeness of **information** and **resources**.

Range:
Information – identification codes and technical data, manufacturers technical information/data, colour codes, component numbering, schematics, material lists, MSDS, sensory checks, fault data, checklists, reports, measurements, test results, inspection sheets, technical bulletins, repair method statements (issue dates, amendments).
Resources – policies, procedures, regulations, guidance, second line verifications, organisational systems and requirements, maintenance information, defect logs, reports, equipment, data systems, electronic document and management systems.

What do learners need to demonstrate?	Skills
Application of accurate information and resources to ensure components are correct, complete, free of fault, and conform to specifications, grades, and dimensions. Application of calibration dates and requirements of components and equipment prior to commencing, the procedures for out-of-date calibrations and electrical safety checks.	EC4, EC5, MC2, MC3, MC4, MC6, MC7, MC8, MC9, DC1, DC2, DC4, DC5.

3.4 **Preparatory checks** for compliance, quality and functionality.

Range:
Preparatory checks – tools, equipment, calibration, isolation, work area, sensory.

What do learners need to demonstrate?	Skills
Carry out preparatory checks for materials, resources, tools, equipment, and other technologies. The advantages and limitations of preparatory checks for compliance, quality and functionality. Application of safe isolation, immobilisation and calibration of vehicles, tools and equipment.	EC5, MC2, DC1.

3.5 **Plan and prepare** work areas for light and electric vehicle maintenance and repair.

Range:
Plan and prepare – health and safety, risk assessments, tools, equipment, materials, technical data, service schedules, workflow processes.

What do learners need to demonstrate?	**Skills**
Plan and prepare the work area for vehicle inspection, maintenance and repair. Plan and prepare for welding activities, following all health and safety requirements for the work area, PPE and VPE. Application of adjustments to tools and equipment according to specifications and parameters in preparation for the task to be completed.	EC5, EC6, MC2, DC1.

Outcome 4

4. Perform relevant maintenance, installation, servicing and repair of vehicles, using appropriate techniques and procedures to achieve the required quality outcomes and solutions

4.1 **Maintain** and repair light and electric vehicle systems, equipment, and components.

Range:
Maintain – total preventative, reactive, service schedule (interim, main/full), corrective, condition-based monitoring.

What do learners need to demonstrate?	Skills
Complete maintenance and repair activities of vehicle systems, equipment and components within agreed specifications, timeframes and vehicle manufacturer standards. Safely operate equipment, machinery and technology when completing light and electric vehicle maintenance and repair tasks. Follow relevant guidelines and instructions, and seek advice and guidance, where necessary. Responsibilities of working individually and collaboratively to meet task, client and organisational standards, policies and expectations, in accordance with working practices. Application of electrical and electronic laws and theorems in light and electric vehicle maintenance, service and repair activities. Follow and comply with all legal, regulatory, and health and safety requirements of maintenance and repair activities.	EC5, EC6. MC1, MC2, MC3, MC4, MC5, MC7, DC1, DC4, DC6.

4.2 **Diagnostic** and measurement techniques, **tools and equipment**.

Range:
Diagnostic tools and equipment – hydraulic pressure, thermal checks, torque devices, EOBD2, oscilloscopes, DTI gauge, testers (coolant, brake fluid, battery, discharge, diagnostic, compression, cooling system pressure, fuel pressure, oil pressure, vacuum gauge, emission), wheel alignment, beam setting, rolling road.

What do learners need to demonstrate?	Skills
Follow manufacturer's instructions when using diagnostic and measuring equipment. Application of diagnostic and measurement techniques, tools and equipment to obtain accurate information and results on performance, condition and compliance. Use fault detection techniques, tools and equipment to identify and locate faults, and their causes in vehicle systems. Interpret and evaluate built in tests and self-diagnostic results.	EC5, EC6, MC1, MC2, MC3, MC4, MC5, MC6, MC7, DC1, DC4, DC6.

4.3 **Reactive** and **preventative** maintenance procedures.

Range:
Reactive – control monitoring, condition-based monitoring, unplanned, emergency, post-fault.
Preventative – scheduled, planned, timed.

