HM Government

T-LEVELS

T Level Technical Qualification in Design and Development for Engineering and Manufacturing

Specification

First teaching from September 2025

Version 1.5

City & Guilds

eal

Qualification at a glance

T Level route	Engineering and manufacturing
T Level pathway	T Level Technical Qualification in Design and Development for Engineering and Manufacturing
City & Guilds number	8730 8714
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 Design and Development for Engineering and Manufacturing (Level 3)	8730 – Core 8714 – Occupational Specialism	610/0516/2

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 25
	Typographic error amended	Unit 300, 6.5
	T Level grading table	Awarding the T Level programme grade Pg 39
1.3 February 2024	Physical resource lists expanded	Physical Resources Pg 14
	Additional guidance added to Unit 323, topic 1.1 Additional range added to Unit 323, topic 4.4	Unit 323
1.4 February 2025	Prototypes added	Unit 324
1.5 March 2026	Retake policy updated	Assessment retake policy Pg 29, 31 & 35
	Disclaimer removed from back contact page	Useful contacts Pg 175

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 Design and Development T level has the best opportunities available to them as they progress through their career with a solid base as a starting point.

- Royal Academy of Engineering
- Xtrac
- Warren Services
- Aeroflex Hose & Engineering LTD
- N&J Lining
- Siemens
- Autodesk
- London Borough of Barnet
- The MTC
- Leonardo Aviation
- EU Skills

The Outline Content for the T Level Technical Qualification in Design and Development for Engineering and Manufacturing 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:

www.instituteforapprenticeships.org/t-levels/approved-t-level-technical-qualifications-and-final-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 Design and Development 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 Design and Development for Engineering and Manufacturing (Level 3). The Technical Qualification forms a significant part of the T Level Technical Qualification in Design and Development 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: • Customer and client requirements • Principles of design • Design processes • Communication in design A learner will have the choice of studying one standalone Occupational Specialism as listed below: • Mechanical engineering • Electrical and electronic engineering • Control and instrumentation engineering • Structural engineering 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

1.14 **Installation** and **integration** of systems.

Range:
Installation – Customer requirements, regulation requirements, manufacturers specifications.
Integration – Combining of system, functions, designs, planning, processes.

What do learners need to learn?	Skills
Requirements, procedures and considerations for installing engineering structures. Key stages and appropriate sequence of integration of systems. How integration is achieved through bringing together individual sub-systems into one system and ensuring that the sub-systems function together as a complete system.	EC5

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 Design and Development 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 Design and Development 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 (321 – 324)

T Level Technical Qualification in Design and Development 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					
8714-31	321	Mechanical engineering	Level 3	680	1000
8714-32	322	Electrical and electronic engineering	Level 3	680	1000
8714-33	323	Control and instrumentation engineering	Level 3	680	1000
8714-34	324	Structural engineering	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 Assessment and standardisation plan
Criteria F Secure live assessment and administration
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 examination-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

Mechanical engineering

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.

Electrical and electronic engineering

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.

Control and instrumentation engineering

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.

Structural engineering

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.

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
- Engineering drawing materials
- PPE
- Scientific calculator
- Technical documentation
- Electrical / electronic equipment
- Measurement devices, instrumentation, and gauges
- Machines and systems
- Components and consumables
- Power supplies
- Tools
- Testing equipment
- Manufacturing equipment
- Materials
- Video camera
- Camera
- Workshop (to include waste disposal facilities)
- ICT equipment and software

Mechanical engineering

- Technical documentation – standards and regulations, organisational procedures, design briefs, specifications (design, manufacturing, manufacturer's), concept drawings, 2D and 3D drawings/Models (CAD and manual), engineering drawings (annotated sketches, orthographic, isometric, schematics, block diagrams, exploded diagrams, wiring diagrams), bill of materials (BoM), material safety data sheets (MSDS), manufacturers manuals, method statements, Standard operating procedures (SOP), production plans, risk assessments, permits to work, inspection and test record sheets.
- Materials - 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, polycarbonate, polypropylene, PMMA/acrylic), Thermosetting polymers (urea formaldehyde, melamine formaldehyde, phenol formaldehyde, epoxy resin, polyester resin), Elastomers (rubber, neoprene), Composites (GRP, CRP) Ceramics (silicon carbide, glass), Smart materials (shape memory alloys, quantum tunnelling composite, thermochromic materials, photochromic materials, piezoelectric crystals).
- Mechanical components - rotating (gears (spur, helical, bevel, worm, rack, pinion), flywheels), linear (levers (class 1,2,3), linkages (reverse motion, parallel motion, bell crank, crank and slider), cams (circular, eccentric, snail), pulleys, belts.
- Fixings and fastenings - screws, nuts, bolts, cable ties, rivets.
- Machines - centre lathe, milling machine, manual and computer numerical control (CNC), pillar/bench drill, linisher, 3D printer, laser cutter, bending machine/press.

- Machine tooling – drill bits, chucks, steadies, lathe cutting tools, boring bars, taps and dies, reamers, milling cutters, drill bits.
- Additional manufacturing processes - aluminium casting equipment (crucible, tongs, heat source, mould (from oil bonded sand)), GRP moulding equipment, appropriate equipment for one of the following welding processes MIG/MAG/TIG (with appropriate fume extraction).
- Lifting equipment - hoist, jacks, chains, slings, D-shackles, eye bolts.
- Consumables – lubricants, coolants, polylactic acid (PLA filament), adhesives, welding rods/wire (as applicable), shielding gas (as applicable), emery cloth.
- Tools 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, angle grinder, metal guillotine, glue gun.
- Measuring and testing equipment - micrometres (Internal, external, depth), vernier callipers, gauges (Go-Nogo, slip, plug), measuring tapes, rules, laser scanning, engineers try square, protractors, dial test indicators (DTI), digital stress and strain machines, welding gauge, dye penetrant testing.

Electrical and electronic engineering

- Technical documentation – circuit diagrams, schematics, wiring diagrams, block diagrams, PCB layouts, drawings, diagrams, specifications, charts and graphs, system diagrams, risk assessments, bill of materials (BoM), test records, datasheets, manufacturer's/technical manuals, standards and regulations.
- Circuit implementation equipment – Printed circuit boards PCBs (single sided, double sided, multi-layer, flexible, chip on board (COB), hybrid), breadboard, stripboard, modular kit.
- Circuit manufacturing - etching, pillar/bench drill, CAM milling.
- Software – circuit simulation software, programmable logic controller (PLC) and microcontroller programming.
- Design and communication technologies – PCB netlists, Verilog/VHDL.
- Cable and wiring – single core, multicore, screen multicore cable, ribbon cable, armoured, fire resistant, flexible, non-flexible, crimp/compression connections, screw terminals, soldered connection.
- Electrical and electronic systems and components – resisters (fixed variable), inductors, transformers, semiconductors (transistors (bipolar (NPN, PNP), field effect (JFET, MOSFET) diodes) resistors, capacitors (polarised, non-polarised), power supplies (cell batteries, photovoltaic cells, supercapacitors), generators, switches (single pole throw SPST), single pole double throw (SPDT), double pole single throw (DPST), double pole double throw (DPDT), sensors and sensor sub-systems (light dependent resistors, thermistors, photodiodes, infrared, passive infrared, proximity, vibration, humidity, heat, moisture, pressure, displacement, ultraviolet radiation), relays, microcontrollers, programmable logic controller (PLC) output devices (lamps, light emitting diodes, buzzers, loudspeakers, bells, motors (solar motors, servo motors, stepper motors, DC motor, AC motors), solenoids), heat pumps, cable clamps, cable clips, timers, counters, latches, logic gates (AND, NOT, OR, NAND, NOR, XOR) pulse width modulation (PWM) power supply architectures, amplifiers, operational amplifier circuits.
- Circuit modelling methods – DC, AC, Monte-Carlo.
- Verification and diagnostic equipment - multimeter, voltmeter, ohmmeter, ammeter, oscilloscope, spectrum analyser, signal generator, function generator, logic probe, logic pulser, logic analyser, insulation resistance tester, current tracer, frequency meter, AC bridge, virtual instruments, bench power supply.

- Tools and equipment - soldering irons, solder, potentiometer trimmers, wire cutters, wire strippers, de-soldering tools, pliers, helping hands (clamps for soldering), hand file, drills (including PCB drills), screwdrivers, hand and power saws.

Control and instrumentation engineering

- Technical documentation – drawings and diagrams (sketches, block diagrams, schematic diagrams, circuit diagrams, wiring diagrams), Standard operating procedures (SOPs), charts and graphs, manufacturers manuals/technical manuals, specifications, instructions, risk assessments, process flowcharts, bill of materials (BoM), test records, standards and regulations, datasheets.
- Technologies – Verilog/VHDL, computer aided design (CAD), Mathematical modelling software, analytical software, programming software for PLCs, Supervisory control and data acquisition (SCADA), configurations (PID, adaptive control).
- Components and sub-assemblies - microcontrollers, programmable logic controllers (PLCs), Human machine interface (HMI), logic systems (sequential and combinational), valves (fluid control, mechanical).
- Input devices and sensors – switches, photodiodes, photoresistors/light dependent resistors (LDR), thermistors (PTC, NTC), thermocouples, piezoelectric, strain gauges, load sensor/cell, pressure pads, pressure sensor, microphone, flow gauge, hall effect, accelerometer, sight glass, moisture/level sensor, infra-red and proximity sensor, voltage and current sensors, logic probe, pH probe/sensor, rotational speed sensor.
- Output devices – sounds outputs (alarms, buzzers, bells, loudspeakers), motors (DC, motor, steppers, servo), pumps (water and air), light output (lamps, light emitting diodes (LEDs)) visual display screen/monitor.
- Cables and wiring -single core, multicore, armoured, fire resistant, flexible, non-flexible, ribbon cable.
- Systems and circuits - potential dividers, operational amplifiers, Wheatstone bridge, interfaces, analogue to digital convertors (ADC) and digital to analogue convertors (DAC).
- Fastenings and fixing - cable clamps, cable clips, cable ties, cable identification marker, terminal connectors, solder, wall plugs, screws, bolts, nuts, mounting panels, enclosures.
- Consumables – solder, adhesive.
- Tools – screwdriver, wire cutters, wire strippers, soldering iron, desoldering equipment hacksaw, hammer, files, Allen keys, spanner, socket set, wrench, crimping tools, heat gun, glue gun, drill, pliers (flat nose, needle nose, angle needle nose).
- Measurement and testing equipment - multimeter, signal generator, oscilloscope, logic probe, logic analyser, data logger, temperature gauge, flow meter, power meter, rule, level, tape measure, set square.
- 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).

Structural engineering

- Technical documentation – general arrangement drawings (concept designs, 2D CAD, 3D model, isometric, assembly drawings, orthographic drawings, schematics, system block diagrams), design specifications, risk assessments, manufacturers specifications, structural assessment surveys/reports, engineering calculations, analysis models and diagrams, manufacturers datasheets, manufacturers technical manuals, BS ISO and European engineering standards and regulations, bill of materials (BoM).
- Construction and modelling materials – steel (stainless steel, mild steel, C-section, I-section, flat bars, round bars, tubes, wires), non-metal (concrete, timber and masonry, plastic, timber/wood).
- Tools (hand and power tools) – pliers, saws, chisel, spanner, scalpels, rotary cutters, drills, rasps and files, screwdrivers, hammers and mallets, hand planes, scissors and snips, ladder, tripod, torch, plumb bob/optical plumb/laser alignment, vice, rivet gun.
- Technologies – structural analysis software.
- Consumables and fixings – nuts, bolts, screws, rivets, bonding agents (metal and non-metal).
- Components – beam, columns, cantilevers, frames, trusses, struts, rods and ties.

- Testing and measurement equipment – Schmidt hammer, crack monitoring gauge, laser distance measurement, theodolite, flow metre, rules, temperature measurement, measuring tape, protractors, callipers (vernier, digital), micrometres (internal, external, depth) gauges (Go-NoGo, slip, plug), compression and flexural testing machine, tensile testing machine, shear testing machine, weigh machine, drying and weighing equipment, set squares, spirit level, ultrasonic testing machine, dye penetrant test kit, particle size analysis equipment, particle powder and magnets, X-ray metal testing equipment, impact testing (Izod, Charpy), wind tunnel.
- Machines – drill (bench/pillar), lathe, milling machine, radial arm saw, 3D printer, laser cutter.
- Finishing equipment – anti-corrosion paint.

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 (DD-CSA) Planning and preparation**
  In relation to design and development engineering this may be evidenced through:
  - Interpreting and confirming project requirements
  - Planning and scoping project parameters (e.g. timescales, resources, costs)
  - Developing project plans

- **Core Skill B (DD-CSB) Communication**
  In relation to design and development engineering this may be evidenced through:
  - Interpreting, using and producing engineering representations and drawings following graphical language and industry conventions
  - Interpreting and using technical information and media
  - Communicating with technical and non-technical audiences using technology

- **Core Skill C (DD-CSC) Developing proposals and concepts**
  In relation to design and development engineering this may be evidenced through:
  - Designing proposals to meet set requirements
  - Developing, modelling and revising concepts

- **Core Skill D (DD-CSD) Evaluation**
  In relation to design and development engineering this may be evidenced through:
  - Carrying out tests, evaluation and analysis
  - Evaluating how well project requirements have been met.

For Design and Development, 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 (DD-CSA)** Planning and preparation e.g. collate information in response to a specification of client brief. In practice this may be:
  - Using Microsoft Project to prepare a programme and critical path for a project
  - preparing a stock inventory plan for a product
  - developing a project plan to meet the needs and requirements of a client

- Producing a project organigram to define the role and responsibilities of different types of project stakeholder
- Using SharePoint to share and manage project documentation with project team - members and stakeholders
- Undertaking a project commercial risk review
- Preparing and initial project costings and budget
- Working collaboratively with different types of stakeholders e.g. client, team and end user
- Behaving in an ethical way towards other team members and stakeholders
- Setting clear project goals and objectives, defining roles, setting realistic milestones and understanding constraints on cost and time

- **Core Skill B (DD-CSB)** Communication e.g. producing sketch design for a product or assembly and then produce a 3D model by hand and/or on SketchUp. In practice this may be:
  - Preparing an AutoCAD drawing for a CNC router
  - Producing a fully dimensions isometric drawing of a part in Solidworks or similar
  - Promoting good customer service providing information and advice to customers
  - Preparing documentation for a tender submission in response to an invitation to tender
  - Using Excel to prepare an initial budget spreadsheet for a project
  - Preparing a short PowerPoint presentation providing different material options for a component of assembly
  - Reporting potentially dangerous situations occurring during the manufacture of a - component
  - Setting clear project goals and objective, defining roles, setting realistic milestones and constraints on cost and time
  - Communicating with a client when a change or alteration is required due to unforeseen circumstances

- **Core Skill C (DD-CSC)** Developing proposals and concepts e.g. The key stages of the design and manufacture process. In practice this may be:
  - Complying with the requirements and needs of a client's brief
  - Producing risk assessments, method statements and safe systems of works
  - Applying the concept of lean manufacturing to minimise waste while manufacturing a product
  - Developing and then re-evaluate prototype design prior to manufacture
  - Planning for production
  - Assessing ergonomics, materials, modularity and sustainability to develop a product or assembly
  - Applying manufacturing standards to produce safe end product
  - Identifying health and safety issues which may impact on a product
  - Considering environmental obligations during the design and manufacture of a product
  - Using and specify manufacturing processes (e.g. welding, machining, fabricating) correctly and safely

- **Core Skill D (DD-CSD)** Evaluation e.g., testing materials to ascertain their properties and suitability for a product. In practice this may be:
  - Using benchmarking, KPI's and target setting when measuring product compliance
  - Applying manufacturing test methods to validate the suitability of a product
  - Using prototypes to evaluate how well a product meets a brief
  - Engaging in end of line inspection and feedback
  - Using the product realisation process to define/validate product design
  - Using the concept of Six Sigma to bring continuous quality improvement to a manufacturing process
  - Carrying out product testing at different stages of a manufacturing process
  - Using current UK and international testing standards

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 (321 – 324)

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 321 – 324) 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	18.5 hours	90	30%	Externally marked	
Occupational Specialism Component - Learners must complete one assessment component						
Assessment component	**Method**	**Duration**	**Marks**	**Weighting**	**Marking**	**Grading**
Mechanical engineering	Externally set assignment	34 hours	90	100%	Externally moderated	All Occupational Specialism components will be awarded on the grade scale P, M, D
Electrical and electronic engineering	Externally set assignment	34 hours	90	100%	Externally moderated	
Control and instrumentation engineering	Externally set assignment	34 hours	90	100%	Externally moderated	
Structural engineering	Externally set assignment	34 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. Any retake must be completed within one year after the completion of the learner's T Level programme. 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 meeting the 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%
AO2 Apply core knowledge and skills as appropriate	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, planning etc appropriately throughout tasks within project.	50%
AO3 Select relevant techniques and resources to meet the 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%
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 evidence presentation.	10%
AO5 Realise project outcome and review how well the outcome meets the brief	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%

*Weightings are rounded to the nearest whole number

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. Any retake must be completed within one year after the completion of the learner's T Level programme.

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: • Research • Design • Plan • Present The project draws on the content from the core knowledge that sits across all specialisms in Design and Development (specific knowledge and skills for each specialism will be assessed in the practical assignments). The project is linked to the core skills: • Planning and preparation • Communication • Develop and manufacture • Evaluation

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	8 hours
3 Plan	City & Guilds sets the assessment window for the centre to timetable	5 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. Any retake must be completed within one year after the completion of the learner's T Level programme. 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.

<table>
<tr><th>Component</th><th>Assessment method</th><th>Overview and conditions</th></tr>
<tr><td>Mechanical engineering</td><td>Externally set, externally moderated</td><td>Content overview
Learners will be able to:
• Analyse and interpret engineering and manufacturing requirements, systems, processes, technical drawings and specifications.
• Evaluate systems, designs, components and processes, managing and integrating design information, proposals and specifications, to develop and improve mechanical engineering and manufacturing proposals and solutions.
• Propose and design mechanical engineering and manufacturing systems, products, components, processes and solutions, considering requirements, constraints and context.
• Collaborate to help manage, develop, test and quality assure mechanical engineering and manufacturing design information, systems, processes and outcomes.
• Communicate proposals, design information and solutions, producing, recording and explaining engineering and manufacturing representations, systems, processes, outcomes, specifications and technical drawings.

