Next Generation Higher National Unit Specification

Engineering Mechanics and Materials (SCQF level 7)

Unit code: J6D3 47

SCQF level: 7 (24 SCQF credit points)

Valid from: session 2024–2025

Prototype unit specification for use in pilot delivery only (version 3.0) October 2024

This unit specification provides detailed information about the unit to ensure consistent and transparent assessment year on year.

This unit specification is for teachers and lecturers and contains all the mandatory information required to deliver and assess the unit.

This edition: October 2024 (version 3.0)

Unit purpose

This unit provides learners with knowledge, understanding and skills in mechanical engineering principles, with a focus on engineering materials, statics and dynamics.

The target group for this unit is learners who want to develop their core engineering design and analysis skills to support a career in fields such as mechanical engineering, systems engineering, manufacturing engineering, or instrumental and control engineering. It is also for learners doing modern apprenticeships and those who want to develop the practical, personal and professional skills required for a successful career as an engineering technician.

Entry is at your centre's discretion. However, we recommend that learners have one or more of the following:

- broad knowledge and understanding of mathematics and mechanical engineering concepts and theorems at SCQF level 6, for example Higher Mathematics or Physics, or a National Certificate (NC) in Mechanical Engineering
- relevant, equivalent workplace experience in the mechanical engineering sector or an equivalent qualification in Engineering at SCQF level 6

Unit outcomes

Learners who complete this unit can:

1 understand the relationship between the structure and properties of materials in relation to mechanical engineering problems
2 apply the principles and laws that relate to engineering dynamics to resolve mechanical engineering problems
3 apply the principles and laws that relate to static equilibrium and strength of materials to resolve mechanical engineering problems

Evidence requirements

All outcomes can be assessed holistically using product, written and/or oral recorded evidence. Learners generate evidence under controlled or supervised, open-book conditions, and it must be authenticated as being all their own work. The evidence must contain a mix of knowledge and skills items that matches the evidence requirements of the unit, and include various forms of evidence, such as:

- assignments
- case studies
- reports
- essays
- simulations
- structured controlled tests
- practical evidence
- other relevant sources of evidence

Where sampling is indicated, you must teach all content in the 'Knowledge and skills' section and it must be available for assessment. Learners should not know which items they will be assessed on in advance. You must use a different sample for each assessment occasion.

To successfully achieve this unit, learners must provide evidence that they can do the following:

Outcome 1

- Define the mechanical and other properties associated with materials used in engineering applications to include metals, polymers, ceramics, natural and composite materials.
- Compare and contrast different types of materials used in engineering applications. Include the following properties:
  - malleability
  - ductility
  - toughness
  - hardness
  - tensile, compressive and shear stress

  - resistivity
  - conductivity
  - fatigue
  - creep
  - toxicity
  - stability
  - wear resistance, where relevant
- Give examples of how materials are selected and used based on the required properties.
- Identify and explain the various material testing procedures with reference to quality standards for a given application.
- With reference to material strength and various testing procedures, investigate the effects of heat treatment (where possible, include other treatments by comparison, such as annealing or work hardening).
- Identify the requirements of safe disposal of engineering materials and the consideration required to meet environmental responsibilities.

Outcome 2

Sample any 12 of the 16 required items:

- Use a linear motion velocity–time graph and equations of motion to solve problems for situations involving periods of constant velocity and during acceleration (or deceleration).
- Use an angular velocity–time graph and equations of angular motion to solve problems for periods of constant angular velocity and during angular acceleration (or deceleration).
- Solve a problem using the linking equations between linear and angular motion.
- Solve a problem involving tractive effort and resistance, including mass, acceleration and friction on either a horizontal or an inclined plane.
- Solve a problem on linear momentum.
- Calculate the moment of inertia using the radius of gyration.
- Solve a problem involving the conservation of momentum in both linear and angular scenarios.
- Solve a problem involving kinetic energy, work and power.
- Solve a problem on the conservation of energy.
- Determine the power required to cause/stop linear motion.
- Determine the power required to cause/stop angular motion.
- Calculate the efficiency of machines.
- Determine the moment of inertia through energy balance.
- Solve a problem involving centripetal acceleration and centripetal force.
- Solve a problem involving centrifugal force.
- Solve a problem that involves a projectile that is launched at an angle above the horizontal.