What do learners need to demonstrate?	Skills
Determine schedule of tasks (remove, replace, repair) from diagnostic and measurement findings. Follow procedures to complete reactive maintenance tasks. Complete preventative maintenance procedures to reduce further failure or downtime, including recommending amendments to the maintenance schedule where appropriate.	EC5, MC1, MC2, MC3, MC4, MC5, MC6, DC4.

4.4 **Disassemble**, **assemble** and **configure** light and electric vehicle components, devices and systems.

Range:
Disassemble – powering down, removal of stored energy, isolation, removal of components, proof marking, disposal requirements, documentation.
Assemble – structures, removal, attachments, fixings, tightening techniques, powering up, re-energising, testing, documentation.
Configure – setting parameters, calibration, testing, first use, operating systems, specifications.

What do learners need to demonstrate?	Skills
Processes to be followed when assembling and disassembling components, devices and systems. Apply requirements and specifications to ensure correct assembly and disassembly, considering technical data and instructions. Accurately position, replace, calibrate and configure devices and equipment to agreed requirements and specifications. Consider and follow regulatory requirements throughout.	EC5, MC1, MC2, MC3, MC4, MC5, MC7, DC1, DC4, DC6.

4.5 Carry out **pre** and **post-work inspections**.

Range:
Pre-work inspections – windscreen (damage free, screen wash level), lights (check rear lights, indicators, headlight, interior), seatbelt, external bodywork (scratches, dents), tyres (condition, pressure).
Post-work inspections – quality control checks (QC), additional checks (inspect for visible leaks, visual condition), checking of all fluid and lubricant levels, checking for dirty handprints on the bodywork, interior is in good condition.

What do learners need to demonstrate?	Skills
Complete pre- and post-work inspections to ensure work is completed to agreed specifications and client requirements. Complete vehicle handover documentation prior to release to client.	EC5, EC6, MC1, MC2, MC3, MC5, DC1, DC4, DC6.

4.6 Planned maintenance, **servicing** and repair **tasks**.

Range:
Servicing – fluid maintenance, calibration, safety and condition checks, functional checks, component change, fitting replacement, reviewing and analysing outputs, data, readings.
Tasks – measuring, cutting, drilling, filing, removing and replacing bolts, screws and clips, replacing seals, extracting and replacing damaged fasteners, applying surface treatments, welding (spot, MIG, MAG, gas (brazing, soldering)), bonding (adhesive (anaerobic, cyanoacrylate, epoxy, plastisol, polyurethane, solvent rubber), friction, fusion, composites), fastening (threaded fixings (bolts, studs, set screws, self-tapping screws), non-threaded fixings (rivets (snap head, pan head, countersunk heads, pop rivets)), nuts, washers, pins, plastic.

What do learners need to demonstrate?	**Skills**
Perform planned maintenance, servicing and repair tasks to vehicle systems according to schedules. Carry out welding, fastening and bonding where appropriate following all health and safety requirements. Review and analyse outputs, data and readings.	EC5, MC1, MC2, MC3, MC5, MC7, DC3, DC4.

4.7 **Re-instate** work areas.

Range:
Re-instate – equipment is functioning to specification, work area is back to original condition, returning of tools and equipment, correct disposal requirements followed, housekeeping.

What do learners need to demonstrate?	**Skills**
Reinstate work areas back to original condition upon completion of tasks. Manage the work area ensuring the area is left in a safe condition. Check and return all tools and equipment back to storage facilities. Follow disposal requirements appropriate to the waste and relevant legislation.	EC5, MC2.

Outcome 5

5. Review and evaluate activities to help improve workplace systems and processes associated with vehicle maintenance, installation, servicing and repair, demonstrating commercial awareness and accountability

5.1 **Safe systems of work** and legal compliance.

Range:
Safe systems of work – procedures, safe working practices, risk assessment and management, recording and documentation.