Assessment overview:
Learners will be assessed against the following assessment themes:
• Health and safety
• Design and planning
• Manufacturing
• Reports</td></tr>
</table>

Component	Assessment method	Overview and conditions
Electrical and electronic engineering	Externally set, externally moderated	**Content overview** Learners will be able to: • Analyse and interpret engineering and manufacturing requirements, systems, processes, technical drawings and specifications. • Evaluate systems, designs, components and processes, managing and integrating design information, proposals and specifications, to develop and improve electrical and electronic engineering and manufacturing proposals and solutions. • Propose and design electrical and electronic engineering and manufacturing systems, products, components, processes and solutions, considering requirements, constraints and context. • Collaborate to help manage, develop, test and quality assure electrical and electronic engineering and manufacturing design information, systems, processes and outcomes. • Communicate proposals, design information and solutions, producing, recording and explaining engineering and manufacturing representations, systems, processes, outcomes, specifications and technical drawings. **Assessment overview:** Learners will be assessed against the following assessment themes: • Health and safety • Design and planning • Manufacturing • Reports

Component	Assessment method	Overview and conditions
Control and instrumentation engineering	Externally set, externally moderated	**Content overview** Learners will be able to: • Analyse and interpret control and instrumentation engineering and manufacturing requirements, systems, processes, technical drawings and specifications. • Evaluate systems, designs, components and processes, managing and integrating design information, proposals and specifications, to develop and improve control and instrumentation-related engineering and manufacturing proposals and solutions. • Propose and design control and instrumentation-related engineering and manufacturing systems, products, components, processes and solutions, considering requirements, constraints and context. • Collaborate to help manage, develop, test and quality assure control and instrumentation related engineering and manufacturing design information, systems, processes and outcomes. • Communicate proposals, design information and solutions, producing, recording and explaining engineering and manufacturing representations, systems, processes, outcomes, design specifications and technical drawings. **Assessment overview:** Learners will be assessed against the following assessment themes: • Health and safety • Design and planning • Manufacturing • Reports

Component	Assessment method	Overview and conditions
Structural engineering	Externally set, externally moderated	**Content overview** Learners will be able to: • Analyse and interpret engineering and manufacturing requirements, systems, processes, technical drawings and specifications. • Evaluate systems, designs, components and processes, managing and integrating design information, proposals and specifications, to develop and improve structural engineering, manufacturing and construction proposals and solutions. • Propose and design structural engineering and manufacturing systems, products, components, processes and solutions, considering requirements, constraints and context. • Collaborate to help manage, develop, test and quality assure structural engineering and manufacturing design information, systems, processes and outcomes. • Communicate proposals, design information and solutions, producing, recording and explaining engineering and manufacturing representations, systems, processes, outcomes, specifications and technical drawings. **Assessment overview:** Learners will be assessed against the following assessment themes: • Health and safety • Design and planning • Manufacturing • Reports

Availability of assessments

Scheduled assessment windows will be set annually for the T Level Technical Qualification in Design and Development for Engineering and Manufacturing (Level 3). Exact key dates for assessment 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 Autumn	Written exam Written exam	May/June November	Set date Set date
Core exam 2	Summer Autumn	Written exam Written exam	May/June November	Set date Set date
Employer-set project	Summer Autumn	Project Project	March – May October	Assessment window 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 both learner and 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 Design and Development 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 Design and Development 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 Design and Development 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 demonstrate' sections
- Links to maths, English and digital skills
- Guidance for delivery
- Suggested learning resources.

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.	DD-CSA, DD-CSC, DD-CSD.

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?
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.

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.	DD-CSB, 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). 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.	MC2, MC3, MC4, MC5, MC6, MC7, MC8.

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?	Skills
The difference between physical and mechanical properties. The definitions of the stated properties. Calculation of density.	DD-CSD

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.	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.	DD-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.	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?

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

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?	Skills
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).	DD-CSC

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.	DD-CSC

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?	Skills
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.	DD-CSC

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.	DD-CSC, DD-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.	DD-CSA, DD-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.	DD-CSA, DD-CSB

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.	DD-CSA, DD-CSB, 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

321 Mechanical engineering

Level:	3
GLH:	680
Assessment method:	Practical assignment

What is this specialism about?

The purpose of this specialism is for learners to know and undertake designing and development processes within mechanical engineering.

Learners will have the opportunity to plan, perform and evaluate their work whilst utilising a range of techniques, methods and resources.

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

- Knowledge of design methodologies and processes.
- Knowledge of the tools, equipment and materials used in mechanical engineering.
- Knowledge of mathematical theories and methods used in mechanical engineering.
- Skills in producing mechanical drawings and representations.
- Skills in designing and developing working models.
- Skills in testing models and prototypes.

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

- What different types of mechanical systems are there and what are they used for?
- What do mechanical engineers do on a daily basis?
- What areas of the engineering industry do mechanical engineers work in?

Underpinning knowledge outcomes

On completion of this specialism, learners will understand:

1. Mechanical engineering knowledge criteria

Performance Outcome
s

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

2. Analyse and interpret engineering and manufacturing requirements, systems, processes, technical drawings and specifications.
3. Evaluate systems, designs, components and processes, managing and integrating design information, proposals and specifications, to develop and improve mechanical engineering and manufacturing proposals and solutions.
4. Propose and design mechanical engineering and manufacturing systems, products, components, processes and solutions, considering requirements, constraints and context.
5. Collaborate to help manage, develop, test and quality assure mechanical engineering and manufacturing design information, systems, processes and outcomes.
6. Communicate proposals, design information and solutions, producing, recording and explaining engineering and manufacturing representations, systems, processes, outcomes, specifications and technical drawings.

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

Common knowledge criteria

Mechanical engineering knowledge criteria

1.1 **Principles** of engineering design in mechanical engineering

Range:
Principles - Requirements (functionality, aesthetics, dimensions, ergonomics, safety, sustainability, cost, materials), methods of identifying requirements (market research, client interviews, client observation, product analysis), methods of recording requirements (design brief, specification, questionnaire/survey forms, observational records), factors that affect design (product life cycles, sustainability (recycling and re-use), safety), fields within mechanical engineering (design, manufacture and processing, fitting and assembly maintenance), methods of communicating designs (orthographic drawings, virtual models, physical models).

What do learners need to learn?	Skills
How to agree the nature and scope of mechanical engineering projects. How to identify, interpret and confirm client and customer requirements, proposals, ideas, objectives and aspirations. How to record client and customer requirements, and the implications of not doing so accurately or effectively. How to evaluate and develop client and customer requirements. Design requirements unique to fields within mechanical engineering, and the factors that affect them. How to communicate design ideas (proposals, solutions, processes, concepts) and technical information relating to mechanical engineering. The different tools for recording, evaluating and developing client and customer requirements. How to evaluate, develop, challenge, and refine ideas, proposals, and objectives.	EC1

Analyse and interpret engineering and manufacturing requirements, systems, processes, technical drawings and specifications (PO2)

1.2 Design **methodologies** for common mechanical engineering contexts.

Range:
Methodologies – Systems approach, sub-assembly, component by component.

What do learners need to learn?	Skills
Design methodologies and practices including planned obsolescence. Contexts where design is undertaken in mechanical engineering. Purpose, benefits and limitations of the different design methodologies. How to interpret tables of anthropometric data for use in ergonomic design. Influence of process capability and tolerances on Design for Manufacture/ Assembly (DFM/DFA).	MC5 MC8

1.3 **Engineering representations** in mechanical engineering contexts and activities.

Range:
Engineering representations –

- Characteristics of orthographic drawings – Sheet size, section views (including hatching style).
- Information conveyed by drawings – Standard features (springs, splines and gears, webs, solid shafts, keys and keyways), mechanical symbols (balloon, diameter, depth).

What do learners need to learn?
The characteristics of, purposes of and audience for different drawing types. How to interpret information, symbols, conventions and annotations used in BS EN 8888 on engineering drawings.

1.4 **Standards and regulatory requirements** relevant to mechanical engineering.

Range:
Standards and regulatory requirements - British Standards (BSI), International Organization for Standardization (ISO), Institution of Mechanical Engineers (IMECHE)

What do learners need to learn?	**Skills**
The purpose, use and requirements of standards and regulatory requirements relevant to the design of mechanical components. The key responsibilities and codes of engineering standards and regulatory requirements. How to access and interpret requirements and responsibilities under regulations.	MC2 MC3 MC4 MC7

1.5 **Mathematical theories and methods** applied in mechanical engineering contexts.

Range:
Mathematical theories and methods - gear ratio, velocity ratio, mechanical advantage, efficiency, stress, strain, pressure, density, velocity, and acceleration.

What do learners need to learn?	**Skills**
How to manipulate and carry out calculations in relation to resource requirements, material properties, the characteristics of mechanical systems and drawing representations. How to apply mathematical theories and methods in mechanical engineering contexts.	MC2 MC3 MC4 MC7

1.6 **Simple machines**

Range:
Simple machines – Gears, pulleys, levers, linkages, cams, ratchet.

What do learners need to learn?	Skills
The machines that can be used to change the magnitude, direction and type of motion. Types of gears and their applications (spur, helical, bevel, worm, rack and pinion) Calculations for simple and compound gear trains. Types of levers and their applications – (class 1, 2 and 3). Types of linkages and their applications - (reverse motion, parallel motion, bell crank, crank and slider). Types of cams and their applications (circular, eccentric, snail).	MC2

Evaluate systems, designs, components and processes, managing and integrating design information, proposals and specifications, to develop and improve mechanical engineering and manufacturing proposals and solutions (PO3)

1.7 Influence of **engineering requirements** on the design outcomes.

Range:
Engineering requirements –

- Mechanical loads – Type of loading (static, dynamic, structural, fluid), point loading (weight), uniformly loaded, torque, shear forces, bending moments, fatigue.
- Service and environmental conditions – Chemical attack/corrosion, temperature, functional properties.

What do learners need to learn?
How the type of loading influences the mechanical properties. How environmental conditions affect material characteristics and functionality. Consideration of other requirements that may influence design outcome such as manufacturing and material choice.

1.8 **Verification** and **validation** in design practices.

Range:
Verification and validation – Comparing against the requirements of the brief and design specification, user testing, comparison matrices, ranking, decision trees, functional testing.

What do learners need to learn?	Skills
The difference between verification and validation practices, where each is applied and why. Importance of ensuring that designs meet specifications, requirements, expectations at key stages of the design process. Methodologies and relative advantages and limitations of the listed approaches. How the verification and validation methods listed confirm that outcomes realise or meet original specification.	EC1 EC2 EC3 EC4

Propose and design mechanical engineering and manufacturing systems, products, components, processes and solutions, considering requirements, constraints and context (PO4)

1.9 Influence of the business **context** and other **constraints and metrics** on the design outcomes.

Range:
Context – Market pull and technology push, commercial advantage, design for reuse, planned obsolescence, sustainability.
Constraints – Commercial factors (competition, profitability), operational factors (tools and equipment, materials, process capabilities, human resources, training needs, legal, confidentiality), design for manufacture.
Metrics – Budget, cost, profit, time.

What do learners need to learn?	Skills
Difference between market pull and technology push.	MC9
How contexts may influence product design.	EC5
How to calculate the cost of manufacturing (materials, labour, overheads) and profit.	EC6
The reasons why the constraints limit what can be done, the causes of these constraints and how the constraints can be overcome.	
Impacts of commercial risk analysis and how it applies to project design review.	

1.10 **Considerations** about **materials** and **standard parts** which influence engineering design.

Range:
Considerations – Fitness for purpose, availability of materials, managing risk, factor of safety.
Materials –

- 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, polycarbonate, polypropylene, PMMA/acrylic).
- Thermosetting polymers (urea formaldehyde, melamine formaldehyde, phenol formaldehyde, epoxy resin, polyester resin).
- Elastomers (rubber, neoprene).
- Composites (GRP, CRP).
- Engineering ceramics (silicon carbide, glass).
- Smart materials: shape memory alloys, quantum tunnelling composite, thermochromic materials, photochromic materials, piezoelectric crystals.

Standard parts – Types of standard part and their functions (valves, sensors, piping, supports and fittings).

What do learners need to learn?
Fitness for purpose includes functionality and all of the other types of need that a product must satisfy (aesthetic, environmental, safety, sustainability, maintenance).
How designs may be affected by the available forms of the specified material.
Reasons why a company may use standard parts rather than manufacturing them.

1.11 Influences of **manufacturing processes** on engineering design.

Range:
Manufacturing processes - Wasting (cutting, filing, turning, milling, grinding), shaping (casting, moulding), forming (bending, pressing), welding (MIG/MAG, TIG), 3D printing, joining, finishing, assembly.

What do learners need to learn?
How the different types of manufacturing process are used to form products and technology, tools and equipment/plant most appropriately used to complete them. Examples of each type of manufacturing process benefits their application and comparisons of their advantages and disadvantages. Why tolerances and fits are important in assembly.

1.12 Effects of **aerodynamic forces** on design.

Range:
Aerodynamic forces – Fluid flow (laminar flow, separation points, vortices, turbulence), lift, drag, turbulence, thrust.

What do learners need to learn?
How 2D representations of fluid flows around simple objects. How lift, drag, thrust and turbulence apply forces to structures subject to aerodynamic loading.

1.13 Mathematical **calculations** for design development in mechanical engineering.

Range:
Calculations –

- Calculation of forces – Stress, strain, Young's modulus, structural members (magnitude of applied loads, direction [compressive or tensile]), beams (simply supported, cantilever, reactions, shear force and bending moment values for various positions).
- Calculation of material requirements – Quantity of materials required (by area, volume, units), cost (materials, manufacturing time).
- Calculation of machine performance – Load, effort, mechanical advantage, velocity ratio, work, energy, power and efficiency.

What do learners need to learn?	**Skills**
How to calculate forces in components, structural members e.g. beams and columns. How to calculate the material requirements and cost of a product. How to calculate the performance of simple machines.	MC2 MC4

Collaborate to help manage, develop, test and quality assure mechanical engineering and manufacturing design information, systems, processes and outcomes (PO5)

1.14 **Health and safety** procedures, regulations, conduct and compliance related to mechanical engineering.

Range:
Health and safety – Environmental Protection Act, Lifting Operations and Lifting Equipment Regulations, Manual Handling Operation Regulations, PUWER, LOLER

What do learners need to learn?
The specific health and safety procedures and protocols, and relevant legal and regulatory requirements that apply to mechanical engineering design, systems, process, outcomes and development activity The importance of compliance and how this is achieved. Responsibilities of employers and employees under the regulations.

1.15 **Factors** which affect quality in and quality assurance and **quality control practices** relevant to mechanical engineering design and development.

Range:
Factors – Assignable systematic error causes (faulty equipment calibration, tool wear, observer bias, human error), random causes (ambient/environmental conditions, temperature, humidity; instrument uncertainties).
Quality control practices –

- Quality assurance (QA) – Procedures, calibration, process capability monitoring, preventative maintenance.
- Quality control (QC) – Testing, inspections.

What do learners need to learn?
The difference between assignable and random causes of variations in products. How the different causes result in errors and how the risk of these causes occurring can be reduced. Reasons why process checks, and inspections are necessary. The benefits and limitations of sampling compared to 100% inspection. How the quantity of parts being produced influences the approach to quality.

1.16 **Installation** and **integration** of systems.

Range:
Installation – Customer requirements, regulation requirements, manufacturers specifications.
Integration – Combining of system, functions, designs, planning, processes.

What do learners need to learn?	Skills
Requirements, procedures and considerations for installing mechanical systems. Key stages and appropriate sequence of integration of systems. How integration is achieved through bringing together individual sub-systems into one system and ensuring that the sub-systems function together as a complete system.	EC5

1.17 **Testing methods** in mechanical engineering.

Range:
Testing methods

- Non-destructive testing methods – visual inspection, measurement, Go-NoGo gauges, ultrasonic testing, penetrant testing, magnetic particle inspection, X-radiography.
- Destructive testing methods – Macro examination, hardness, tensile, impact tests (Izod, Charpy).

What do learners need to learn?
The methodology of each of these test methods.
The types of defects detected.
The relative benefits and limitations of each test method.

1.18 Measurement **equipment**.

Range:
Equipment – Rules, protractors, callipers (Vernier, digital), micrometres (outside, inside, depth), gauges (go/no-go, slip, plug), dial test indicators, coordinate measuring machines (CMMs), laser scanning, digital stress and strain machines.

What do learners need to learn?
What can be measured by each item of equipment and how it is used.
The accuracy and relative limitations and benefits of the listed devices.
Technology used for measuring other mechanical characteristics such as air flow.

1.19 Mathematical methods for processing measurement and performance **data** in mechanical engineering.

Range:
Data – Test results, performance.

What do learners need to learn?	Skills
Determination and analysis of statistical values when measuring, checking and confirming test and performance data.	MC5 MC7

Communicate proposals, design information and solutions, producing, recording and explaining engineering and manufacturing representations, systems, processes, outcomes, specifications and technical drawings. (PO6)

1.20 **Methods** of communicating mechanical engineering information relevant to purpose and **audience.**

Range:

Methods – CAD models, engineering drawings, written data (specifications, SOPs, reports), presentations, transmission of instructions to control CNC machines (direct entry, intranet, WiFi), Graphs (performance data, test results, SPC).

Audience – Designers, manufacturing engineers, customers and non-technical personnel.

What do learners need to learn?

Types of media, formats and conventions used to communicate engineering data, including BS 8888

Methods of transferring data from CAD to CAM machines.

The different applications and benefits of 2D and 3D CAD.

How to use CAE tools to visualise simulated performance of CAD assembly.

Uses of visualisation software.

Practical criteria for Performance Outcomes

Outcome 2

2. Analyse and interpret engineering and manufacturing requirements, systems, processes, technical drawings and specifications

2.1 Access, interpret and respond to mechanical design projects and tasks and requirements from different **sources**.

Range:
Sources – Design briefs, specifications, concept drawings, stakeholders (supervisors, colleagues, client/end user).

What do learners need to demonstrate?	Skills
Follow processes to access, examine, interpret, review and respond to information on mechanical engineering projects and tasks from different sources.	EC1 EC5 EC6

2.2 Evaluate design **project expectations** and requirements, including risks associated with requirements.

Range:
Project expectations – Materials requirements, manufacturing timescale, cost.

What do learners need to demonstrate?	Skills
Determine and evaluate the materials requirements, manufacturing timescale and costs for a specified project. Identify risks to a design project and their mitigation actions. Consider different types of risks associated with requirements which may include design risks and/or commercial risks.	EC4 EC5

2.3 Interpret, evaluate and modify engineering information in a range of **formats**.

Range:
Formats – Specifications, CAD models, engineering drawings, mechanical process and instrument diagrams, standard operating procedures, production plans.

What do learners need to demonstrate?	Skills
Interpret requirements and responding to a range of different sources of engineering information. Identify inaccuracies or errors in engineering drawings and information and ways of making corrective amendments. Identify and manage scope creep or design change (process driven change) within remit of responsibility, escalating or reporting as necessary.	EC5 MC1 MC5 MC6 MC7 DC1

2.4 Verify mechanical design **information** in relation to context, **function and requirements.**

Range:
Information – Concept drawings, briefs and specifications.
Function and requirements – Components, materials, application, location, risk and environment.

What do learners need to demonstrate?	Skills
Interpret mechanical design information and evaluate whether a design proposal meets the requirements.	MC2 EC5

2.5 Use **technology** to evaluate **mechanical design elements** in design proposals.

Range:
Technology – Mathematical calculations, CAD simulations, physical modelling.
Mechanical design elements – Systems, components, assemblies, products and processes.

What do learners need to demonstrate?	Skills
Use technology appropriate to task including CAD to review, analyse and interpret mechanical design elements in proposals and products. Engineering information may be used for design proposals and representations.	DC1 DC4 DC6

Outcome 3

3. Evaluate systems, designs, components and processes, managing and integrating design information, proposals and specifications, to develop and improve mechanical engineering and manufacturing proposals and solutions

3.1 Select and use **technology** to model and evaluate the **performance** of mechanical designs.

Range:
Technology – Mathematical modelling tools, spreadsheets, CAD simulations.
Performance – Features, issues, current and potential performance.

What do learners need to demonstrate?	Skills
Considerations when selecting technology for use – cost, availability, compatibility, training required, time. Select appropriate tool given a relevance to failure modes being assessed.	MC1 MC2 MC3 MC4 DC1

3.2 Analyse **factors** that affect mechanical designs, justifying recommendations as to how the designs can be improved or adapted.