Outcome 3

Sample any 12 of the 17 required items:

- Perform calculations using the equations of static equilibrium.
- Solve a framework problem stating the magnitude of forces in each member and determine whether it is in tension or compression.
- Draw shear force and bending moment diagrams for simply supported beams or cantilevers.
- Determine the position of maximum shear for simply supported beams or cantilevers.
- Determine the positions of maximum tensile and compressive bending for simply supported beams or cantilevers.
- Calculate at least two stresses, cross-sectional areas and compressive/tensile forces (for either hollow rectangular/circular or I-shaped cross sections).
- Calculate the strain and change in length due to compressive and tensile loading.
- Calculate the shear stress in a simple component in ether single or double shear.
- Determine the correct size and number of pins/bolts etc subjected to direct shear loading.
- Determine the correct size and number of pins/bolts/keys etc subjected to a torque.
- Calculate at least one neutral axis position for either I, T or channel section.
- Determine at least one second moment of area value for either hollow rectangular, hollow, circular, I, T or channel section.
- Solve a problem using the general bending equation.
- Calculate polar moments of area.
- Calculate shear stress in solid and hollow shafts being subjected to a torque.
- Solve a problem using the torque equation.
- State the maximum deflection of a cantilever or a simple supported beam being subjected to both a point load and a UDL using the superposition principle in standard cases.

Knowledge and skills

The following table shows the knowledge and skills covered by the unit outcomes:

Knowledge	Skills
Outcome 1 Learners should understand: ♦ mechanical properties of materials ♦ the structure of engineering materials ♦ different types of materials used within engineering ♦ the selection and application of materials based on their properties ♦ different heat treatment processes with reference to phase diagrams ♦ material testing processes ♦ the environmental impact of materials and their disposal	**Outcome 1** Learners can: ♦ define properties of metals, polymers, ceramics, natural and composite materials ♦ compare properties including malleability, ductility, toughness, hardness, stress, resistivity, conductivity, fatigue, creep, toxicity, stability and wear resistance ♦ consider a range of materials and justify the most appropriate solution for an engineering application ♦ perform heat treatment on a range of engineering materials ♦ carry out material testing on a range of engineering materials

Knowledge	Skills
Outcome 2 Learners should understand: ♦ Newton's laws of motion ♦ how to interpret velocity-time diagrams ♦ connected systems that link linear to angular motion ♦ tension and frictional forces involving tractive effort in both horizontal and inclined planes ♦ moment of inertia ♦ radius of gyration ♦ the principle of conservation of energy in relation to engineering dynamics ♦ the relationship between work, energy and power in engineering dynamics ♦ the importance of efficiency of machines ♦ the concept of centripetal and centrifugal forces ♦ the concept of projectile motion	**Outcome 2** Learners can: ♦ solve problems involving equations of motion for linear and angular dynamics ♦ use velocity-time graphs to solve problems in both linear and angular motion scenarios ♦ calculate the frictional resistance and tractive effort required on horizontal and inclined planes ♦ solve problems involving linear and angular impulse and momentum ♦ solve problems using kinetic energy, work and power ♦ calculate the efficiency of machines ♦ determine the power to start or stop linear and angular motion ♦ solve problems involving centripetal and centrifugal forces ♦ calculate the range and maximum height reached by a projectile