What do learners need to demonstrate?	Skills
Anticipate and identify potential risks and actual risks. Apply safe systems of work, following policies and procedures relevant to the task. Complete documentation of activities and reflect on outcomes. Follow and comply with safe working practices and legal compliance.	EC4, EC5, EC6, MC1, MC2, MC4, MC5, MC6, MC10, DC1, DC2, DC4.

5.2 Work area **practices**.

Range:
Practices – safe working, guidance, regulatory requirements, organisational requirements, scope, responsibility, documentation, reporting procedures.

What do learners need to demonstrate?	Skills
Monitor working area practices to prevent, resolve, manage, and mitigate issues arising during tasks. Identify potential issues, following correct procedures to report and record. Implement practices to manage stock levels, materials, and availability of resources.	EC4, EC5, MC1, MC2, MC5, MC6, MC7, MC10, DC4, DC5.

5.3 Deal promptly and effectively with **issues**.

Range:
Issues – health and safety, age related use/wear, not meeting required standards or regulations, inappropriate use/lack of training, time constraints, cost implications, documentation discrepancies, tool and equipment failure.

What do learners need to demonstrate?	Skills
Deal with issues encountered throughout vehicle tasks in a timely manner. Apply problem solving techniques to resolve issues within the limits of own authority and expertise. Follow reporting procedures to ensure issues and problems are communicated. Report and escalate issues and problems where falling outside the limits of own authority.	EC3, EC4, EC5, EC6, MC2, MC6, MC9, MC10, DC1.

5.4 Carry out **quality monitoring** and **assurance checks** to review processes.

Range:
Quality monitoring – inspections, reviewing (self, peer to peer, supervisory), amending, supervisory checks, checking of quality.
Assurance checks – checking and validating reliability and durability, post-repair performance and functional tests.

What do learners need to demonstrate?	Skills
Conduct quality monitoring and assurance checks as part of vehicle maintenance, servicing and repair operations and processes. Review efficiency of processes, practices and outcomes to improve quality. Consistently check validity, accuracy and relevance of documentation. Communicate technical information, advice and suggestions for improvements. Suggest strategies to increase efficiency of quality monitoring processes, with consideration of performance and potential improvements.	EC4, EC5, EC6, MC4, MC5, MC6, MC10, DC1, DC2, DC3, DC4.

5.5 Make positive **contributions** for maintenance and operations whilst working effectively with others.

Range:
Contributions – communicate solutions, improvements, ideas, findings, designs, technical information, recommendations, research, facts, methods, operational changes, maintenance requirements.

What do learners need to demonstrate?	Skills
Recommend improvements, methods and other technical information as part of a team. Contribute effectively to maintenance, operations and team discussions. Working effectively with others and willing to assist where necessary and appropriate.	EC2, EC3, EC4, EC5, EC6, MC2, MC9, MC10.

5.6 Respond constructively to **feedback** and identify opportunities for personal and **organisational** improvement.

Range:
Feedback – reviews (self, peer to peer, supervisory), appraisals, reports, progress reviews, evaluation, client.
Organisational – commercial, productivity, safety, growth, activities, services, quality, technology, continuing professional development (CPD).

What do learners need to demonstrate?	Skills
Reflect and respond constructively to feedback provided throughout tasks and activities. Make suggestions for organisational improvements for commercial, productivity, and safety. Review feedback, identifying and implementing opportunities, personally and professionally within the organisation.	EC2, EC6, MC2, MC9, MC10, DC2, DC3.

Outcome 6

6. Communicate vehicle maintenance, installation, servicing and repair information, proposals and solutions, producing, recording and explaining relevant technical information

6.1 **Record and amend** technical information, data, risks and issues.

Range:
Record and amend – job cards, diagrams, drawings, reports, results, service information/records, recall bulletins, reports, checklists, test certificates.

What do learners need to demonstrate?	Skills
Record findings, data, risks and issues from the task accurately to support vehicle maintenance, servicing and repair work. Create technical reports to communicate maintenance, service and repair information. Make amendments and recommendations at relevant stages, within the limits of own authority and expertise. Use records, information, and data to inform improved practices, recommendations, and continuous improvement.	EC3, EC4, MC2, MC5, DC1, DC3, DC4, DC5, DC6.