Range:
Factors – Materials, application, location, risk, environment, configuration, geometry, scale.

What do learners need to demonstrate?	Skills
Consider impacts of the factors, assessing and categorising them by priority or importance. Compare factors related to all situations and which will only apply in certain situations. The difference between optimisation of a design concept as opposed to development of a new one and how this may impact on stages in the design process.	MC5 EC2 EC5

3.3 Select and justify the use of **materials** for specific uses.

Range:
Materials –
- 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, polycarbonate, polypropylene, PMMA/acrylic).
- Thermosetting polymers (urea formaldehyde, melamine formaldehyde, phenol formaldehyde, epoxy resin, polyester resin).
- Elastomers (rubber, neoprene).
- Composites (GRP, CRP).
- Engineering ceramics (silicon carbide, glass).
- Smart materials (shape memory alloys, quantum tunnelling composite, thermochromic materials, photochromic materials, piezoelectric crystals).

What do learners need to demonstrate?	Skills
Use appropriate information sources on material properties and characteristics. Select and justify the use of a materials for a specific use, with reference to context.	EC1 EC2 EC5

3.4 Apply knowledge of how materials **degrade and fail**, and appropriate prevention and mitigation methods, to evaluate design proposals and outcomes.

Range:
Degrade and fail – Chemical attack/corrosion, fracture, mechanical abrasion, creep and fatigue.

What do learners need to demonstrate?	Skills
The application of knowledge of material degradation and failure processes, and prevention and mitigation methods, to investigate and evaluate design proposals, projects, processes, and outcomes.	EC5

3.5 Review and confirm the relevance, implications and value of **test** results.

Range:
Test –

- Non-destructive testing methods – visual inspection, measurement, Go-NoGo gauges, ultrasonic testing, penetrant testing, magnetic particle inspection, X-radiography.
- Destructive testing methods – Macro examination, hardness, tensile, impact tests (Izod, Charpy).

What do learners need to demonstrate?	Skills
Determine the relevance and value of testing methods. Use results of testing to influence the design. Consider the purpose, context, traceability, recording and reporting on tests, modelling and research.	MC4 EC4 EC5 DC4 DC6

3.6 **Evaluate** designs and design processes against application **requirements.**

Range:
Evaluate – Quality, performance.
Requirements – Purpose and functionality, environmental and working conditions, application requirements (cost, value engineering).

What do learners need to demonstrate?	Skills
Evaluate the fitness for purpose of mechanical engineering designs and design processes.	MC6 MC7 EC4 EC5

3.7 Compare alternative **design options** and identify design improvements.

Range:
Design options – Mechanical engineering designs, design elements, design processes, iterations of design options.

What do learners need to demonstrate?	**Skills**
Compare and evaluate mechanical engineering design options and iterations and design processes to determine the most appropriate solution and identify improvements. Areas of comparison – Fitness for purpose, context, constraints, agreed metrics, compliance with design specification.	EC4 EC5 MC10

3.8 **Review** the performance of individuals, teams and the organisation across the design process and manufacture and identify improvements.

Range:
Review – Design methods, quality systems, standards, manufacturing methods, performance targets, KPI's.

What do learners need to demonstrate?	**Skills**
Reflect upon and review performance across mechanical engineering design and manufacture and identify potential improvements.	EC4 EC5

3.9 Respond constructively and creatively to project and task changes and feedback.

What do learners need to demonstrate?	**Skills**
Follow steps when confirming the nature and scope of new requirements, and the process for revision or resolution. Respond constructively, importance of this and implications if this does not happen. Log and record changes throughout the design process.	EC6

Outcome 4

4. Propose and design mechanical engineering and manufacturing systems, products, components, processes and solutions, considering requirements, constraints and context

4.1 Propose and develop mechanical engineering designs to address engineering and manufacturing **requirements**.

Range:
Requirements – Design brief, specification, mechanical principles (scientific, mathematical), properties of materials.

What do learners need to demonstrate?	Skills
Take ideas and develop these into detailed designs for mechanical engineering concepts by sketching. Use annotations to demonstrate where requirements are being addressed and justify the selection of materials.	EC1 EC2 EC4 MC6

4.2 Practically model and calculate the performance of mechanical **systems** report findings.

Range:
Systems – Linear (levers, linkages), rotating (gears, flywheels), lifting machines (cranes, pulleys).

What do learners need to demonstrate?	Skills
Model and calculate the dynamic effects associated with the acceleration of mechanical systems. Determine and calculate the performance of rotating systems. Analyse the characteristics and operation of lifting machines.	EC1 MC2 MC3 MC4

4.3 Produce effective **representations** of components, using CAD software, **tools and technology.**

Range:
Representations – Sketching (freehand and isometric) 2D drawings, 3D drawings, models, simulations, accurate 3D assemblies.
Tools and technology – 3D CAD solid modelling, manual techniques.

What do learners need to demonstrate?	Skills
Use technology and tools effectively and safely. Access information and support when required. Identify when the types of representations are required or most appropriate (i.e. when to use a model rather than a 2D drawing).	EC1 DC1 DC2 DC3 DC4 DC5 DC6

4.4 Produce detailed mechanical engineering drawings to relevant **standards and codes.**

Range:
Standards and codes – 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)).

What do learners need to demonstrate?	Skills
Follow process in order to produce accurate and detailed drawings. Consider accuracy, tolerances, units of measurement and use of scale and accurate symbols when producing drawings.	MC1 MC8 DC1 DC2 DC3 DC4

4.5 Develop high-quality, working **models** that demonstrate ability to meet functional and non-functional **requirements**.

Range:
Models – Block, rapid prototyping/3D printed, one-off prototype manufacture.
Requirements – Dimensions (fit, form), aesthetics, mechanical properties, cost.

What do learners need to demonstrate?	Skills
Apply design, manufacturing and production principles and practices to develop models. Follow safe working practices that when manufacturing models using the different techniques and processes.	MC1 MC7

4.6 Use basic hand and powered **tools** safely and effectively to carry out basic **engineering processes** to meet specifications.

Range:
Tools – Screwdriver, hacksaw, hammer, files, Allen keys, spanner, socket set, wrench, glue gun, drill, pliers, rule, set square, protractor, Verner callipers, micrometres (internal, external, depth).
Engineering processes – Wasting (cutting, filing, turning, milling, grinding), shaping (casting, moulding), forming (bending, pressing), welding, 3D printing.

What do learners need to demonstrate?	Skills
Select and use appropriate basic hand and powered tools for required tasks. Carry our required checks before using tools and equipment and safe working practices before, during and after working with them – including calibration, storage and dealing with/reporting damage or concerns about functionality. Respond positively to instructions and guidance and potential implications of not doing this. Use one type of welding and one type of 3D printing when prototyping.	MC1

4.7 **Assemble** and **disassemble** mechanical systems.

Range:
Assemble – Configuration, sequence of operations, aligning, bending, fixing, mechanical jointing, pre-tensioning, sealing, sequential tightening, threaded jointing and locking devices, functional testing.
Disassemble – Release of tension/pressure, proof marking, safe use of tools.

What do learners need to demonstrate?	Skills
Use tools and equipment safely for manual assembly and disassembly mechanical engineering systems. Follow established process and protocols including relating to ensuring full training has been given.	MC1

4.8 Produce high-quality, designs of realisable mechanical systems which satisfy **requirements.**

Range:
Requirements – Standards, functional (dimensions, mechanical properties, aesthetics, maintenance), non-functional (cost, quality).

What do learners need to demonstrate?	Skills
Test and evaluate finished products	EC2
Demonstrate that finished products are suitable for commercial realisation.	EC3
Carry out checks which can ensure as far as possible designs can be manufactured, operated and maintained effectively.	MC1

Outcome 5

5. Collaborate to help manage, develop, test and quality assure mechanical engineering and manufacturing design information, systems, processes and outcomes

5.1 Follow **professional standards,** company management systems, **policies and procedures** and safe working practice.

Range:

Professional standards – Engineering Council standards, IMechE standards, IET standards.

Policies and procedures – Workplace policies, standard operating procedures, health and safety procedures (national, industry specific).

What do learners need to demonstrate?	Skills
Identify where standards and policies are located, their role under them and importance of adhering to them with consideration of potential consequences to self and others. Follow requirements for compliance with relevant national and industry health and safety requirements in relation to mechanical engineering. Assess, manage and mitigate risks present in mechanical engineering contexts.	MC1

5.2 Work effectively with others to agree and complete **tasks.**

Range:

Tasks – Design, development, investigation, research, problem solving, testing, validation, quality assurance, quality control, producing and interpreting documentation.

What do learners need to demonstrate?	Skills
Contribute effectively and respond appropriately to other inputs. Implications of different task considerations: timeframes, deadlines, dynamic contexts and conditions.	DC1 DC3 DC4 DC5 DC6 DC10

5.3 Complete detailed risk management analyses in response to project requirements.

What do learners need to demonstrate?	Skills
Carry out risk management and identify appropriate mitigation actions in mechanical engineering contexts including machining, mechanical handling and high power applications. Respond appropriately when dealing with unfamiliar situations. Consider commercial risk, how risks are ranked and what models/standards are employed to do this.	EC1 MC6 MC9

5.4 Develop and test **models** and prototypes of design proposals.

Range:
Models – Virtual, physical (block, rapid prototyping/3D printed, one-off prototype manufacture).

What do learners need to demonstrate?	Skills
Produce models using the different methodologies ranged Test, assess, report and respond to the performance of models. Carry out concept testing, functional tests, measurements and visual inspection of production prototypes.	MC1 MC5 MC10 DC1 DC4 DC6

5.5 Produce and quality assure **design information** in accordance with **professional standards** and protocols.

Range:
Design information – Proposals, specifications, engineering drawings, technical information.
Professional standards – Engineering Council standards, IMechE standards, IET standards.

What do learners need to demonstrate?	Skills
Produce, manage, quality assure and validate design information in accordance with relevant professional engineering standards and protocols. Check completed drawings for quality, technical compliance and completeness and the importance of doing so.	EC1 EC2 EC3 MC8

Outcome 6

6. Communicate proposals, design information and solutions, producing, recording and explaining engineering and manufacturing representations, systems, processes, outcomes, specifications and technical drawings.

6.1 Produce and manage **technical documentation**, using **digital tools** and appropriate conventions.

Range:
Technical documentation – Design specification, engineering drawings.
Digital tools – CAD software, document management systems, SharePoint, spreadsheets.

What do learners need to demonstrate?	Skills
Produce, amend, check, manage and version control technical documentation, using appropriate conventions, annotations and protocols, and standard document management systems. Use digital tools and technology (including collaborative types) to manage, review, update, revise, integrate, and quality assure technical and mechanical design information, data and associated documentation. Annotate mechanical engineering design drawings and representations (e.g. geometrical tolerances, limits and fits, surface finishes).	EC1, EC2, EC3, EC4, DC1, DC2, DC3, DC4

6.2 Communicate **design information** and options with technical and non-technical **audiences**, using available of **formats**.

Range:
Design information – Specifications, proposals, working drawings, representations, technical and non-technical information and data, systems, processes, projects, tasks, progress, issues, risks, solutions, outcomes.
Audiences – Relevant stakeholders, colleagues and clients.
Formats - Sketches, schemes, detailed drawings, diagrams, models, reports.

What do learners need to demonstrate?	Skills
Select suitable formats and media to present information appropriately for the audience – cost, time, availability, end user, environment, project value and scale. Clearly evidence stages of the design process – in context of project requirements. Prepare and use different media and technology to communicate mechanical engineering design information to technical and non-technical audience. Communicate and co-ordinate mechanical engineering design information with technical and non-technical audiences.	EC1, EC2, EC3, EC6, MC7, MC8, DC1, DC2, DC3

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 mechanical engineering design and development, 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 – Mechanical engineering

The Mechanical engineering occupational specialism is assessed by one practical assignment. The duration of the assessment is 33 hours and 40 minutes. Learners will be assessed against the following assessment themes:

- Health and safety
- Design and planning
- Manufacturing
- Reports.

By completing the following tasks:

Task	Typical Knowledge and skills
Task 1 – Design	Displays a breadth of knowledge and practical skills that enables them to plan and carry out the design of the prototype/ model. Candidates will need to produce documents and drawings to industry standards that clearly states how they will develop the prototype/ model in line with the brief. Candidates will need to use CAD software to produce engineering drawings as well as a virtual model. Candidates will provide feedback on their peer's engineering drawings.
Task 2 – Manufacture and test	Applies a breadth of knowledge and practical skills that enables them to carry out the manufacture and testing of the prototype/ model in accordance with their planning and designs. The task is carried out in a clear and logical sequence. Works in a safe manner, able to carry out testing and interpret and record test results accurately. Tools, materials and equipment are selected and used correctly.
Task 3 – Peer review	Engage in discussions with their peers to gain feedback on designs to inform any adaptions to their initial design prior to implementation. Able to constructively critique others designs and provide feedback and recommendations for improvements.
Task 4 – Evaluation and implementation	Displays a breadth of knowledge and understanding in the evaluation of their own design and manufacture, recommending adaptions and improvements to the model. Justifications for test methods provided, and information necessary for a third party to implement the model. Justifications for how peer review feedback was considered and implemented.

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*	***Typical evidence***	**Assessment Theme**
PO2 Analyse and interpret engineering and manufacturing requirements, systems, processes, technical drawings and specifications (16%)	T1 – Design	Design specification, annotated sketches, virtual modelling, design calculations	Design and planning Health and safety
	T2 – Manufacture and test	Manufacture of the prototype	Manufacturing
	T4 – Evaluation and implementation	Evaluation and implementation report	Reports
PO3 Evaluate systems, designs, components and processes, managing and integrating design information, proposals and specifications, to develop and improve mechanical engineering and manufacturing proposals and solutions (22%)	T1 – Design	Engineering drawings, virtual modelling, Bill of materials	Design and planning Health and safety
	T2 – Manufacture and test	Manufacture of the prototype	Manufacturing
	T4 – Evaluation and implementation	Evaluation and implementation report, revision control document	Reports
		Evaluation and implementation report	Health and safety
PO4 Propose and design mechanical engineering and manufacturing systems, products, components, processes and solutions, considering requirements, constraints and context (23%)	T1 – Design	Design specification, sketches, engineering drawings, virtual modelling	Design and planning
	T2 – Manufacture and test	Manufacture of the prototype, testing of the prototype	Manufacturing
		Records of testing	Reports
	T2 – Manufacture and test	Manufacture of the prototype, testing of the prototype	Health and safety

PO5 Collaborate to help manage, develop, test and quality assure mechanical engineering and manufacturing design information, systems, processes and outcomes (26%)	T2 – Manufacture and test	Manufacture of the prototype, testing of the prototype	Manufacturing
		Risk assessment, manufacture of the prototype, testing of the prototype	Health and safety
	T4 – Evaluation and implementation	Evaluation and implementation report, records of testing, revision control document	Reports
PO6 Communicate proposals, design information and solutions, producing, recording and explaining engineering and manufacturing representations, systems, processes, outcomes, specifications and technical drawings (13%)	T1 – Design	Engineering drawings, design specification, annotated sketches, records of testing, virtual modelling	Design and planning
	T4 – Evaluation and implementation	Evaluation and implementation report	Reports

322 Electrical and electronic engineering

Level:	3
GLH:	680
Assessment method	Practical assignment

What is this specialism about?

The purpose of this specialism is for learners to know and undertake designing and development processes within electrical and electronic engineering.

Learners will have the opportunity to plan, perform and evaluate their work whilst utilising a range of techniques, methods and resources.

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

- Knowledge of design methodologies and processes.
- Knowledge of the tools, equipment and materials used in electrical and electronic engineering.
- Knowledge of representations, symbols, conventions, and annotations used in electrical and electronic engineering.
- Skills in producing electrical and electronic drawings and representations.
- Skills in designing and developing working models.
- Skills in testing models and prototypes.

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

- What different types of electrical and electronic systems are there and what are they used for?
- What do control and electrical and electronic engineers do on a daily basis?
- What areas of the engineering industry do electrical and electronic engineers work in?

Underpinning knowledge outcomes

On completion of this specialism, learners will understand:

1. Electrical and electronic engineering knowledge criteria

Performance Outcomes

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

2. Analyse and interpret engineering and manufacturing requirements, systems, processes, technical drawings and specifications.
3. Evaluate systems, designs, components and processes, managing and integrating design information, proposals and specifications, to develop and improve electrical and electronic engineering and manufacturing proposals and solutions.
4. Propose and design electrical and electronic engineering and manufacturing systems, products, components, processes and solutions, considering requirements, constraints and context.
5. Collaborate to help manage, develop, test and quality assure electrical and electronic engineering and manufacturing design information, systems, processes and outcomes.
6. Communicate proposals, design information and solutions, producing, recording and explaining engineering and manufacturing representations, systems, processes, outcomes, specifications and technical drawings.

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

Knowledge criteria for Performance Outcomes

1.1 **Principles** of engineering design in electrical and electronic engineering.

Range:

Principles – Requirements (functionality, aesthetics, dimensions, ergonomics, safety, sustainability, cost, materials), methods of identifying requirements (market research, client interviews, client observation, product analysis)**,** methods of recording requirements (design brief, specification, questionnaire/survey forms, observational records)**,** factors that affect design (product life cycles), sustainability (recycling and re-use), safety)**,** fields within electrical and electronic engineering (manufacture and processing, maintenance, installation, servicing, repair and decommissioning), methods of communicating designs (circuit schematics, systems diagrams, wiring diagrams, breadboards, stripboards, virtual models).

What do learners need to learn?	Skills
How to agree the nature and scope of electrical and electronic engineering projects. How to identify, interpret and confirm client and customer requirements, proposals, ideas, objectives and aspirations. How to record and present client and customer requirements, and the implications of not doing so accurately or effectively. How to evaluate and develop client and customer requirements. Design requirements unique to fields within electrical and electronic engineering, and the factors that affect them. How to communicate design ideas (proposals, solutions, processes, concepts) and technical information relating to electrical and electronic engineering. The different tools for recording, evaluating and developing client and customer requirements. How to how to evaluate, develop, challenge, and refine ideas, proposals, and objectives.	EC1

1. Electrical and electronic engineering knowledge criteria

Analyse and interpret engineering and manufacturing requirements, systems, processes, technical drawings and specifications (PO2)

1.2 **Design methodologies, practices, processes**, applications and integration.

Range:

Design methodologies – Component by component circuit design, systems approach.

Practices and processes – Printed circuit board (PCB) manufacturing processes (etching, CAM milling), commercial circuit assembly processes (flow soldering, surface mount technology, through-hole construction, use of pick and place machines), electrical installation (power, lighting, three phase wiring, single phase wiring).

What do learners need to learn?	Skills
Common design methodologies, practices, processes, applications and integration, relevant to contemporary electrical and electronic engineering contexts. How electrical and electronic circuits are designed either one component at a time or through the use of the systems approach, and the advantages/disadvantages of each method. How user-centred design and inclusive design are used when designing electrical and electronic circuits, systems and products, and the benefits/limitations of each method. Practices and processes used to manufacture and assemble printed circuit boards (PCBs) and their advantages/disadvantages.	EC4 EC5

1.3 Engineering **representations**, **symbols**, conventions, and annotations used within electrical and electronic engineering contexts and activities.

Range:

Representations – Circuit diagrams, schematics, wiring diagrams, block diagrams.