6.2 Complete **handover procedures**.

Range:
Handover – complete work, incomplete work, modifications, faults, further investigation, suggested updates and improvements to maintenance schedules, demonstration of system functionality, confirmation (completion, responsibility, quality standards, specific requirements and outcomes, agreement), due date of next maintenance activity, technical documentation.
Procedures – communication methods (verbal, written, digital), de-brief, technical documentation (test results and certificates, calibration certificates, appropriate calculations, maintenance schedules, drawings and diagrams, software update information, maintenance records), signatures and date.

What do learners need to demonstrate?	Skills
Accurately communicate handover information following organisational procedures The functionality of the system following maintenance, service and repair activities. Communicate the reasons for non or partial functionality following maintenance, service and repair activities, including any outstanding faults, defects or issues, and suggestions for future improvements. Follow and implement document version control for relevant paperwork and technical documentation where updates are made, including maintenance schedules and representations. Follow organisational handover procedures. Apply organisational policies (brief, meetings, documentation) to the handover procedures.	EC1, EC4, MC2, MC7, MC8, MC10, DC1, DC4.

6.3 Team-working, inter-personal skills and communication with **technical** and **non-technical audiences**.

Range:
Technical audiences – supervisors, engineers, colleagues, skilled technicians, managers, apprentices.
Non-technical audiences – stakeholders, clients, investors, colleagues (sales/service advisers, in house health and safety advisor).

What do learners need to demonstrate?	**Skills**
Communicate technical information as part of a team. Work as part of a team to obtain desired outcomes, maintaining positive and professional working relationships. Interact using inter-personal skills to contribute to team success. Adapt technical language appropriately to communicate with non-technical client/customers and colleagues.	EC1, EC2, EC3, EC4, EC5, EC6, DC3, DC4.

6.4 Communication methods, including **written**, **verbal** and **media**.

Range:
Written – note taking (lists, mind mapping/flow diagrams), writing style (business letter, memo writing, report styles and format, email), proofreading and amending text, use of logbook for planning and prioritising work schedules, graphical presentation techniques (graphs, charts and diagrams).
Verbal – speaking (with peers, supervisors, use of appropriate technical language, tone and manner), listening (use of paraphrasing and note taking to clarify meaning), impact and use of body language in verbal communication.
Media – inter/intranet (manuals, data, analytical software, manufacturers' catalogues), spreadsheets, databases, fault diagnostic software.

What do learners need to demonstrate?	**Skills**
Communicate information, requirements, expectations, plans, performance, and outcomes using different communication methods to convey and confirm maintenance, installation and repair information. Use different methods of communication to meet the needs of clients and colleagues.	EC1, EC2, EC3, EC4, EC5, EC6, MC7, MC8, MC10, DC1, DC2, DC3, DC4, DC5.

Guidance for delivery

Opportunities for visits/engagement with local industry, employers and manufacturers should be provided throughout the delivery of the content within this specialism – where appropriate local employers could present details of recent projects including a variety of light and electric vehicle maintenance, servicing and repair activities, problems faced and how they were overcome. Learners work placement experiences could be presented to peers detailing where knowledge and skills within the content was seen in practice.

Formative assessment for the content may include oral Q&A, presentations to peers, observation of measuring activities etc. Reinforcement of learning can be encouraged through revisiting learning, group discussions, and the establishment of a peer support system within the cohort.

Providers must ensure content is delivered in line with current, up-to-date industry practice which will require;

- Provision of appropriate tools, equipment and test instrumentation for demonstration and practical training purposes
- Teaching coverage representing the type of equipment currently available and accepted for use in the UK industry

Suggested learning resources

Books

- A. Bonnick, — *Vehicle Electronic Systems and Fault Diagnosis,* 1st edition, Butterworth - Heinemann, 2004, ISBN 9780340706305
- V. Hillier, *Hillier's Fundamentals of Automotive Electronics Book 2,* 6th Edition, Nelson Thornes, 2012, ISBN 9781408515372
- M. Nunney, *Light and Heavy Vehicle Technology,* 4th edition, Butterworth-Heinemann, 2006, ISBN 9780750680370
- N. J. Smith, *Engineering Project Management,* 3rd edition, Wiley-Blackwell Publishing, 2007, ISBN 9781405168021
- Denton Tom — *Automobile Electrical and Electronic Systems* (Butterworth-Heinemann, 2004) ISBN 0750662190

Websites

https://www.hse.gov.uk/pUbns/priced/hsg261.pdf

Scheme of Assessment – Light and Electric Vehicles

The Light and Electric Vehicles Occupational Specialism is assessed by one practical assignment. The duration of the assessment is 22 hours. Learners will be assessed against the following assessment themes:

- Health and safety
- Planning and preparation
- Systems and components
- Working with faults
- Reviewing and reporting

By completing the following tasks:

Task	Typical Knowledge and skills
Task 1 – Plan and prepare	Displays a breadth of knowledge and practical skills that enables them to plan and prepare for carrying out maintenance, installation and repair activities on light and electric vehicles. Candidates will need to produce documents and complete risk assessments that clearly details how they plan to complete the maintenance, servicing, installation and repair activities to meet the requirements of the with the brief.
Task 2 – Perform maintenance	Applies a breadth of knowledge, understanding and practical skills that enables them to carry out maintenance, servicing, installation and repair activities on a variety of light and electric vehicles. The task is carried out in a clear and logical sequence. Works in a safe manner, able to carry out fault detection, diagnosis, isolation and resolution methods effectively Tools, materials and equipment are selected and used correctly.
Task 3 – Review and report	Displays a breadth of knowledge and understanding in the evaluation of their maintenance, installation and repair activities, recommending personal and organisational improvements to the process. Justifications for diagnosis, isolation and resolution methods used. Justifications for how peer review feedback was considered and implemented.
Task 4 - Handover	Displays breath of knowledge and skills in communicating technical information to a variety of audience types and how to complete handover procedures effectively. Candidates will need to demonstrate critical thinking skills when responding to peer review feedback.

The information provided in the following tables demonstrates to approved providers the weightings of each performance outcome and how each performance outcome is assessed.

Performance outcome and weighting (%)	***High level tasks*** *Provide specific instructions for candidates to provide evidence for and are the same for every version of the assessment*	**Assessment Theme**	***Typical evidence***
PO2 Analyse requirements, specifications and technical information to enable the delivery of successful maintenance, installation, servicing and repair of vehicles. (10%)	T1- Plan and prepare	Planning and preparation	List of requirements and resources, and job cards.
PO3 Plan and prepare the maintenance, installation, servicing and repair of vehicles, taking into account the specific requirements and context. (20%)	T1- Plan and prepare T2 – Perform	Health and safety Planning and preparation Systems and components Health and safety Planning and preparation Systems and components	List of requirements and resources, and job cards. Risk assessment. Work area preparation

PO4 Perform relevant maintenance, installation, servicing and repair of vehicles, using appropriate techniques and procedures to achieve the required quality outcomes and solutions. (40%)	T1- Plan and prepare T2 – Perform T3 – Review and report T4 - Handover	Health and safety Health and safety Systems and components Working with faults Health and safety Systems and components Reviewing and reporting Health and safety Reviewing and reporting	List of requirements and resources, and job cards. Risk assessment. Completed test records, updated manufacturer's service sheets, maintenance records and control documents Annotated method statement. Maintenance activities and work area re-instatement Technical report Technical report and maintenance schedule. Handover meeting.
PO5 Review and evaluate activities to help improve workplace systems and processes associated with vehicle maintenance, installation, servicing and repair, demonstrating commercial awareness and accountability. (20%)	T2 – Perform T3 – Review and report T4 - Handover	Systems and components Reviewing and reporting Health and safety Reports and information	Completed test records, updated manufacturer's service sheets, maintenance records and control documents Annotated job cards. Technical report and maintenance schedule. Handover meeting.