Symbols – Cells, batteries, resistors (fixed, variable), capacitors (polarised, non-polarised), diodes, transformers, inductors, switches (single pole single throw (SPST), single pole double throw (SPDT), double pole single throw (DPST), double pole double throw (DPDT), sensors (light dependent resistors, thermistors, photodiodes), bipolar transistors (NPN, PNP), field effect transistors (JFET, MOSFET), relays, operational amplifiers, logic gates (NOT, AND, OR, NAND, NOR, XOR), microcontrollers, output devices (lamps, light emitting diodes, buzzers, loudspeakers, bells, motors, solenoids).

What do learners need to learn?	Skills
The purpose, benefits and limitations of different types of electrical and electronic circuit and system representations. How to recognise and interpret component symbols, conventions, component references and annotations, terminology and nomenclature used on representations of electrical and electronic circuits. Appropriate terminology and nomenclature in electrical and electronic engineering contexts and activities with consideration of the meaning, definition and application of appropriate terminology and nomenclature in electrical and electronic engineering contexts and activities including - voltage (potential difference), current, resistance, capacitance, power, conductivity, resistivity, inductance, frequency, time, electrical energy, electrical efficiency, magnetic flux, magnetic flux density. How relevant representations, symbols, conventions, and annotations are used within electrical and electronic engineering contexts and activities, and the reasons why they are used.	EC1 DC4 DC6

1.4 **Standards and regulatory requirements** relevant to electrical and electronic engineering.

Range:

Standards and regulatory requirements – IET wiring regulations (BS 7671), BS 3939, BS 8888.

What do learners need to learn?
The purpose, use and requirements of standards and regulatory requirements relevant to electrical and electronic engineering. How to interpret and use the current IET wiring regulations.

1.5 **Mathematical theory and methods**, calculations and their application.

Range:

Mathematical theory and methods – Watt’s law, resistors in series and parallel, capacitors in series and parallel, resistor colour code, electrical energy transferred, electrical work done, electrical efficiency, potential dividers.

What do learners need to learn?	Skills
How to apply mathematical theory and methods in electrical and electronic engineering contexts. How to use Watt’s law to calculate power, current and voltage. How to calculate the total resistance of series, parallel and combined series and parallel circuits. How to calculate the total capacitance of series, parallel and combined series and parallel circuits. How to use the resistor colour code to determine resistor values. How to use relevant formulae to calculate electrical energy transferred, electrical work done and electrical efficiency. How to calculate the output voltage of potential divider circuits, including light and temperature sensing circuits. How to simplify responses to electrical and electronic calculations using appropriate multiples and submultiples. How to select and use appropriate mathematical methods and calculations for design development practices in electrical and electronic engineering.	MC1 MC2 MC4 MC5 MC6 MC7

1.6 **Scientific principles** relevant to electrical and electronic engineering activities and their application.

Range:

Scientific principles – Electrostatic theory, electron theory, magnetism and electromagnetic induction, Fleming’s rules, Faraday’s laws, Lenz’s law.

What do learners need to learn?	Skills
An overview of the scientific principles relevant to electrical and electronic engineering activities, their main underpinning theories and how they are applied. How to apply the scientific principles in different electrical and electronic engineering contexts. How and why these principles affect design processes, decisions and outcomes.	MC5 MC6 MC7

Evaluate systems, designs, components and processes, managing and integrating design information, proposals and specifications, to develop and improve electrical and electronic engineering and manufacturing proposals and solutions (PO3)

1.7 Standard **electrical and electronic engineering processes and technologies.**

Range:

Electrical and electronic engineering processes and technologies –

- Electrical and electronic components, sub-assemblies and sub-systems – Resistors (fixed, variable), inductors, transformers, semiconductors (transistors (bipolar, field effect), diodes), resistors, capacitors (polarised, non-polarised), power supplies (cells, batteries, photovoltaic cells, supercapacitors), generators, switches (single pole single throw (SPST), single pole double throw (SPDT), double pole single throw (DPST), double pole double throw (DPDT), sensors and sensor sub-systems (light dependent resistors, thermistors, photodiodes, infrared sensors, proximity sensors), relays, microcontrollers, output devices (lamps, light emitting diodes, buzzers, loudspeakers, bells, motors (solar motors, servo motors, stepper motors, DC motor, AC motors), solenoids), heat pumps.
- Cable types – Single core, multicore, armoured, fire resistant, flexible, non-flexible.
- Connectors and cable termination methods - Crimp/compression connections, screw terminals, soldered connections, cable clamps, cable clips.
- Design contexts – The electricity distribution network, electrical and hybrid vehicles.
- Common circuit configurations – Amplifiers (including operational amplifier circuits), power supply architectures, pulse width modulation (PWM) circuits, timers, counters, latches, logic circuits (AND, NOT, AND, OR, NAND, NOR, XOR).
- Circuit analysis methods – DC, AC, Monte-Carlo.
- Circuit implementation technologies – PCBs (Single sided, double sided, multi-layer, flexible, chip on board (COB), hybrid), breadboard, stripboard.
- Service and environmental conditions – Surrounding air temperature, vibration, humidity.

What do learners need to learn?

Standard engineering processes and technologies relevant to electrical and electronic engineering, and their implications for design concepts, decision- making, performance and outcomes.

The operating characteristics, functions and applications of contemporary available electrical and electronic components, sub-assemblies, sub-systems, cable types and connectors. The difference between passive and active components, and examples of each.

The junction characteristics of semiconductor devices.

Common terminology used in component datasheets, including electrical and non-electrical parameters (such as thermal performance).

Specific factors to be considered when designing within contexts, including but not limited to the range given above.

The function and applications of common circuit configurations.

The principles of logic gates and logic circuits, including sequential and combinational circuits, truth tables, Boolean expressions, De Morgan's theorem and Karnaugh maps.

The purpose, selection and use of different circuit analysis methods.

Characteristics, applications and processes associated with circuit implementation technologies, and how they are used.

The effects of service and environmental conditions on electrical and electronic engineering activities.

Standards and conventions in engineering representations and technical information for electrical and electronic systems, assemblies, sub-assemblies, and components.

1.8 Verification and validation in design practices.

What do learners need to learn?

Verification activities to ensure that designs meet specifications, requirements and expectations at key stages.

Validation activities to confirm that outcomes realise or meet original specification, brief and customer/client requirements.

Propose and design electrical and electronic engineering and manufacturing systems, products, components, processes and solutions, considering requirements, constraints and context (PO4)

1.9 Design purposes, **metrics, contexts** and **constraints.**

Range:

Metrics – Budget, cost, profit, time.

Context – Market pull and technology push, commercial advantage, design for reuse, planned obsolescence, sustainability.

Constraints – Commercial factors (competition, profitability), operational factors (tools and equipment, materials, process capabilities, human resources, training needs, legal, confidentiality), design for manufacture.

What do learners need to learn?

Difference between market pull and technology push.

How contexts may influence product design.

How to calculate the cost of manufacturing (materials, labour, overheads) and profit.

The reasons why the constraints limit what can be done, the causes of these constraints and how the constraints can be overcome.

Impacts of commercial risk analysis and how it applies to project design review.

1.10 Principles, component selection and application.

What do learners need to learn?

How electrical and electronics principles, component selection and application affect key design stages, decision-making, processes and outcomes.

1.11 Effects of **non-electrical parameters.**

Range:

Non-electrical parameters – Heat, humidity, moisture, pressure, displacement, ultraviolet radiation.

What do learners need to learn?

How non-electrical parameters affect circuit/system implementation (including device placement) and enclosure design, and how these effects can be minimised.

Collaborate to help manage, develop, test and quality assure electrical and electronic engineering and manufacturing design information, systems, processes and outcomes (PO5)

1.12 **Health and safety procedures, regulations**, conduct and compliance related to electrical and electronic engineering.

Range:
Health and safety procedures – Safety management procedures, procedures and controls for prevention of electric shock (permit to work, lock out tag out (LOTO), the safe isolation procedure, earthing, discharging charged components, inspection of circuit boards, components, wiring and cables.
Regulations – Electricity Supply Regulations, Electrical Equipment (Safety) Regulations, Electromagnetic Compatibility Regulations, IET wiring regulations (BS 7671).

What do learners need to learn?
The specific health and safety procedures and protocols, and relevant legal and regulatory requirements that apply to electrical and electronic design, systems, processes, outcomes and development activities. The importance of compliance and how this is achieved. Safety management procedures including the four C's of positive health and safety (Competence, Control, Co-operation, Communication) and the hierarchy of control (elimination, reduction/substitution, isolation, controls, administration/training/safe system of work and personal protective equipment (PPE)).

1.13 **Installation** and integration of systems.

Range:
Installation – Connecting sub-systems together (connecting input/output devices to PCBs, connecting separate PCBs together, cabling and wiring), electrical installations (power circuits, lighting circuits, single and three phase circuits).

What do learners need to learn?	Skills
How to install electrical and electronic systems. How integration is achieved through bringing together individual sub-systems into one system and ensuring that the sub-systems function together as a complete system.	EC5

1.14 **Test and fault diagnostic methods** in electrical and electronic engineering.

Range:
Test and fault diagnostic methods – Visual inspection, functional testing, six-point technique, input to output checks, half split method, injection and sampling, emergent problem sequence, component isolation, unit substitution.

What do learners need to learn?	Skills
The difference between a symptom, cause and root cause of a fault.	MC1 MC2

The characteristics, benefits and limitations, selection and application of test and fault diagnosis methods. How test and diagnostic methods are used to identify common faults in electrical and electronic circuits. Common faults - Total or partial failure of components, components performing outside of tolerance, short circuits, open circuit connections, intermittent faults, power supply faults, circuit design faults, logic stuck-at faults, digital input and output faults.	

1.15 Circuit/system **verification and diagnostic equipment**.

Range:

Verification and diagnostic equipment – Multimeter, voltmeter, ohmmeter, ammeter, oscilloscope, spectrum analyser, signal generator, function generator, logic probe, logic pulser, logic analyser, insulation resistance tester, current tracer, frequency meter, AC bridge, virtual instruments.

What do learners need to learn?	Skills
The function, characteristics, applications, benefits and limitations of circuit/system verification and diagnostic equipment. What is meant by calibration of verification and diagnostic equipment and why it is needed.	MC1

1.16 **Mathematical methods and calculations.**

Range:

Mathematical methods and calculations – Equivalent circuits, statistical methods for variation in component values, time and frequency domain analysis.

What do learners need to learn?	Skills
The use of mathematical methods and calculations when developing and testing electrical and electronic circuits and systems.	EC2

Communicate proposals, design information and solutions, producing, recording and explaining engineering and manufacturing representations, systems, processes, outcomes, specifications and technical drawings (PO6)

1.17 Engineering **representations** and communication technology, media, formats and conventions.

Range:

Representations – physical models and prototypes.

What do learners need to learn?	Skills
How electrical and electronic engineering circuit, system and casing designs are communicated to customers, clients and other engineers using different methods,	EC1 EC2 EC4

including communications technologies, media, different formats and their conventions.	

1.18 **Presentation techniques** and standard requirements for design and technical information.

Range:
Presentation techniques – Models, prototypes, drawings, diagrams, specifications, charts and graphs, oral and visual presentations.

What do learners need to learn?	Skills
Presentation techniques and standard requirements for design and technical information relevant to purpose and audience, specifically in electrical and electronic engineering design contexts.	EC1 EC2 EC3 EC4

1.19 **Design and communication technologies** used within electrical and electronic engineering contexts and processes.

Range:
Design and communication technologies – PCB netlists, schematics, Verilog/VHDL.

What do learners need to learn?	Skills
How design and communication technologies are used within electrical and electronic engineering contexts and processes, and the reasons why they are used.	EC1 DC1

Practical criteria for Performance Outcomes

Outcome 2

2. Analyse and interpret engineering and manufacturing requirements, systems, processes, technical drawings and specifications

2.1 Respond effectively to projects, tasks and requirements from different **sources.**

Range:
Sources – Specifications, drawings/diagrams, concepts, stakeholders, clients, customers.

What do learners need to demonstrate?	Skills
Access, examine, review, interpret and respond effectively to electrical and electronic projects, tasks and requirements from different sources.	EC4 EC5

2.2 Define **project expectations** and requirements.

Range:
Project expectations - Materials requirements, manufacturing timescale, cost.

What do learners need to demonstrate?	Skills
Critique, challenge and confirm design project expectations and requirements appropriately, including requirement risks. Ensure full understanding of design expectations and requirements. Identify any contradictions in design brief, challenge and resolve to a coherent project requirement. Confirm effectiveness of the design project expectations and requirements.	EC4 EC5 EC6 MC6

2.3 Interpret information from available **formats, media and technology.**

Range:
Formats, media and technology – Circuit diagrams, schematics, system block diagrams, Verilog/VHDL, system and program flowcharts.

What do learners need to demonstrate?	Skills
Interpret information relevant to electrical and electronic engineering in a range of formats, media and technology. Links to digital skills when using relevant technologies to interpret technical information.	MC4 MC5 DC1

2.4 Interpret electrical and electronic process and instrument circuit/system diagrams.

What do learners need to demonstrate?	Skills
Interpret electrical and electronic process and instrument circuit/system diagrams. Critically appraise and respond effectively to relevant technical information.	MC5 MC7

2.5 Identify **inaccuracies** in circuit designs.

Range:

Inaccuracies – Incorrect positioning of components in schematics and circuit diagrams (including polarised components), incorrect symbols used, incorrect connections of components, incorrect positioning and use of system block diagram features (blocks/functions, signals, feedback loops, summing points), errors in specification criteria (including discrepancies with known standards).

What do learners need to demonstrate?	Skills
Identify inaccuracies or discrepancies in circuit diagrams, schematics, system diagrams and specifications, make necessary amendments, and propose solutions.	MC2

2.6 Verify electrical and electronic design concepts, briefs and specifications, in relation to **context, function and specific requirements.**

Range:

Context, function and specific requirements – Components, application, location, risk, environment.

What do learners need to demonstrate?	Skills
Verify electrical and electronic design concepts, briefs and specifications, in relation to the design context, intended function and the specific requirements of the design. Modify design concepts, briefs and specifications in response to feedback from stakeholders.	MC1

2.7 Use **technology** to review, analyse and interpret electrical and electronic design elements.

Range:

Technology – CAD models and simulations, spreadsheets, mathematical modelling software.

What do learners need to demonstrate?	Skills
Use appropriate technology to review, analyse and interpret electrical and electronic design elements within proposals, representations, systems, components, assemblies, products and processes.	DC1 DC4 DC6

Outcome 3

3. Evaluate systems, designs, components and processes, managing and integrating design information, proposals and specifications, to develop and improve electrical and electronic engineering and manufacturing proposals and solutions

3.1 Use **technologies** to model and evaluate electrical and electronic circuit designs.

Range:
Technologies – Breadboards, stripboards, modular kits, printed circuit boards (PCBs), circuit simulation software, programmable logic controller (PLC) and microcontroller programming and simulation software.

What do learners need to demonstrate?	Skills
Select and use appropriate technology to model and evaluate electrical and electronic design features, issues, performance and potential. Use circuit and programming simulation software.	MC1 DC1

3.2 Analyse **factors** that affect electrical and electronic design concepts, design components, and complete designs.

Range:
Factors – Materials/components required (source, availability, stock forms), application, location, risk, environment.

What do learners need to demonstrate?
Analyse factors that affect electrical and electronic design concepts, design components, and complete designs. Make suggestions and recommendations about their development, improvement, refinement and optimisation.

3.3 Use information **sources** to select engineering and manufacturing materials and components.

Range:
Sources – Drawings, diagrams, specifications, datasheets, manufacturer's/technical manuals, relevant standards and regulations.

What do learners need to demonstrate?	Skills
Use appropriate information sources, and own judgement to select, evaluate, recommend, and confirm suitable engineering and manufacturing materials and components for specific uses. Select and justify choices of materials and components with reference to the design context.	EC1 EC2 EC4 EC5 MC2 MC3

3.4 Evaluate electrical and electronic engineering circuit/system designs, components, sub-assemblies and design processes for compliance, quality and performance.

What do learners need to demonstrate?	Skills
Evaluate electrical and electronic engineering circuit/system designs, components, sub-assemblies and design processes for compliance, quality and performance, in relation to purpose, function, conditions (including material change in certain conditions) and specific requirements (including cost and value engineering).	MC7 MC9

3.5 Evaluate electrical and electronic engineering designs, design elements and design **processes** to compare design options and iteration**.**

Range:

Processes – Iterative process; Producing an initial model/prototype, testing and evaluation, producing a new iteration, repeating as a cyclic process.

What do learners need to demonstrate?	Skills
Apply the iterative design process to activities within electrical and electronic engineering contexts. Evaluate electrical and electronic engineering designs, design elements and design processes to compare design options and iterations. Deliver improvements based on this process and determine the most appropriate solutions for purpose, context and constraints, using established sound or agreed metrics.	MC4 MC5

3.6 Evaluate systems, designs, components and processes in within **electrical power engineering** contexts.

Range:

Electrical power engineering – Generation, distribution (including voltage transformation principles) and installation (including cable types).

What do learners need to demonstrate?	Skills
Evaluate systems, designs, components and processes in relation to power generation, distribution and installation. How to manage and integrate relevant design information and develop and improve proposals and solutions accordingly. Perform calculations relevant to electrical power engineering design contexts.	DC4 DC6

3.7 Confirm electrical and electronic **test** results.

Range:
Test – Visual inspection, functional testing, six point technique, input to output checks, half split method, injection and sampling, emergent problem sequence, component isolation, unit substitution.

What do learners need to demonstrate?	Skills
Accurately record and report the outcomes of testing, modelling and research using appropriate methods. Consider the relevance, implications, and value of electrical and electronic test results, with reference to the original purpose and relevant design context.	MC6 DC4

3.8 Reflect on methods, quality, standards and performance within different **stakeholders.**

Range:
Stakeholders – As an individual, within a team, organisation-wide.

What do learners need to demonstrate?	Skills
Reflect upon, review, develop and seek to improve methods, quality, standards and performance across electrical and electronic engineering design and manufacture, within different stakeholders.	EC6 MC9 MC10

3.9 Respond positively to required changes and feedback.

What do learners need to demonstrate?	Skills
Respond constructively and creatively to project and task changes and feedback. Work with other relevant people to confirm the nature and scope of new requirements and the process for revision or resolution.	EC6

Outcome 4

4. Propose and design electrical and electronic engineering and manufacturing systems, products, components, processes and solutions, considering requirements, constraints and context

4.1 Design and **model** electrical and electronic engineering concepts, components and features.

Range:
Model – Breadboards, stripboards, modular kits, virtual models.

What do learners need to demonstrate?	Skills
Design and model electrical and electronic engineering concepts, components and features, and how to develop existing design elements and proposals, to address or solve engineering and manufacturing challenges.	EC1 EC2 EC3

4.2 Develop effective electrical and electronic engineering solutions to satisfy **requirements.**

Range:
Requirements – Functional and non-functional requirements (including cost and quality), relevant standards, manufacturability, ability to be proven, operated and maintained effectively.

What do learners need to demonstrate?	Skills
Develop effective electrical and electronic engineering solutions which meet functional and non-functional requirements, satisfy the required standards and can be manufactured, proven, operated and maintained effectively.	MC5

4.3 Use CAD software to produce electrical and electronic engineering **diagrams, models and simulations.**

Range:
Diagrams, models and simulations – Circuit diagrams, system block diagrams, PCB layouts.