PO6 Communicate vehicle maintenance, installation, servicing and repair information, proposals and solutions, producing, recording and explaining relevant technical information. (10%)	T3 – Review and report T4 - Handover	Reports and information Reports and information	Technical report and maintenance schedule. Handover meeting

Appendix 1 Maths, English and digital skills

General English Competencies

The General English Competencies outline a framework of six General Digital Competences, with no prioritisation or interpretation of order intended:

- EC1. Convey technical information to different audiences
- EC2. Present information and ideas
- EC3. Create texts for different purposes and audiences
- EC4. Summarise information/ideas
- EC5. Synthesise information
- EC6. Take part in/lead discussions

General Mathematical Competencies

The General Mathematical Competencies outline a framework of ten General Mathematical Competences, with no prioritisation or interpretation of order intended:

- MC1. Measuring with precision
- MC2. Estimating, calculating and error spotting
- MC3. Working with proportion
- MC4. Using rules and formulae
- MC5. Processing data
- MC6. Understanding data and risk
- MC7. Interpreting and representing with mathematical diagrams
- MC8. Communicating using mathematics
- MC9. Costing a project
- MC10. Optimising work processes

General Digital Competencies

The following outlines a framework of six General Digital Competences, with no prioritisation or interpretation of order intended:

- DC1. Use digital technology and media effectively
- DC2. Design, create and edit documents and digital media
- DC3. Communicate and collaborate
- DC4. Process and analyse numerical data
- DC5. Be safe and responsible online
- DC6. Controlling digital functions

Appendix 2 Sources of general information

The following documents contain essential information for Providers delivering City & Guilds T Level Technical Qualifications. They should be referred to in conjunction with this specification and the Provider approval and quality assurance information.

You can download these from **www.cityandguilds.com**.

Centre Contract General Terms
Quality Assurance Standards: Centre Handbook
Quality Assurance Standards: Centre Assessment

Within these documents you will find information in relation to;

- centre assessment,
- internal quality assurance (IQA),
- IQA strategy,
- alternative locations and subcontractors,
- non-compliance,
- malpractice, and
- centre support roles and resources

All T Level providers must ensure they familiarise themselves with the above documents and adhere to the general terms as part of their conditions of approval.

Useful contacts

UK learners General qualification information	**E: learnersupport@cityandguilds.com**
International learners General qualification information	**E: intcg@cityandguilds.com**
Centres Exam entries, Certificates, Registrations/enrolment, Invoices, Missing or late exam materials, Nominal roll reports, Results	**E: centresupport@cityandguilds.com**
Single subject qualifications Exam entries, Results, Certification, Missing or late exam materials, Incorrect exam papers, Forms request (BB, results entry), Exam date and time change	**E: singlesubjects@cityandguilds.com**
International awards Results, Entries, Enrolments, Invoices, Missing or late exam materials, Nominal roll reports	**E: intops@cityandguilds.com**
Walled Garden Re-issue of password or username, Technical problems, Entries, Results, e-assessment, Navigation, User/menu option, Problems	**E: walledgarden@cityandguilds.com**
Employer Employer solutions, Mapping, Accreditation, Development Skills, Consultancy	**T: +44 (0)121 503 8993** **E: business@cityandguilds.com**

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

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As the UK's leading vocational education organisation, City & Guilds is leading the talent revolution by inspiring people to unlock their potential and develop their skills. City & Guilds is recognised and respected by employers across the world as a sign of quality and exceptional training.

City & Guilds Group

The City & Guilds Group operates from three major hubs: London (servicing Europe, the Caribbean and Americas), Johannesburg (servicing Africa), and Singapore (servicing Asia, Australia and New Zealand). The Group also includes the Institute of Leadership & Management (management and leadership qualifications), City & Guilds Licence to Practice (land-based qualifications) and Learning Assistant (an online e-portfolio).

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Get in touch

The City & Guilds Quality team are here to answer any queries you may have regarding your T Level Technical Qualification delivery.

Should you require assistance, please contact us using the details below:

Monday - Friday | 08:30 - 17:00 GMT

T: 0300 303 53 52

E: **technicals.quality@cityandguilds.com**

W: **www.cityandguilds.com/tlevels**

Web chat available **here**.