What do learners need to demonstrate?	Skills
Use CAD software, tools and technology to produce detailed electrical and electronic engineering circuit and system diagrams to relevant standards and codes, including BS 3939. Use simulation program with integrated circuit emphasis (SPICE) software to model and simulate circuit designs, including investigating the behaviour of electricity within circuits.	MC7 DC1 DC2 DC5 DC6

4.4 Apply **knowledge and understanding** to design electrical and electronic **systems, products**, components and solutions.

Range:

Knowledge and understanding – Electrical and electronic principles, scientific and mathematical understanding, knowledge of material and component properties, manufacturing and production processes.

Systems and products – Small power systems, lighting products and systems, security products and systems, temperature control systems.

What do learners need to demonstrate?	Skills
Application of knowledge and understanding of relevant electrical and electronic principles, (including scientific and mathematical understanding and methods), materials and components, and relevant manufacturing and production processes to propose and design electrical and electronic systems, products, components and solutions. Complete of high-quality, producible designs, ready for realisation, using appropriate technology, tools and equipment.	EC4 MC2 MC3 MC4 MC6 MC9 DC1

4.5 Use hand and powered **tools** safely and effectively for specific **purposes**, checking them before use and storing them appropriately.

Range:

Tools – Soldering irons, wire cutters, wire strippers, de-soldering tools, pliers, helping hands, drills (including PCB drills), screwdrivers, hand and power saws.

Purposes – Populating and assembling PCBs, producing circuit prototypes, producing and fitting circuits to casings, installing circuits and cabling.

What do learners need to demonstrate?	Skills
Use tools correctly and safely, the correct use of associated PPE for tools and tool inspection requirements. Application of technology to finalise design ready for realisation. Select tools and equipment appropriate for purpose, that will be required for next stages of the design as part of preparation for realisation stage.	MC1

4.6 Carry out **engineering processes and activities** safely**.**

Range:

Engineering processes and activities – Cutting, drilling, milling, shaping, forming, PCB production, soldering, 3D printing.

What do learners need to demonstrate?	Skills
Safely carry out basic engineering processes according to straightforward specifications, instructions and guidance. Use either milling or etching to produce PCBs.	MC1

Outcome 5

5. Collaborate to help manage, develop, test and quality assure electrical and electronic engineering and manufacturing design information, systems, processes and outcomes

5.1 Work in accordance with **professional standards**, and company management systems, policies and procedures.

Range:
Professional standards – Codes of practice, rules of conduct, ethics, technical competence.

What do learners need to demonstrate?
Follow professional standards and processes (confidentiality, accountability) and throughout activity and the importance and implications of doing so. Comply with and follow company standards and processes throughout design and development activities.

5.2 Comply with **health and safety requirements and regulations** and **risk** assessments.

Range:
Requirements and regulations – Health and Safety at Work Act, Electricity Supply Regulations, Electricity at Work Regulations, Electrical Equipment (Safety) Regulations, Electromagnetic Compatibility Regulations, Control of Substances Hazardous to Health (COSHH), Personal Protective Equipment at Work Regulations, Provision and Use of Work Equipment (PUWER), lifting operations and lifting equipment regulations (LOLER), IET wiring regulations (BS 7671).
Risks – Electric shock (burns, muscle damage, neurological damage, heart stoppage, electrocution/death), fire, arc flash.

What do learners need to demonstrate?
Work safely at all times by complying with relevant national and industry health and safety requirements. Assess, manage and mitigate risks present in electrical and electronic engineering contexts, including dangers presented by working with high power and high voltage equipment.

5.3 Work effectively with others to agree and complete **tasks.**

Range:
Tasks – Design, development, investigation, research, problem solving, testing, validation, quality assurance, quality control, producing and interpreting documentation.

What do learners need to demonstrate?	Skills
Contribute effectively and respond appropriately to other inputs. Implications of different task considerations: timeframes, deadlines, dynamic contexts and conditions.	DC1 DC3 DC4 DC5 DC6 DC10

5.4 Complete detailed **risk management analyses.**

Range:
Risk management analyses – Identify risks, evaluate risks, implement risk handling and control measures.

What do learners need to learn?	Skills
Complete detailed risk management analyses in response to specific requirements, projects and activities within in electrical and electronic engineering.	EC3 MC6

5.5 Develop and **test** models and prototypes.

Range:
Test – Concept testing, testing of production prototypes.

What do learners need to demonstrate?	Skills
Develop and test models and prototypes for different purposes and design questions, including technical function. Investigate and analyse tests, performance, and results. Report and respond to findings of tests.	EC1 EC4 EC5 MC1 MC5 DC6

5.6 Produce and quality assure **design information** in accordance with **professional standards** and protocols.

Range:
Design information – Proposals, specifications, engineering drawings, technical information.
Professional standards – Engineering Council standards, IET standards.

What do learners need to demonstrate?	Skills
Develop, test and quality assure information, systems, outcomes relating to earthing and lightning protection. Produce, manage, quality assure and validate design information in accordance with relevant professional engineering standards and protocols. Check completed drawings for quality, technical compliance and completeness and the importance of doing so. Investigate, check and confirm relevant electrical and electronic design proposals, information, models or prototypes, and outcomes.	EC1 EC2 EC3 MC8

Outcome 6

6. Communicate proposals, design information and solutions, producing, recording and explaining engineering and manufacturing representations, systems, processes, outcomes, specifications and technical drawings

6.1 Communicate **proposals, design information and solutions.**

Range:
Proposals, design information and solutions – Engineering and manufacturing representations, systems, processes, outcomes, specifications and technical drawings.

What do learners need to demonstrate?	Skills
Communicate proposals, design information and solutions using different methods. Produce, record and explain engineering and manufacturing representations, systems, processes, outcomes, specifications and technical drawings.	EC1 EC2 EC3 EC4 EC6 DC3

6.2 Produce technical documentation, using industry **conventions.**

Range:
Conventions – Annotations, protocols, document management systems.

What do learners need to demonstrate?	Skills
Application of ISO 9001 standards to document and drawing preparation, amendment, checks, management and version control. Produce accurate drawings and technical information using correct annotations, conventions and symbols. Labelling of components, products, processes and outcomes, best practice in how to do this and the importance of doing so.	EC5 MC7 MC8 DC1 DC2

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 electrical and electronic engineering design and development, 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 – Electrical and electronic engineering

The Electrical and electronic engineering occupational specialism is assessed by one practical assignment. The duration of the assessment is 33 hours and 40 minutes. Learners will be assessed against the following assessment themes:

- Health and safety
- Design and planning
- Manufacturing
- Reports.

By completing the following tasks:

Task	Typical Knowledge and skills
Task 1 - Design	Displays a breadth of knowledge and practical skills that enables them to plan and carry out the design of the prototype/ model. Candidates will need to produce documents and drawings to industry standards that clearly states how they will develop the prototype/ model in line with the brief. Candidates will need to use CAD software to produce a virtual model.
Task 2 – Manufacture and test	Applies a breadth of knowledge and practical skills that enables them to carry out the manufacture and testing of the prototype/ model in accordance with their planning and designs. The task is carried out in a clear and logical sequence. Works in a safe manner, able to carry out testing and interpret and record test results accurately. Tools, materials and equipment are selected and used correctly.
Task 3 – Peer review	Engage in discussions with their peers to gain feedback on designs to inform any adaptions to their initial design prior to implementation. Able to constructively critique others designs and provide feedback and recommendations for improvements.
Task 4 – Evaluation and implementation	Displays a breadth of knowledge and understanding in the evaluation of their own design and manufacture, recommending adaptions and improvements to the model. Justifications for test methods provided, and information necessary for a third party to implement the model. Justifications for how peer review feedback was considered and implemented.

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*	***Typical evidence***	**Assessment Theme**
PO2 Analyse and interpret engineering and manufacturing requirements, systems, processes, technical drawings and specifications (16%)	T1 – Design	Design specification, virtual modelling, design calculations records of the results of testing the physical model, engineering drawings (wiring diagram/ circuit diagram)	Design and planning Health and safety
	T2 – Manufacture and test	Design specification Manufacture of the prototype	Manufacturing
	T4 – Evaluation and implementation	Evaluation and implementation report	Reports
PO3 Evaluate systems, designs, components and processes, managing and integrating design information, proposals and specifications, to develop and improve electrical and electronic engineering and manufacturing proposals and solutions (22%)	T1 – Design	Engineering drawings (wiring diagram/ circuit diagram), virtual modelling, Bill of materials	Design and planning Health and safety
	T2 – Manufacture and test	Manufacture of the prototype Revision document and any updated drawings	Manufacturing
	T4 – Evaluation and implementation	Evaluation and implementation report	Reports
		Evaluation and implementation report	Health and safety
PO4 Propose and design electrical and electronic engineering and manufacturing systems, products, components, processes and solutions, considering requirements, constraints and context (23%)	T1 – Design	Design specification, virtual modelling	Design and planning
	T2 – Manufacture and test	Manufacture of the prototype, testing of the prototype	Manufacturing
		Records of testing	Reports
	T2 – Manufacture and test	Manufacture of the prototype, testing of the prototype	Health and safety

PO5 Collaborate to help manage, develop, test and quality assure electrical and electronic engineering and manufacturing design information, systems, processes and outcomes (26%)	T2 – Manufacture and test	Manufacture of the prototype, testing of the prototype Revision control form	Manufacturing
		Risk assessment, Manufacture of the prototype, testing of the prototype	Health and safety
	T4 – Evaluation and implementation	Evaluation and implementation report, records of testing	Reports
PO6 Communicate proposals, design information and solutions, producing, recording and explaining engineering and manufacturing representations, systems, processes, outcomes, specifications and technical drawings (13%)	T1 – Design	Engineering drawings (wiring diagram/ circuit diagram) design specification, annotated sketches, records of testing, virtual modelling	Design and planning
	T4 – Evaluation and implementation	Evaluation and implementation report	Reports

323 Control and instrumentation engineering

Level:	3
GLH:	680
Assessment method:	Practical assignment

What is this specialism about?

The purpose of this specialism is for learners to know and undertake designing and development processes within Control and Instrumentation.

Learners will have the opportunity to plan, perform and evaluate their work whilst utilising a range of techniques, methods and resources.

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

- Knowledge of instrumentation and control systems used in process control.
- Knowledge of the process control systems and controllers.
- Knowledge of basic features and configurations of control systems.
- Skills in the process of tuning techniques.
- Skills in design process for a process control system.

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

- What differences are there in the control systems found on modern motor vehicles, aircrafts and robots?
- What different types of control systems are there and what are they used to control?
- What do control and instrumentation engineers do on a daily basis?
- What areas of the engineering industry do control and instrumentation engineers work in?

Underpinning knowledge outcomes

On completion of this specialism, learners will understand:

1. Control and instrumentation engineering knowledge criteria.

Performance Outcomes

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

2. Analyse and interpret control and instrumentation engineering and manufacturing requirements, systems, processes, technical drawings and specifications.
3. Evaluate systems, designs, components and processes, managing and integrating design information, proposals and specifications, to develop and improve control and instrumentation-related engineering and manufacturing proposals and solutions.
4. Propose and design control and instrumentation-related engineering and manufacturing systems, products, components, processes and solutions, considering requirements, constraints and context.
5. Collaborate to help manage, develop, test and quality assure control and instrumentation related engineering and manufacturing design information, systems, processes and outcomes.
6. Communicate proposals, design information and solutions, producing, recording and explaining engineering and manufacturing representations, systems, processes, outcomes, design specifications and technical drawings.

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

Knowledge criteria for Performance Outcomes

1.1 **Principles** of engineering design in control and instrumentation engineering.

Range:

Principles - Requirements (desired states, outcomes, processes, operational parameters, components, specifications), methods of identifying requirements (technical documentation, client meetings, client requirements, feedback, reviewing and analysing of system), methods of recording requirements (reports, questionnaires, feedback forms, software), factors that affect design (environment, usage, life span of components, safety, sustainability), fields within control and instrumentation engineering (manufacturing, processing, control systems, maintenance, installation), methods of communicating designs (briefs, reports, technical documents, diagrams, flowcharts, emails, meetings).

What do learners need to learn?	Skills
How to agree the nature and scope of control and instrumentation engineering projects. How to identify, interpret and confirm client and customer requirements, proposals, ideas, objectives and aspirations. How to record client and customer requirements, using standard compliance methods and the implications of not doing so accurately or effectively. How to evaluate and develop client and customer requirements. Design requirements unique to fields within control and instrumentation engineering, and the factors that affect them. How to communicate design ideas (proposals, solutions, processes, concepts) and technical information relating to control and instrumentation engineering. The different tools for recording, evaluating and developing client and customer requirements. How to how to evaluate, develop, challenge, and refine ideas, proposals, and objectives.	EC1

Analyse and interpret control and instrumentation engineering and manufacturing requirements, systems, processes, technical drawings and specifications (PO2)

1.2 Design **methodologies** used in contemporary control and instrumentation engineering and manufacturing contexts.

Range:

Methodologies – Practices, processes, applications and integration**,** structural assessment surveys, concept design, control systems (block diagrams, instrumentation systems, elements belonging to an instrumentation system, system terminology).

What do learners need to learn?	Skills
Methodologies and technical information required. How to design methodologies using the correct terminology considering key elements required for the operation of a system – including accuracy, error, linearity, reliability, sensitivity, resolution range, span, zero drift, set point. The use of block diagrams in specific control and instrumentation applications. The purpose of an instrumentation system used for making measurements The elements required for a system to operate using signal processor, sensors and how to interpret data. Tendering, bid phase and contract award.	MC2 EC4

1.3 Engineering **representations** used in control and instrumentation engineering contexts and activities.

Range:

Representations – Drawings and diagrams (sketches, circuit diagrams, block diagrams, wiring diagrams, electrical drawing), diagrams, technical information, charts, graphs, software, notes, spreadsheets, software, ladder logic, symbols, conventions, process flowcharts, specifications, manuals, instructions, reports, results, statements.

What do learners need to learn?	Skills
Application of engineering representations within control and instrumentation as part of design proposals and the design process. Symbols, conventions and annotations including how they are applied in technical documentation – Annotations including standard notation, terminology and nomenclature. Methods of communications used when sharing or collaborating on engineering representations including - internet, verbal, presentations, reports, briefs, meetings, emails.	EC1 EC2 EC4 MC1 MC4 MC5 DC1

1.4 Engineering **standards and regulatory requirements** relevant to control and instrumentation.

Range:

Standards and regulatory requirements – Safe working practices, legal requirements (BS standards, IET regulations), Health and Safety procedures, organisational standards, isolation requirements, IEC standards 61355 (consistent terminology, structure, control, versioning, legibility), ISO standards, HSE guidance, EMC directive.

Legal requirements/regulations – Traceability, revisions management, British Standard ISO9001, The General Data Protection Regulation 2016/679.

What do learners need to learn?	Skills
Maintain and comply with current engineering Standards. Standards and regulatory requirements relevant to design, control and instrumentation activities. Standards, regulations and legal requirements that must be adhered to and complied with when managing, creating, editing, storing and using technical documentation – with consideration of traceability, revisions management, British Standard ISO9001, The General Data Protection Regulation 2016/679.	EC4 EC6 MC5 DC3

1.5 Mathematical **methods** used in control and instrumentation engineering contexts.

Range:
Methods – Percentages (tolerances, efficiencies), substitution, formula, measurements, logarithms, exponential, Indices, linear equations, straight line graphs, calculus, transposition, complex numbers, trigonometry, radians and statistical techniques, Boolean algebra, partial fractions, differentiation and integration.

What do learners need to learn?	Skills
How mathematical methods are applied to engineering control and instrumentation practices. Mathematical methods used to aid designs and calculate predicted efficiency and outcomes of system.	MC2 MC4 MC7 EC4

1.6 **Principles** relevant to control and instrumentation engineering activities.

Range:
Principles –

- Scientific principles – Magnetism, electromagnetism, Ohm's law, capacitance, inductance, measurement of temperature, linear displacement, angular displacement, speed and velocity, force, mass and acceleration, pressure in fluids
- Electrical principles – Ohm's law, resistivity, capacitance, inductance, motor principles, magnetism, electromagnetism, ac and dc theory.
- Mechanical principles – Fluid control, pneumatics and hydraulics, speed, velocity, acceleration and pressure.

What do learners need to learn?	Skills
Scientific principles, including Mechanical and Electrical principles, used in Control and Instrumentation designing processes. How scientific principles are applied during control and instrumentation engineering design activities and their potential impacts on the design process - how design processes, decisions and outcomes can be affected by scientific principles.	EC4 MC2 MC4 DC4

Evaluate systems, designs, components and processes, managing and integrating design information, proposals and specifications, to develop and improve control and instrumentation-related engineering and manufacturing proposals and solutions (PO3)

1.7 Engineering **processes** and **technologies** relevant to control and instrumentation, and their implications for the design process.

Range:
Processes – Concept, decision-making, performance, outcomes, plans, research, requirements, specifications, approach, evaluations, proposals, considerations (environmental, effects, standards and conventions), implementation.
Technologies – Components and sub-assemblies (controllers, valves, sensors), configurations (PID, adaptive control), combinational and sequential logic and control systems, microcontrollers, programmable logic controller (PLC).

What do learners need to learn?	Skills
Engineering technologies utilised in design processes. Engineering processes followed as part of a design process. The function and application of technologies relevant to process control and instrumentation. The technologies used to measure pressure, light, sound, temperature, flow, level, distance, weight, size, electrical signals (digital, analogue), density, viscosity, pH.	EC4 EC5 MC1 MC4 MC5 DC4

1.8 **Verification** and **validation** in design practices.

Range:
Verification – Examination, analysing, evidence, expectations.
Validation – Requirements, expected output, specifications (pressure, sensors, signal processing, flow rate, positioning, measurements).

What do learners need to learn?	Skills
Verification methods used in design practices and understand the application of verification methods to confirm specifications and requirements of the design are met. Validation methods to confirm outcomes are achieved.	MC4 MC5 DC4

Propose and design control and instrumentation-related engineering and manufacturing systems, products, components, processes and solutions, considering requirements, constraints and context (PO4)

1.9 How the **context** of the design purpose can affect the design process.

Range:
Context – Wider factors (organisational, user, environment), economic restrictions (financial constraints, budgeting), legislations or regulatory constraints, commercial and operational factors.

What do learners need to learn?	Skills
Factors associated with design context. How context of design purpose can interfere and restrict the design process. Methods used to ensure full understanding of a design purpose (methods - Analysis, research (Project design, production methods, technical information, operational conditions, scale of operation, cost, size, style), questioning) How potential issues, sustainability, quality, timescales and human resources can implicate design processes.	EC1 EC6 MC5 MC7 DC3

1.10 **Impacts** of electrical and electronics **principles.**

Range:

Impacts – On constants, results, parameters, response times, inputs, outputs, charging and discharging, leakage, tolerance.

Principles – Potential dividers, operational amplifiers, Wheatstone bridge, interfaces, analogue to digital convertors and digital to analogue convertors.

What do learners need to learn?	Skills
Principles of electrical and electronic circuits within control and instrumentation including application of controlling, measuring and monitoring processes. How different components and equipment can impact and change the outcome of the design. The interfaces of signal conventions and standard interfaces on the design of control systems.	EC4 EC6 MC4 MC5 MC7 DC4

1.11 Effects of different **parameters** on control and instrumentation system design.

Range:

Parameters – Process variable (accuracy and error, hysteresis, linearity, response time, sensitivity), calibration, quantity, value, instruction, stability.

What do learners need to learn?	Skills
Parameters and how parameters are set, altered and implemented as per system requirements. How parameters can affect visual and sound system outputs for desired purpose.	EC4 MC5 DC2

1.12 Effects of **mechanical loadings** on structures and components.

Range:

Mechanical loadings – weight, torque, fatigue, aerodynamics, force (shear, tensile), stress, strain, elasticity, Hooke's law, ductility, brittleness, malleability, mass, moments.

What do learners need to learn?	Skills
Effects of the ranged of loadings and their impacts on different types of structures in relation to control and instrumentation. How loadings can impact the condition and serviceability of components. How the effects of forces and loading can be minimised.	EC4 MC4 DC4

1.13 Mathematical **methods and calculations** for design development practices in control and instrumentation.

Range:

Methods and calculations – Complex numbers, frequency domain analysis, trigonometric methods, mensuration, calculus, statistical Techniques, S-plane, partial fractions, algebraic methods, three term controller constants.

What do learners need to learn?	Skills
How mathematical methods are applied to the control and instrumentation design and development practices. How calculations are implemented to aid with designing of practice. specifications, installation requirements and setting up of components.	EC4 MC4 DC4

Collaborate to help manage, develop, test and quality assure control and instrumentation related engineering and manufacturing design information, systems, processes and outcomes (PO5)

1.14 **Health and safety** procedures, conduct and compliance.

Range:
Health and Safety – Risk assessments, guidance, organisational procedures and policies, Electricity at work act 1989, Safe use of work equipment, Provision and Use of Work Equipment Regulations 1998, Puwer, Manual Handling Operations Regulations 1992, Construction Design and Management 2015.

What do learners need to learn?	Skills
How to comply with Health and Safety procedures relevant to design engineering activities including organisational and industry procedures. Ensure proper conduct through the following of procedures and understand rules, roles and responsibilities in place to maintain the required level of Health and Safety.	EC4 DC2

1.15 **Installation** and **integration** of systems.

Range:
Installation – Customer requirements, regulation requirements, 1st fix, 2nd fix of components, commissioning, isolation, manufacturers specifications.
Integration – Combining of system, functions, designs, planning, processes.

What do learners need to learn?	Skills
Requirements, procedures and considerations for installation of engineering and manufacturing systems. Integration processes in relation to systems and installation.	EC5

1.16 Test and diagnostic **methods** in control and instrumentation engineering.

Range:
Methods – Corner analysis, function/performance testing, half-split technique, unit substitution, input output technique, injection and sampling, equipment self-diagnostics six-point technique, emergent sequence.

What do learners need to learn?	Skills
Testing and diagnostic methods used within control and instrumentation engineering.	MC5 EC5

1.17 Control and instrumentation verification and diagnostic **equipment**.

Range:

Equipment – Multimeter, signal generator, oscilloscope, logic probe, logic analyser, data logger, temperature gauge, flow meter, power meter.

What do learners need to learn?	Skills
Types of verification and diagnostic equipment used to aid with diagnostic and verification processes within engineered systems. How to use each type of equipment accurately, safely and for correct purpose.	MC5

1.18 Mathematical and **data science** methods and calculations.

Range:

Data science – Equivalent circuits, statistical methods for variation in component values, time and frequency domain analysis, diagnostic data analysis techniques, machine learning.

What do learners need to learn?	Skills
Data science methods and calculations used in relation to control and instrumentation design and development. Standard applications of data science including – Poisson distribution, normal distribution and linear correlation.	MC2 MC5

Communicate proposals, design information and solutions, producing, recording and explaining engineering and manufacturing representations, systems, processes, outcomes, design specifications and technical drawings (PO6)

1.19 **Presentation techniques** and **technologies** for design and technical information.

Range:

Presentation – Design information (plans, processes, planning, quality, outcomes), processes, methods, Health and Safety information, standardised information.

Techniques – Software, verbal, discussion, briefing, visual aids, graphical representations.

Technologies – Collaborative technologies (computer systems, data systems, recording systems, electronic document and management systems).

What do learners need to learn?	Skills
Design and technical information within control and instrumentation engineering and manufacturing design. Effective methods in communicating design and technical information to audiences including the application of design and communication technologies.	DC1

Outcome 2

2. Analyse and interpret control and instrumentation engineering and manufacturing requirements, systems, processes, technical drawings and specifications

2.1 Interpret requirements from available **sources** and **formats.**

Range:
Sources – Specifications, concepts, stakeholders, instructions, manufacturers requirements, client requirements, guidance.
Formats – Media and technology (BIM; PIM; CAD, process flowcharts; Circuit/system diagrams; Verilog/VHDL).

What do learners need to demonstrate?	Skills
Collate and interrogate information from a range of available sources and formats, to identify brief requirements to; • Produce a specification that's technical and operational • Evaluate different solutions to the project specification • Monitor and record achievements Evaluate and summarise requirements for system and design specifications.	EC4 EC5 MC4 MC5 MC9 DC1 DC4 DC6

2.2 Challenge and confirm design **project expectations** and requirements.

Range:
Project expectations - Materials requirements, manufacturing timescale, cost.

What do learners need to demonstrate?	Skills
Ensure full understanding of design expectations and requirements. Upon evaluation and summarisation of project expectations and requirements, highlight potential challenges. Identify any contradictions in design brief, challenge and resolve to a coherent project requirement. Confirm effectiveness of the design project expectations and requirements.	EC4 EC6 DC1

2.3 Interpret control and instrumentation process flowcharts.

What do learners need to demonstrate?	Skills
Interpret control and instrumentation process flowcharts and applications. Apply methods to interpret process flowcharts accurately and follow process flow charts as part of a sequence. Interpret symbols used in flowcharts following key/ legend.	DC1

2.4 Identify and amend **inaccuracies** in drawings and specifications.

Range:
Inaccuracies – Dates, data, information, steps, discrepancies, content, procedures, components, equipment, identification, errors, specifications.

What do learners need to demonstrate?	Skills
Identify inaccuracies within drawings and specifications. Make amendments and annotations where appropriate, following correct procedures and protocols with consideration of Limits of own authority, reporting, supervisory checks, industry standards, communication, questioning, validate, verify.	EC4 MC1 MC2 DC1

2.5 Verify control and instrumentation concepts in relation to specific **requirements.**

Range:
Requirements – Materials, components, application, location, risk, environment.

What do learners need to demonstrate?	Skills
Inspect and analyse control and instrumentation specifications. Verify accuracy of control and Instrumentation specifications with consideration of context, functions and specific requirements. Verify specifications are correct following procedures.	MC4 MC5 MC6 MC7

2.6 Use **technology** to **interpret** control and instrumentation elements in designs.

Range:
Technology – Software, digital and analogue.
Interpret – Proposals, representations, systems, components, assemblies, products and processes.

What do learners need to demonstrate?	Skills
Identify and use appropriate technology to review, analyse and interpret design data to ensure full understanding and to aid in the subsequent stages of the development process.	EC2

Outcome 3

3. Evaluate systems, designs, components and processes, managing and integrating design information, proposals and specifications, to develop and improve control and instrumentation-related engineering and manufacturing proposals and solutions.

3.1 Use **technology** to model and evaluate control and instrumentation.

Range:
Technology – Mathematical software, analytical software, modelling software, simulation software.

What do learners need to demonstrate?	Skills
Use technology to create prototypes of designs and perform mathematical calculations relevant to control and instrumentation design contexts. Evaluate features, functionality, performance, potential outcomes and efficiency of design systems using technology.	DC1 DC4 DC6 MC5

3.2 Analyse **factors** affecting control and instrumentation design concepts and components, and complete designs.

Range:
Factors – Materials, applications, locations, risks and environments.

What do learners need to demonstrate?	Skills
Follow processes for analysing factors which may affect design concepts and components required. Make suggestions and recommendations about development, improvement, refinement and optimisation.	EC4 EC5

3.3 Evaluate control and instrumentation engineering designs, design elements, and design processes.

What do learners need to demonstrate?	Skills
Complete evaluation on proposed engineering designs, elements and processes. Complete reviews for compliance, quality, success and performance as part of evaluation process. Ensure requirements, costing and specifications have been achieved. Identify edge cases and any required changes (material change in certain conditions) and specific requirements (cost and value engineering).	MC4 MC5 MC6 MC7 MC9 MC10

3.4 Use **information sources** and judgement to confirm suitable engineering and manufacturing materials for specific uses.

Range:

Information sources – Standards, manufacturers datasheets, legislation, technical manuals, drawings, diagrams.

What do learners need to demonstrate?	Skills
Use different types of information sources available when selecting materials for specific use. Use information sources to ensure suitable engineering and manufacturing materials are selected for specific use. Justify choices for selection of materials with reference to context.	MC1 MC2 EC4

3.5 Evaluate control and instrumentation designs, comparing **options** to deliver improvements.

Range:
Options – solutions, alternative designs, costs.

What do learners need to demonstrate?	Skills
Optimise the design for a particular parameter. Compare options when evaluating designs. Implement comparison findings to suggest and deliver improvements.	EC4 MC2 MC3

3.6 Evaluate designs in relation to power generation, distribution and **installation**.

Range:
Installation – Cable types, customer requirements, regulation requirements, 1st fix, 2nd fix of components, commissioning, isolation, manufacturers specifications.

What do learners need to demonstrate?	Skills
Evaluate designs in relation to power generation to ensure the correct distribution systems and installation methods have been selected. Evaluate the selection of components and cables, ensuring the correct selection for the power generation, distribution (voltage transformation requirements) and installation requirements.	MC5

3.7 **Review** and use instrumentation test results to **improve processes**.

Range:
Review – Purpose and context, recording and reporting on tests, modelling and research.
Improve – Individually, within teams, organisation wide.
Processes – Quality, standards, performance**,** repeatability.

What do learners need to demonstrate?	Skills
Follow processes for obtaining instrument test results and implement as part of a review process. Appropriate application of test results obtained to review the effectiveness and success of the instrumentation process. Use information obtained as part of review is used to check and confirm success of the systems.	EC4

3.8 Respond to feedback and changes required to process.

What do learners need to demonstrate?	Skills
Obtain and review feedback provided, acknowledging the feedback constructively. Confirm the nature and scope of new requirements. Follow procedures involved with implementing required changes to the process.	EC4

Outcome 4

4. Propose and design control and instrumentation-related engineering and manufacturing systems, products, components, processes and solutions, considering requirements, constraints and context

4.1 Design and model control and instrumentation engineering processes to solve engineering and manufacturing **challenges.**

Range:
Challenges – Concepts, component design and selection, improve features.

What do learners need to demonstrate?	Skills
Design processes including developing prototypes and usability testing to solve engineering and manufacturing challenges. Carry out modelling as part of the design process in order to check and test functionality and performance of selected components and process. Develop existing design elements and proposals to address manufacturing challenges.	EC1 EC2 EC3 MC5 MC10

4.2 Develop control and instrumentation engineering solutions to satisfy required standards and meet functional and non-functional **requirements.**

Range:
Requirements – Cost, weight, quality, schedule.

What do learners need to demonstrate?	Skills
Develop a design that fulfils the criteria. Produce a viable engineering solution that can be manufactured, proven, operated and maintained effectively.	EC4

4.3 Design and produce control and instrumentation **engineering diagrams.**

Range:
Engineering diagrams – Circuit diagrams, system block diagrams, wiring diagrams.

What do learners need to demonstrate?	Skills
Produce diagrams to using correct annotations, symbols and conventions. Use digital technology to produce engineering diagrams including CAD software. Propose and design control and instrumentation systems applying relevant principles and design processes to achieve desired outcome.	EC1 EC2 EC3 EC4 MC4 DC1 DC2 DC5 DC6

4.4 Use **technology**, **tools** and equipment to complete designs, ready for realisation.

Range:

Technology – CAD, CAM, CNC.

Tools – Screwdriver, wire cutters, wire strippers, soldering iron, hacksaw, hammer, files, Allen keys, spanner, socket set, wrench, crimping tools, heat gun, glue gun, drill, pliers (flat nose, needle nose, angle needle nose), rule, set square, PCB, stripboard.

What do learners need to demonstrate?	Skills
Use tools correctly and safely, the correct use of associated PPE for tools and tool inspection requirements. Application of technology to finalise design ready for realisation. Select tools and equipment appropriate for purpose, that will be required for next stages of the design as part of preparation for realisation stage.	MC1 MC2

4.5 Carry out basic **engineering processes** to meet specifications.

Range:

Engineering processes – Modular prototyping, calibrations, electrical safety checks, function checks.

What do learners need to demonstrate?	Skills
Carry out basic engineering processes to ensure design process specifications and requirements are achieved.	EC4 MC1 MC3 MC6 MC7

Outcome 5

5. Collaborate to help manage, develop, test and quality assure control and instrumentation related engineering and manufacturing design information, systems, processes and outcomes

5.1 Follow professional and company **standards** and processes.

Range:
Standards – Codes of practice, rules of conduct, ethics, technical competence.

What do learners need to demonstrate?	Skills
Follow professional standards and processes (confidentiality, accountability) and throughout activity and the importance and implications of doing so. Comply with and follow company standards and processes throughout design and development activities.	EC4 MC9 DC1

5.2 Follow **safe systems of working**.

Range:
Safe systems of working – Procedures, safe working practices, hazard identification, risk reduction.

What do learners need to demonstrate?	Skills
Apply safe systems of work within engineering and manufacturing design activities and the assessment, managing and mitigation of risks. Work safely in order to reduce harm to self and others and appropriate methods and remit for doing so.	EC4 DC1

5.3 Work effectively with others to agree and complete **tasks.**

Range:
Tasks – Design, development, investigation, research, problem solving, testing, validation, quality assurance, quality control, producing and interpreting documentation.

What do learners need to demonstrate?	Skills
Contribute effectively and respond appropriately to other inputs. Implications of different task considerations: timeframes, deadlines, dynamic contexts and conditions.	DC1 DC3 DC4 DC5 DC6 DC10

5.4 Complete **risk management analysis**.

Range:
Risk management analysis – Identify, assess, prevent, measure, review, evaluate.

What do learners need to demonstrate?	Skills
Complete detailed risk management analyses in response to specific requirements, projects and activities. Complete risk management documentation.	EC4 MC6 DC1

5.5 Develop and test models for different purposes and **design questions.**

Range:
Design questions – Technical function, concept testing, production prototype.

What do learners need to demonstrate?	Skills
Develop and test models for engineering and manufacturing design purposes. Identify the correct model for different purposes and design questions. Investigate and analyse tests, performance and results and accurately report and respond to findings.	EC4 MC8 DC1 DC4 DC6

5.6 Produce and quality assure **design information** in accordance with **professional standards** and protocols.

Range:
Design information – Proposals, specifications, engineering drawings, technical information.
Professional standards – Engineering Council standards, IET standards.

What do learners need to demonstrate?	Skills
Develop, test and quality assure information, systems, outcomes relating to earthing and lightning protection. Produce, manage, quality assure and validate design information in accordance with relevant professional engineering standards and protocols. Check completed drawings for quality, technical compliance and completeness and the importance of doing so. Investigate, check and confirm relevant electrical and electronic design proposals, information, models or prototypes, and outcomes.	EC1 EC2 EC3 MC8

Outcome 6

6. Communicate proposals, design information and solutions, producing, recording and explaining engineering and manufacturing representations, systems, processes, outcomes, design specifications and technical drawings

6.1 Communicate control and instrumentation engineering design **options**, information and evidence with consideration of audience.

Range:
Options – Solutions, selections, alternative designs, constraints, specifications, outcomes, financial, sketches, schemes, models, components.

What do learners need to demonstrate?	Skills
Communicate different options of design elements to technical and non-technical audiences. Use methods to ensure accurate and clear communication of options. Use presentation techniques used for effective communication of information and evidence at each of the design stages. Produce, amend, check, manage and version control technical documentation, using appropriate conventions, annotations and protocols, and standard document management systems.	EC1 EC2 EC3 EC4 EC6 MC7 MC8 DC1

6.2 Produce and annotate control and instrumentation **drawings** and **technical information**.

Range:
Drawings – Sketches, circuit diagrams, block diagrams, wiring diagrams, electrical drawing.
Technical information – Specifications, manuals, instructions, reports, results, statements.

What do learners need to demonstrate?	Skills
Produce accurate drawings and technical information using correct annotations, conventions and symbols. Labelling of components, products, processes and outcomes, best practice in how to do this and the importance of doing so.	EC2 EC4 DC1

6.3 Use **digital tools** and technology to manage design information and produce technical documentation.

Range:
Digital tools – Spreadsheets, CAD software, revision control system, drawing software, presentations.

What do learners need to demonstrate?	Skills
Application and use of digital and collaborative tools and technology, systems and software to manage design information. Review, update and revise design information using tools and technology. Record and explain technical and non-technical information accurately and efficiently record technical and non-technical information following correct procedures. Use effective techniques to communicate and explain recorded information accurately.	EC4 DC1 DC2 DC3

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 control and instrumentation engineering design and development, 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.html**.
- Gadallah, A., *Instrumentation & Control Process Control Fundamentals,* (n.d.) **https://www.academia.edu/36548458/Instrumentation_and_Control_Process_Control_Fundamentals**

Scheme of Assessment – Control and instrumentation

The Control and instrumentation occupational specialism is assessed by one practical assignment. The duration of the assessment is 33 hours and 40 minutes. Learners will be assessed against the following assessment themes:

- Health and safety
- Design and planning
- Manufacturing
- Reports.

By completing the following tasks:

Task	Typical Knowledge and skills
Task 1 – Design	Displays a breadth of knowledge and practical skills that enables them to plan and carry out the design of the prototype/ model. Candidates will need to produce documents and drawings to industry standards that clearly states how they will develop the prototype/ model in line with the brief. Candidates will need to use CAD software to produce a virtual model.
Task 2 – Manufacture and test	Applies a breadth of knowledge and practical skills that enables them to carry out the manufacture and testing of the prototype/ model in accordance with their planning and designs. The task is carried out in a clear and logical sequence. Works in a safe manner, able to carry out testing and interpret and record test results accurately. Tools, materials and equipment are selected and used correctly.
Task 3 – Peer review	Engage in discussions with their peers to gain feedback on designs to inform any adaptions to their initial design prior to implementation. Able to constructively critique others designs and provide feedback and recommendations for improvements.
Task 3 – Evaluation and implementation	Displays a breadth of knowledge and understanding in the evaluation of their own design and manufacture, recommending adaptions and improvements to the model. Justifications for test methods provided, and information necessary for a third party to implement the model. Justifications for how peer review feedback was considered and implemented.

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*	***Typical evidence***	**Assessment Theme**
PO2 Analyse and interpret engineering and manufacturing requirements, systems, processes, technical drawings and specifications (16%)	T1 – Design	Design specification, virtual modelling, design calculations, records of the results of testing the physical model, engineering drawings (wiring diagram/ block diagram)	Design and planning Health and safety
	T2 – Manufacture and test	Manufacture of the prototype	Manufacturing
	T4 – Evaluation and implementation	Evaluation and implementation report	Reports
PO3 Evaluate systems, designs, components and processes, managing and integrating design information, proposals and specifications, to develop and improve control and instrumentation and manufacturing proposals and solutions (22%)	T1 – Design	Engineering drawings (wiring diagram/ block diagram), virtual modelling, Bill of materials	Design and planning Health and safety
	T2 – Manufacture and test	Manufacture of the prototype	Manufacturing
	T4 – Evaluation and implementation	Evaluation and implementation report	Reports
		Evaluation and implementation report	Health and safety
PO4 Propose and design control and instrumentation and manufacturing systems, products, components, processes and solutions, considering requirements, constraints and context (23%)	T1 – Design	Design specification, virtual modelling	Design and planning
	T2 – Manufacture and test	Manufacture of the prototype, testing of the prototype	Manufacturing
		Records of testing	Reports
	T2 – Manufacture and test	Manufacture of the prototype, testing of the prototype	Health and safety

PO5 Collaborate to help manage, develop, test and quality assure control and instrumentation and manufacturing design information, systems, processes and outcomes (26%)	T1 – Planning T2 – Manufacture and test T4 – Evaluation and implementation	Peer review form Manufacture of the prototype, testing of the prototype Revision control form Risk assessment, Manufacture of the prototype, testing of the prototype Evaluation and implementation report, records of testing	Design and planning Manufacturing Design and planning Health and safety Reports
PO6 Communicate proposals, design information and solutions, producing, recording and explaining engineering and manufacturing representations, systems, processes, outcomes, specifications and technical drawings (13%)	T1 – Design T4 – Evaluation and implementation	Engineering drawings (wiring diagram/ block diagram) design specification, annotated sketches, records of testing, virtual modelling Evaluation and implementation report	Design and planning Reports

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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 undertake fundamental structural engineering work. Learners will have the opportunity to plan, perform and evaluate their work whilst utilising a range of techniques, methods and resources.

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

- Knowledge of methods used to analyse the loads and forces applied to simple structures.
- Knowledge of approaches used to design elements, components and assemblies for simple structures.
- Knowledge of how structural materials degrade and fail.
- Skills for the presentation of structural engineering 2D and 3D drawings and documentations.
- Skills for the interpretation of briefs and project constraints to develop structural concepts for different scenarios.
- Skills in the design, development and testing of prototypes and models.

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

- What forces and loads impact buildings and structures during and after construction?
- What types of materials are used when constructing different parts of buildings?
- What types of projects require structural engineering designs to be developed?

Underpinning knowledge outcomes

On completion of this specialism, learners will understand:

1. Structural engineering knowledge criteria.

Performance Outcomes

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

2. Analyse and interpret engineering and manufacturing requirements, systems, processes, technical drawings and specifications.
3. Evaluate systems, designs, components and processes, managing and integrating design information, proposals and specifications, to develop and improve structural engineering, manufacturing and construction proposals and solutions.
4. Propose and design structural engineering and manufacturing systems, products, components, processes and solutions, considering requirements, constraints and context.
5. Collaborate to help manage, develop, test and quality assure structural engineering and manufacturing design information, systems, processes and outcomes.
6. Communicate proposals, design information and solutions, producing, recording and explaining engineering and manufacturing representations, systems, processes, outcomes, specifications and technical drawings.

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

Knowledge criteria for Performance Outcomes

1.1 **Principles** of engineering design in structural engineering

Range:

Principles – Requirements (functionality, aesthetics, durability, dimensions, ergonomics, safety, sustainability, cost, materials), methods of identifying requirements (market research, client interviews, client observation, product analysis), methods of recording requirements (design brief, specification, questionnaire/survey forms, observational records), factors that affect design (product life cycles, sustainability (recycling and re-use), safety), fields within structural engineering (design, manufacture, installation, maintenance), methods of communicating designs (orthographic drawings, virtual models, physical models and prototypes).

What do learners need to learn?	Skills
How to agree the nature and scope of structural engineering projects. How to identify, interpret and confirm client and customer requirements, proposals, ideas, objectives and aspirations. How to record client and customer requirements using standard compliance methods and the implications of not doing so accurately or effectively. How to evaluate and develop client and customer requirements. Design requirements unique to fields within structural engineering, and the factors that affect them. How to communicate design ideas (proposals, solutions, processes, concepts) and technical information relating to structural engineering. The different tools for recording, evaluating and developing client and customer requirements. How to how to evaluate, develop, challenge, and refine ideas, proposals, and objectives.	EC1

1. Structural engineering knowledge criteria

Analyse and interpret engineering and manufacturing requirements, systems, processes, technical drawings and specifications (PO2)

1.2 **Design methodologies**, **practices, processes**, applications and integration.

Range:

Design methodologies, **practices and processes** – Client consultation letter and agreement, structural assessment surveys, concept design, detailed design general arrangement drawings and structural details, method statements, temporary works, technical change communications, completion certificates, schedule of rates and estimate.

What do learners need to learn?	Skills
Common design methodologies, practices, processes, applications and integration relevant to contemporary structural engineering contexts. Stages of the design process relevant to structural engineering including structural assessment survey, concept design etc Process for tendering, bid phase and contract award.	EC1 MC5 MC9 DC1

1.3 Engineering **representations** used in structural engineering contexts and activities.

Range:

Representations – Engineering calculation sheet templates, BS EN 1SO 8560: 2019 and BS EN ISO 128-2:2020, technical drawings, construction drawings, representation of modular sizes, lines and grids, specifications for key structural materials.

What do learners need to learn?	Skills
How to use standards to interpret structural drawings and specifications. The typical controls and importance of tolerances, limits, fits and finishes for structural material. Industry conventions on the use of symbols and annotations on engineering representations.	DC1 MC1 MC3

1.4 **Standards and regulatory requirements** relevant to structural engineering.

Range:

Standards and regulatory requirements – Construction (Design and Management) Regulations 2015, Eurocodes, British Standards (BSI), Institution of Structural Design Guidance, Building Regulations (Part A).

What do learners need to learn?	Skills
The purpose, use and requirements of standards and regulatory requirements relevant to the design of structures and not necessarily how construction is carried out. The key responsibilities and codes of structural engineering standards and regulatory requirements. How to access and interpret requirements and responsibilities under regulations.	EC5

1.5 **Mathematical theory and methods** calculations and their application.

Range:

Mathematical theory and methods – Young's modulus, second moment of area and parallel axis theorem, Euler-Bernoulli beam equation, Euler buckling formula.

What do learners need to learn?	Skills
How to apply mathematical theory and methods in structural engineering contexts in relation to the review of existing designs. How to calculate the Young's modulus of different structural materials. The typical units used to express Young's modulus for different materials. How to calculate the first and second moment of area of typical structural shapes including rectangles, circles, and trapezoids. The use of Parallel Axis Theorem for compound shapes. The use of Euler-Bernoulli beam equation to describe deflection, slope, bending moment and shear force in a beam. The use of the Euler buckling formula to define the axial compression force which will cause a strut (or column) to fail in buckling. The concept of effective length arising from the application of the formula to the different end conditions of a strut (or column). How to use the theory of bending (M/I=f/y) to determine the size and stress levels in rectangular beam sections. The concept and characteristic of the effective length of a structural member takin into account different end fixity conditions. How to calculate safe loads for given section size, and section size required for a given load, for axially loaded columns comprised of rectangular, circular, 'T', 'I' and 'C' sections made from structural steel, timber or concrete. How to calculate stress values in eccentrically loaded columns of circular section. How to use Bow's notation to calculate the magnitude and direction (compressive or tensile) of loads applied to a structural frame. How to use the moment distribution method to determine bending moments in a pinned frame. The use of method of joints to solve for unknown forces acting on members of a truss.	MC4 MC5

1.6 **Scientific principles** relevant to structural engineering activities.

Range:

Scientific principles – Strength, stiffness and resonance, Newton's laws of motion, static determinacy, elasticity, plasticity, buckling, stress, strain, shear stress, bending, torsion.

What do learners need to learn?	Skills
The application of the principles of axial stress, strain, shear stress, bending and torsion to the strength of materials. The implication on the material of the exceedance of the axial stress, strain, shear stress, bending or torsional capacity. The standard units used to measure the parameters of stress, strain, shear stress, bending and torsion. Stiffness as the product between Young's modulus and the second moment of area. The units of stiffness and the impact of stiffness on deflection and a structural elements dynamic response. The principles of resonance and its possible effect on periodic motion systems. The concept of limit state in structural design and the application of partial safety factors. Newton's laws of motion (first, second and third). The concept that force = mass x acceleration and its application for motion under gravity (defining g = 9.81ms-2). The concept of inertia. The definition of a Newton as the force required to accelerate a mass of 1kg at the rate of 1ms-2.	MC8 MC5

The concept of static determinacy and the equilibrium of internal and external forces within a structural system. The principles of the elastic behaviour of materials obeying Hooke's Law. The principles of plasticity and the yield point of a structural materials. The principles of buckling and its impact on the stability of structural elements subject to axial compressive loads.	

Evaluate systems, designs, components and processes, managing and integrating design information, proposals and specifications, to develop and improve structural engineering, manufacturing and construction proposals and solutions (PO3)

1.7 Standard **structural engineering processes and technologies**.

Range:
Structural engineering processes and technologies – Materials and material performance; fabrication, transportation, construction and joining techniques; static, dynamic, structural loads; effects of service and environmental conditions, standard products and fixings, uses and applicability; standards and conventions in engineering representations and technical information for structural elements and layouts.

What do learners need to learn?	Skills
The purpose and use of different engineering technologies including their limitations and advantages for design concepts, decision-making, performance, and outcomes. Factors influencing the selection of the principle materials (steel, concrete, timber and masonry) for different engineering technologies for given scenarios. How different engineering technologies are fabricated, transported and constructed. How different connections methods are used to join structural elements. The effect of the application of structural load applied to different engineering technologies including load pathways and principal structural behaviour. How service and environmental conditions influence the specification of materials and structural finishes. How engineering drawings are presented and annotated. Technologies used to model and evaluate structural design features, issues, performance and potential.	EC4 MC8

1.8 **Verification and validation** in design practices.

Range:
Verification and validation – Levels (self-checking, internal, independent), verification of the output of structural analysis computer model by 'hand' methods, design reviews, stage-gate design process.

What do learners need to learn?	Skills
The function of verification and validation in the structural design process – and the difference between the two. The characteristics of the stage-gate design process. The responsibilities of engineers at each structural design check level.	MC10

The purpose of design reviews. Methods of reviewing and checking which can be used as part of improving design elements such as performance and quality. The role of the individual in verification and validation review activity in comparison with wider team and/or organisation activity.	

Propose and design structural engineering and manufacturing systems, products, components, processes and solutions, considering requirements, constraints and context (PO4)

1.9 Design purposes, **metrics, contexts** and **constraints**.

Range:

Metrics – Budget, cost, profit, time.

Contexts – Market pull and technology push, commercial advantage, design for reuse, planned obsolescence, sustainability.

Constraints – Commercial factors (competition, profitability), operational factors (tools and equipment, materials, process capabilities, human resources, training needs, legal, confidentiality), design for manufacture.

What do learners need to learn?	Skills
Difference between market pull and technology push. How contexts may influence product design. How to calculate the cost of manufacturing (materials, labour, overheads) and profit. The reasons why the constraints limit what can be done, the causes of these constraints and how the constraints can be overcome. Impacts of commercial risk analysis and how it applies to project design review.	EC5

1.10 **Structural principles,** material selection and application.

Range:

Structural principles – Plastic, elastic, buckling, shear, stress, torsion, bending, axial compression, fire resistance, workability, composite behaviour.

What do learners need to learn?	Skills
Effects of principles material selection and application on design stages, decision-making, processes and outcomes. Different approaches to structural analysis in relation to different materials. Impacts on the process of developing design drawings. The effect of different structural frame selection on the structural analysis process. The effect of different materials selection on the preparation of structural drawings.	EC2

1.11 **Effects** of structural loadings on structures and components.

Range:

Effects – Variable and permanent loads, partial factors of safety, the concept of ultimate limit state and serviceability limit state, load combinations, reactions, shear forces and bending moments, beam deflections under loading, columns subject to axial compression, axial forces in simple trusses.

What do learners need to learn?	Skills
How to determine permanent loads from material densities. How to calculate variable loads. How to determine ultimate limit state and serviceability limit state load combinations using partial factors of safety. How to calculate reactions, shear forces and bending moment values for various positions on simply supported beams (with and without overhangs) and cantilever beams. How to draw shear force diagrams for simply supported beams where the load is applied at a point, uniformly distributed or a combination of these two loads. How to produce bending moment diagrams for beams where the load is applied at a point, uniformly distributed or a combination of these two loads. How to calculate deflections at mid-span for simply supported beams. How to use the 'method of joints' in statically determinate trusses to determine the axial forces (including graphical methods)	MC5 MC6 MC7 MC8

Collaborate to help manage, develop, test and quality assure structural engineering and manufacturing design information, systems, processes and outcomes (PO5)

1.12 Technical, quality, and safety **standards**, regulations and legal requirements.

Range:

Standards – ISO 9001 Quality Management**,** ISO14001 Environmental Management.

What do learners need to learn?	Skills
The key requirements of ISO 9001 and ISO 14001. The benefits to an organisation of implementing ISO 9001 and ISO14001.	EC2 MC5

1.13 Health and safety procedures, **regulations,** conduct and compliance related to structural engineering.

Range:

Regulations – Confined Spaces Regulations, Environmental Protection Act**,** Lifting Operations and Lifting Equipment Regulations**,** Manual Handling Operation Regulations**,** Working at Height Regulations.

What do learners need to learn?	Skills
The specific health and safety procedures and protocols, and relevant legal and regulatory requirements that apply to structural engineering design, systems, process, outcomes and development activity The importance of compliance and how this is achieved.	EC5

Responsibilities of employers and employees under the regulations. How to avoid working at height, and where this is not possible the controls that should be put in place. How to plan and manage lifting operations. The importance of designing structures to limit manual handling operation, and the strategies that can be adopted to limit manual handling.	

1.14 **Installation** and **integration** of systems.

Range:
Installation – Customer requirements, regulation requirements, manufacturers specifications.
Integration – Combining of system, functions, designs, planning, processes.

What do learners need to learn?	Skills
Requirements, procedures and considerations for installing engineering structures. Key stages and appropriate sequence of integration of systems. How integration is achieved through bringing together individual sub-systems into one system and ensuring that the sub-systems function together as a complete system.	EC5

1.15 **Testing methods** in structural engineering.

Range:
Testing methods –

- Non-destructive testing methods – Visual inspection, measurement, Go-NoGo gauges, ultrasonic testing, penetrant testing, magnetic particle inspection, X-radiography
- Destructive testing methods - Macro examination, hardness, tensile, impact tests (Izod, Charpy)

What do learners need to learn?	Skills
The function of destructive and non-destructive testing in structural engineering. The purpose of standard tests for different types of materials, when they are used within the design process. How to complete and report the results for standard test methods for different materials as part of the structural engineering design process.	EC5

1.16 Measurement and testing **equipment.**

Range:
Equipment –

- Instruments – Schmidt hammer, crack monitoring gauge, laser distance measurement, moisture meter, thermal imaging camera, theodolite, laser scanners, GPS, level, rod, flow metre, rules, protractors, callipers (vernier, digital), micrometres (outside, inside, depth), gauges (go/no-go, slip, plug), dial test indicators, coordinate measuring machines (CMMs), digital stress and strain machines.

- Technologies – GNSS.
- Tools and equipment – Measuring tape, ladder, camera, tripod, torch, plumb bob, spirit level, optical plumb, laser alignment.

What do learners need to learn?	Skills
Testing instruments, technologies, tools and equipment and their function and purpose linked to relevant testing methods for structural engineering design processes. Matching and selection of equipment, tools and measurement instruments to undertake structural engineering testing activity. The safe and correct use of equipment, tools and measurement instrument to undertake structural and topographical surveys including the sources of errors. Calibration and checks for equipment, tools and measurement instruments prior to use.	MC2 DC4

1.17 **Mathematical methods and calculations** for confirming structural engineering testing and performance data.

Range:

Mathematical methods and calculations – Error calculations, standard distribution, standard deviation, percentiles, stress, strain, averages (mean, mode, modal).

What do learners need to learn?	Skills
Mathematical methods and calculations, including statistical analysis, for measuring, checking and confirming structural engineering testing and performance data. The concept and principles of characteristic material properties and the 95 percentile.	MC8 MC2

1.18 **Failures** in relation to structural engineering materials and their **causes**.

Range:

Failures –

- Serviceability failure – Deterioration, corrosion, abrasion, fatigue, weathering, deflection, cracking, breach of integrity, condensation, transmission (excessive noise, hear or cold), vibrations.
- Functional failure – Buckling, collapse.

Causes – Excessive loads, bad design, faulty construction, foundation failure, natural disaster, building use, solar radiation, frost, moisture, biological attack and chemical changes.

What do learners need to learn?	Skills
Factors which affect quality in structural engineering and quality assurance processes, failure modes, and the properties, standard forms, and failure modes of materials. The principles characteristics and causes of serviceability and functional failure.	EC5

Communicate proposals, design information and solutions, producing, recording and explaining engineering and manufacturing representations, systems, processes, outcomes, specifications and technical drawings (PO6)

1.19 Engineering **representations** and communication technology, media, formats and conventions.

Range:
Representations – Design reviews, drawings, calculations, test results, inspection reports, method statements, specifications.

What do learners need to learn?	Skills
How structural engineering representations (plans, designs, diagrams, test results etc) are communicated to customers, clients and other engineers using different methods, including communications technologies, media, different formats and their conventions. Types of computer drawing software packages available, their purposes and the hardware required to run them.	EC1 EC2 EC4

1.20 **Presentation techniques** and standard requirements for design and technical information.

Range:
Presentation techniques – Design reviews, drawings, calculations, emails, letters, lest results, structural inspection reports, laboratory reports, memos, public meetings, presentations, method statements, risk assessment, specifications.

What do learners need to learn?	Skills
Presentation techniques and standard requirements for design and technical information relevant to purpose and audience, specifically in structural engineering design contexts. The content and key function of the different types of documentation.	EC1 EC3

1.21 **Design and communication technologies** used within structural engineering contexts and processes.

Range:
Design and communication technologies – 2D CAD software, 3D CAD software.

What do learners need to learn?	Skills
How design and communication technologies are used within structural engineering contexts and processes, and the reasons why they are used. Appreciation of the key functions of the range of structural design software packages currently used within the industry, their benefits and specific purpose. The types of users/audience of different types of technologies and how these may differ – e.g. clients and end users vs other engineering professionals.	DC1 DC4

Outcome 2

Practical criteria for Performance Outcomes

2. Analyse and interpret engineering and manufacturing requirements, systems, processes, technical drawings and specifications

2.1 Respond effectively to projects, tasks and requirements from different **sources.**

Range:
Sources – Design briefs, specifications, drawings/diagrams, concepts, stakeholders, clients, customers.

What do learners need to demonstrate?	Skills
Examine, review, interpret and respond effectively to structural design project requirements, through the review and interpretation of technical information from relevant sources. Considerations when designing a structural engineering project.	EC5

2.2 Define **project expectations** and requirements

Range:
Project expectations - Materials requirements, manufacturing timescale, cost.

What do learners need to demonstrate?	Skills
Critique, challenge and confirm design project expectations and requirements appropriately, including requirement risks. Determine and evaluate the materials requirements, manufacturing timescale and costs for a specified project. Consideration of a project brief to draft a scope of works for structural services. Consideration of the project expectation to appraise technical and commercial risk and their mitigation actions. Consider different types of risks associated with requirements which may include design risks and/or commercial risks	EC1 EC5 EC6

2.3 Interpret information from available **formats, media and technology.**

Range:
Formats, media and technology – Specifications, 3D BIM models, 2D CAD, schematics, system block diagrams, engineering calculations, virtual fly throughs, analysis models and diagrams, general arrangement drawings

What do learners need to demonstrate?	Skills
Read key information from 2D CAD structural general arrangement drawings. Read product and material information from simple 3D BIM models. Read structural engineering calculations to interpret design checks undertaken on simple structural members.	EC5 MC1 MC2 MC5 MC7

Review virtual fly through tours of structures to interpret structural framing requirements. Interpret structural analysis models and diagrams reading key forces and loads.	DC1 DC3 DC4 DC6

2.4 Interpret structural process documents and **drawings.**

Range:
Drawings – General arrangement, sections, details, elevations.

What do learners need to demonstrate?	Skills
Critically appraise technical information. Respond effectively to communicate responses following review of technical information with consideration of impacts and audience. Interpret draft requests for information. Review information from inspection reports and material tests. Action findings and apply as part of the design and planning process going forwards.	EC4 EC5 MC4

2.5 Identify potential **inaccuracies** in engineering **drawings**, models and specifications.

Range:
Drawings – General arrangement, sections, details, elevations.
Inaccuracies – Incorrect dimensions, errors in specification criteria (including discrepancies with known standards), incorrect hatching and symbols used, incorrect connection of components, incorrect use of grid lines.

What do learners need to demonstrate?	Skills
Resolve inconsistencies and errors in structural engineering information and sources e.g. simple structural analysis models. Review a specification against engineering drawings and note inconsistencies. Follow steps and methods of checking and conforming potential inaccuracies systematically with a measured and considered approach. Follow processes for flagging and proposing solutions or amendments in line with roles and responsibilities and lines of reporting.	MC1 MC2 MC6 DC3 DC2 DC6

2.6 Verify structural design concepts, briefs and specifications, in relation to **context,** function and specific requirements.

Range:
Context – Components, application, location, risk, environment.

What do learners need to demonstrate?	Skills
Verify structural concepts against briefs and specifications considering the key factors influencing the design. Modify design concepts, briefs and specifications in response to feedback from stakeholders.	EC5 MC5

Outcome 3

3. Evaluate systems, designs, components and processes, managing and integrating design information, proposals and specifications, to develop and improve structural engineering, manufacturing and construction proposals and solutions

3.1 Select and use **technologies** to review, analyse, model and evaluate the performance of structural engineering designs.

Range:
Technologies – Structural analysis software, spreadsheets.

What do learners need to demonstrate?	Skills
Evaluate features, issues, performance, and potential within structural engineering designs. Use structural analysis software to apply loads (permanent and variable) to simple structural elements. Use structural analysis software to complete simple elastic analysis of different elements and calculate deflections and extensions. Interpretation of design elements as found in proposals, representations, systems, components, assemblies, products and processes. Use software packages to interpret structural elements, systems, components, assemblies, products and processes.	MC4 MC7 DC1 DC2 DC3 DC4 DC6

3.2 Analyse **factors** that affect structural design concepts, design components, and complete designs.

Range:
Factors – Location considerations, serviceability requirements, loading, maintenance requirements, robustness against failure, sustainability issues, environment, procurement, operation, material efficiency, materials, risk.

What do learners need to demonstrate?	Skills
Analyse factors influencing design for a given project scenario and develop and communicate using hand drawn sketches of elevations, plans and sections a structural concept solution. Make suggestions and recommendations that can be made in relation to the development, improvement, refinement and optimisation and appropriately record/communicate. Consideration of factors at different levels within a design i.e. consideration at component level and holistically from whole design level.	EC2 EC4 EC5 MC9

3.3 Use information **sources** to select engineering and manufacturing materials and components.

Range:
Sources – Drawings, diagrams, specifications, datasheets, manufacturer's/technical manuals, relevant standards and regulations.

What do learners need to demonstrate?	Skills
Use appropriate information sources, and own judgement to select, evaluate, recommend, and confirm suitable engineering and manufacturing materials and components for specific uses. Explain and justify choices of materials and components with reference to the design context. Assess the advantages and limitations of materials and components for a given project scenario.	MC1 MC2 MC3 EC5

3.4 Apply knowledge of material **degradation and failure** processes, and prevention and mitigation methods, to investigate and evaluate proposals, projects, processes, and outcomes.

Range:

Degradation and failure – Chemical attack/corrosion, fracture, mechanical abrasion, creep and fatigue.

What do learners need to demonstrate?	Skills
Consider the material degradation and failure processes for elements of a structure in a given scenario.	EC5

3.5 Review and confirm results of structural and materials **tests.**

Range:

Tests –

- Non-destructive testing methods – Visual inspection, measurement, Go-NoGo gauges, ultrasonic testing, penetrant testing, magnetic particle inspection, X-radiography
- Destructive testing methods – Macro examination, hardness, tensile, impact tests (Izod, Charpy)

What do learners need to demonstrate?	Skills
Apply knowledge of material degradation and failure processes, and prevention and mitigation methods, to investigate and evaluate design proposals, projects, processes, and outcomes. Consider the relevance, implications, and value of structural and materials test results with reference to purpose and context, recording and reporting on tests, modelling and research. Use results of testing to evaluate and influence the design.	EC5 MC5 MC6

3.6 **Evaluate** structural engineering designs, design elements, and design processes for compliance, quality and performance.

Range:

Evaluate – Quality, performance.

What do learners need to demonstrate?	Skills
Importance of checking compliance in relation to purpose, function, conditions (material change in certain conditions) and project specific requirements (environmental and working conditions, application requirements (cost, value engineering). Links to compliance in relation to regulations and standards. Undertake structural design reviews for compliance against a project brief. The iterative process of design development and review – how improvements are identified, solutions proposed and refined. Evaluate potential solutions with reference to design purpose, project context and known constraints to ensure the most appropriate changes are made. The principles and stages of 'design development'. The application of 'design development' to a given structural engineering project scenario.	EC4 EC5 EC2 MC5 MC10

3.7 **Review** methods, quality, standards and performance within different **stakeholders.**

Range:

Review – Design methods, quality systems, standards, manufacturing methods, performance targets, KPI's.

Stakeholders – As an individual, within a team, organisation-wide, customers/clients, regulatory bodies.

What do learners need to demonstrate?	Skills
Reflect upon, review, develop and seek to improve methods, quality, standards and performance across structural design and manufacture, within different stakeholders. Characteristics of approaches to improve structural engineering design and construction for different activities within an engineering practice. The key principles of ISO 9001.	EC1

3.8 Respond positively to required changes and feedback.

What do learners need to demonstrate?	Skills
Follow steps when confirming the nature and scope of new requirements, and the process for revision or resolution. Respond constructively, importance of this and implications if this does not happen. Log and record changes throughout the design process. Managing 'scope creep' and 'scope changes'. Apply structural engineering communication skills to define scope change for a range of different activities. Manage document and drawing revisions when changes are required. Log and record changes throughout the design process.	EC1 EC5

Outcome 4

4. Propose and design structural engineering and manufacturing systems, products, components, processes and solutions, considering requirements, constraints and context

4.1 Design and develop structural engineering concepts, **components** and features.

Range:
Components: beam, columns, cantilevers, frames, trusses, struts, rods and ties.

What do learners need to demonstrate?	Skills
Complete designs in accordance with codes for simple structural elements, for a given site and scenario. Design and develop structural engineering concepts, components and features, and how to develop existing design elements and proposals, to address or solve engineering and construction challenges. Design elements will depend on site and scenario but will cover design and structural elements.	EC1 EC2 MC4 MC5 MC6 MC7 MC8

4.2 Use **CAD software** to produce 2D and 3D drawings, models and simulations.

Range:
CAD software –

- 2D CAD software tools – drawing (page) set up; line types, styles and colour; insert shapes (circle, arc, polygon, rectangle, ellipse); insert and edit text (position, font style, font height, rotation); grid spacing and snap to grid; editing tools (zoom in/zoom out, pan, erase, copy, mirror, offset, move); dimensioning (linear, angular, diameters, radii, leader, tolerances); annotation; hatching simple enclosed areas.
- 3D CAD software tools – extrude; revolve; 3D primitive shapes (box, cuboid, sphere, cylinder, cone, torus); creation of irregular/asymmetric shapes; rendering using a range of materials; assembly of products from component (align, mate).

What do learners need to demonstrate?	Skills
Use technology and tools effectively and safely. Use drawing software tools to produce 2D CAD drawings and 3D CAD drawings and models to relevant standards and in like with industry conventions. Convert 3D CAD models to orthographic (working) drawings. Follow process in order to produce accurate and detailed drawings. Consider accuracy, tolerances, units of measurement and use of scale and accurate symbols.	MC1 MC2 DC1 DC2 DC3 DC5 DC6

4.3 Use manufacturing and production **practices** to develop models and prototypes.

Range:
Practices – 3D printing, solid modelling, rendering, prototyping, machining, hand-fitting, fabrication.

What do learners need to demonstrate?
Apply design, manufacturing and production principles and practices to develop models and prototypes. Follow safe working practices when manufacturing models and prototypes using the different techniques and processes. Construct and finish working structural models and prototypes using different materials (steel, concrete, timber, masonry and thermoplastics). Select and use appropriate materials for different types of model and prototype development – 3D printing, physical modelling and prototyping. Select and use appropriate types of 3D printing.

4.4 Produce detailed structural engineering drawings and solutions to relevant **standards, codes** and specifications as stated in the brief, which can be realised.

Range:
Standards and codes – BS EN 1SO 8560: 2019 and BS EN ISO 128-2:2020.

What do learners need to demonstrate?	Skills
Develop structural engineering solutions which satisfy the required standards and specifications as stated on the brief. Complete high-quality, producible designs, ready for realisation, using appropriate technology, tools and equipment. Produce accurate and detailed drawings. Present drawings to conform to BS EN 1SO 8560: 2019 and BS EN ISO 128-2:2020. Print/plot drawings from 2D and 3D CAD packages. Consider accuracy, tolerances, units of measurement and use of scale and accurate symbols. The application of constructability to different substructures and superstructures related to scenario.	EC1 EC2 MC1 MC2 DC2

4.5 Use **tools** to produce models and prototypes safely**.**

Range:
Tools

- Hand tools – Rules, levels, gauges, pliers, screw drivers, files, hammers, saws, scalpels, rotary cutters.
- Power tools – Drills, files, electric screwdrivers.

What do learners need to demonstrate?	Skills
Select and use hand and power tools safely. The safety checks, calibration maintenance and storage requirements for keeping hand and power tools in serviceable condition. Carry out basic engineering processes in the production of models and prototypes including where necessary cutting, drilling, shaping, forming and 3D printing. Consider health and safety when producing models and prototypes, including actions normally taken to reduce risk.	MC1

Outcome 5

5. Collaborate to help manage, develop, test and quality assure structural engineering and manufacturing design information, systems, processes and outcomes

5.1 Work in accordance with **professional standards**, and company management systems, policies and procedures.

Range:
Professional standards – Codes of practice, rules of conduct, ethics, technical competence.

What do learners need to demonstrate?	Skills
Application of professional code of conduct to structural engineering business activities. Application of company management systems, policies and procedures to structural engineering business activities. Follow requirements for compliance with relevant national and industry health and safety requirements in relation to structural engineering.	EC1 EC2

5.2 Comply with health and safety requirements and regulations and **risk** assessments.

Range:
Risks – Working at height, confined spaces, temporary stability, lifting.

What do learners need to demonstrate?	Skills
Work safely at all times, complying with relevant national and industry health and safety requirements, and analysing, managing and mitigating risks present in structural engineering contexts. Undertake structural engineering risk assessments using appropriate principle and formats for site and design activities.	EC2 EC3

5.3 Work effectively with others to agree and complete **tasks.**

Range:
Tasks – Design, development, investigation, research, problem solving, testing, validation, quality assurance, quality control, producing and interpreting documentation.

What do learners need to demonstrate?	Skills
Contribute effectively and respond appropriately to other inputs. Implications of different task considerations: timeframes, deadlines, dynamic contexts and conditions.	DC1 DC3 DC4 DC5 DC6 DC10

5.4 Complete detailed **risk** management analyses.

Range:
Risk – Technical, commercial, legal, ergonomic, aesthetic.

What do learners need to demonstrate?	Skills
Complete detailed risk management analyses in response to specific requirements, projects and activities within structural engineering. Identify risks and appropriate mitigation actions in structural engineering contexts. Application of principles and use of software to complete detailed risk management analysis for structural engineering scenarios.	MC6 DC1

5.5 Develop and **test models** and prototypes.

Range:
Test – Concept testing, testing of production prototypes.
Models – Virtual, physical (block, rapid prototyping/3D printed, one-off prototype manufacture).

What do learners need to demonstrate?	Skills
Develop and test models for different purposes. Carry out tests used for investigation and analysis to check and confirm performance, expected results and implications of results outside those expected. Accurately report and respond to findings, escalating in line with role and responsibility. Use structural analysis models under different loading combinations to access forces in structural elements. Construct physical to scale models from different materials (steel, concrete, timber, masonry and thermoplastics) and to use these to test structural concepts. Use BIM models and virtual fly throughs with clients and others to interrogate a brief and look for clashes.	MC5 MC8 DC2

5.6 Check completed drawings for quality, technical compliance and **completeness.**

Range:
Completeness – Notes, drawing title block, revisions, use of dimensions, technical detail, standards.

What do learners need to demonstrate?	Skills
Check technical drawings for completeness and technical compliance.	EC2 EC5 MC5

Outcome 6

6. Communicate proposals, design information and solutions, producing, recording and explaining engineering and manufacturing representations, systems, processes, outcomes, specifications and technical drawings

6.1 Communicate design **information** and options using media and **technology**.

Range:
Information – Scheme drawings, technical representations, specifications, processes, changes/amendments.
Technology – Virtual meeting spaces, cloud-based file sharing, virtual-fly-throughs, structural analysis models, BIM models, presentations, email, virtual rendering software.

What do learners need to demonstrate?	Skills
Prepare and use different media and technology to communicate structural engineering design information to technical and non-technical audience. Communicate and co-ordinate structural engineering design information with technical and non-technical audiences Manage prioritisation and matching considerations to the situation. Consider advantages and disadvantages relating to the use of different types of technology, format, media and technology Consider end user as part of allocating media, format and language used and the potential implications of mismanagement of these considerations. Demonstrate effective use of information security management systems.	EC1 EC2 EC4 EC6 DC1 DC2 DC3 DC6

6.2 Produce technical documentation, using industry **conventions.**

Range:
Conventions – Annotations, protocols, document management systems, scales, symbols, abbreviations, wording.

What do learners need to demonstrate?	Skills
Application of ISO 9001 standards to document and drawing preparation, amendment, checks, management and version control. Effectively annotate structural engineering design drawings and representations (e.g. geometrical tolerances, limits and fits; layouts and details).	EC3 EC5 MC7 MC8

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 structural engineering design and development, 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

- Durka, H Al Nageim, W Morgan, D William, Structural Mechanics: Loads, Analysis, Materials and Design of Structural Elements, 7th Edition, Pearson, 2010 ISBN-10 0132239647
- Trevor Draycott, Peter Bullman, Structural Element Design Manual: Working with the Eurocodes, 2nd Edition, Butterworth-Heinemann, 2009, ISBN 0080942873
- Structural and Stress Analysis by T. H. G. Megson, 2019
- Hugh Morris, Structural engineering art and approximation, 2nd edition, Hugh Morrison, 2015, ISBN 1782223169
- Mattys Levy, Mario Salvadori, Why buildings fall down: how structures fail, W.W.Norton, 2002, ISBN 039331152X

Websites

- The Institution of Structural Engineers www.istructe.org
- Expedition Workshed www.expeditionworkshed.org
- Timber Research and Development Association www.trada.co.uk
- The Concrete Centre www.concretecentre.com
- The Steel Construction Institute **www.steel-sci.com**
- **www.bsigroup.com/en-GB**

Scheme of Assessment – Structural engineering

The Structural engineering occupational specialism is assessed by one practical assignment. The duration of the assessment is 33 hours and 40 minutes. Learners will be assessed against the following assessment themes:

- Health and safety
- Design and planning
- Manufacturing
- Reports.

By completing the following tasks:

Task	Typical Knowledge and skills
Task 1 - Design	Displays a breadth of knowledge and practical skills that enables them to plan and carry out the design of the prototype/ model. Candidates will need to produce documents and drawings to industry standards that clearly states how they will develop the prototype/ model in line with the brief. Candidates will need to use CAD software to produce engineering drawings as well as a virtual model.
Task 2 – Manufacture and test	Applies a breadth of knowledge and practical skills that enables them to carry out the manufacture and testing of the prototype/ model in accordance with their planning and designs. The task is carried out in a clear and logical sequence. Works in a safe manner, able to carry out testing and interpret and record test results accurately. Tools, materials and equipment are selected and used correctly.
Task 3 – Peer review	Engage in discussions with their peers to gain feedback on designs to inform any adaptions to their initial design prior to implementation. Able to constructively critique others designs and provide feedback and recommendations for improvements.
Task 4 – Evaluation and implementation	Displays a breadth of knowledge and understanding in the evaluation of their own design and manufacture, recommending adaptions and improvements to the model. Justifications for test methods provided, and information necessary for a third party to implement the model. Justifications for how peer review feedback was considered and implemented.

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*	***Typical evidence***	**Assessment Theme**
PO2 Analyse and interpret engineering and manufacturing requirements, systems, processes, technical drawings and specifications (16%)	T1 – Design T2 – Manufacture and test T4 – Evaluation and implementation	Design specification, annotated sketches, virtual modelling, design calculations Manufacture of the prototype Evaluation and implementation report	Design and planning Health and safety Manufacturing Reports
PO3 Evaluate systems, designs, components and processes, managing and integrating design information, proposals and specifications, to develop and improve structural engineering and manufacturing proposals and solutions (22%)	T1 – Design T2 – Manufacture and test T4 – Evaluation and implementation	Engineering drawings, virtual modelling, Bill of materials Manufacture of the prototype Evaluation and implementation report, revision control document	Design and planning Health and safety Manufacturing Reports Health and safety
PO4 Propose and design structural engineering and manufacturing systems, products, components, processes and solutions, considering requirements, constraints and context (23%)	T1 – Design T2 – Manufacture and test T4 – Evaluation and implementation	Design specification, sketches, engineering drawings, virtual modelling Manufacture of the prototype, testing of the prototype Records of testing	Design and planning Manufacturing Reports Health and safety

PO5 Collaborate to help manage, develop, test and quality assure structural engineering and manufacturing design information, systems, processes and outcomes (26%)	T2 – Manufacture and test T4 – Evaluation and implementation	Manufacture of the prototype, testing of the prototype Risk assessment, Manufacture of the prototype, testing of the prototype Evaluation and implementation report, records of testing	Manufacturing Health and safety Reports
PO6 Communicate proposals, design information and solutions, producing, recording and explaining engineering and manufacturing representations, systems, processes, outcomes, specifications and technical drawings (13%)	T1 – Design T4 – Evaluation and implementation	Engineering drawings, design specification, annotated sketches, records of testing, virtual modelling Evaluation and implementation report	Design and planning Reports

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**

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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.

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W: **www.cityandguilds.com/tlevels**

Web chat available **here**.