Knowledge	Skills
Outcome 3 Learners should understand: ♦ direct stress and strain ♦ and identify when in double shear ♦ the relationship between Young's modulus and stress and strain ♦ the principle of static equilibrium ♦ the different forms of support including, rollers and hinges and whether a beam is statically determinate ♦ forces, moments and reactions in relation to beam analysis ♦ the effect of forces on engineering structures ♦ the principle of torsion theory ♦ the design of beams ♦ the theory of simple bending ♦ polar moments ♦ the relationship between the bulk modulus of elasticity, angle of twist and the length of the shaft to the torque applied and shear stress ♦ whether a framework is safe/unsafe ♦ how to identify redundant member/s ♦ frame reactions and internal forces	**Outcome 3** Learners can: ♦ solve problems involving tensile and compressive strength ♦ solve problems involving shear stress ♦ perform calculations using the equations of static equilibrium ♦ solve problems involving beam analysis and selection for simple supported and cantilever beams ♦ create shear force and bending moment diagrams ♦ determine the position and magnitude of maximum bending stress or point of contraflexure in simply supported and cantilever beams ♦ determine the neutral axis and 2nd moment of area of complex shapes including I, T or channel sections ♦ apply the bending equation to solve problems ♦ calculate slope and deflection using standard formulae ♦ solve problems involving torsional shear stress ♦ calculate polar moments of area in hollow and solid shafts ♦ apply the torque equation to solve problems ♦ determine the correct standard size and number of pins/bolts/keys subjected to direct shear loading or torque ♦ carry out analysis of pin-jointed frames stating whether the members are in tension or compression

Meta-skills

Throughout the unit, learners develop meta-skills to enhance their employability in the engineering sector.

Self-management

Learners develop the skills of adapting and initiative through critical reflection and independent thinking, as they work through the course material and case studies.

Social intelligence

Learners develop the skills of communicating and collaborating, as they work with other learners on case studies and assignments.

Innovation

Learners develop a number of skills including critical thinking, curiosity and sense-making, as they analyse problems relating to mechanical engineering principles.

Literacies

Learners develop core skills in the following literacies:

Numeracy

Learners develop their numeracy skills when solving problems using applied engineering mathematical techniques.

Communication

Learners develop their communication skills by studying the course material, engaging with other learners and teachers or lecturers, and writing academic and reflective reports.

Digital

Learners develop their digital literacy throughout the unit by accessing course materials through a virtual learning environment, collaborating online and keeping an e-portfolio.

Delivery of unit

This unit is part of the Higher National Certificate in Engineering. The framework includes a number of mandatory and optional units, and you can tailor the selected combination of units to specific engineering pathway needs.

The notional design length is 120 hours, however, the amount of time you allocate to each outcome is at your centre's discretion (particularly given the unit's holistic approach). We suggest the following distribution of time, including assessment:

Outcome 1 — Understand the relationship between the structure and properties of materials in relation to mechanical engineering problems
(24 hours)

Outcome 2 — Apply the principles and laws that relate to engineering dynamics to resolve mechanical engineering problems
(32 hours)

Outcome 3 — Apply the principles and laws that relate to static equilibrium and strength of materials to resolve mechanical engineering problems
(64 hours)

Additional guidance

The guidance in the section is not mandatory.

Content and context for this unit

Understand the relationship between the structure and properties of materials in relation to mechanical engineering problems (outcome 1)

This introduces learners to the properties of engineering materials and how these properties can be used in engineering applications. They should understand further treatments and work to further alter the properties, and should also understand the testing procedures used.

Apply the principles and laws that relate to engineering dynamics to resolve mechanical engineering problems (outcome 2)

This introduces learners to Newton's laws of motion, as they apply it in relation to linear, angular and projectile motion. Learners apply the energy balance equation in situations that involve work, energy and power. This outcome also introduces learners to centripetal and centrifugal forces, leading on to damped and undamped spring and mass problems.

Apply the principles and laws that relate to static equilibrium and strength of materials to resolve mechanical engineering problems (outcome 3)

This introduces learners to static equilibrium and strength of materials. This provides them with a study of the application of force in structures and beams, allowing the calculation of reaction forces. Outcome 3 also introduces learners to the stress-strain relationship and the application of Hooke's law. They develop this into the torque load condition and the application of the torque equation in practical engineering examples.

You could use structural analysis simulation software.

Approaches to delivery

We recommend a sequential approach to delivery, where learners study and complete the outcomes in order. However, you could deliver outcome 2 first and then outcomes 1 and 3 together if you prefer.

You should deliver these in a learning space or virtual learning environment. Teach learners primarily by problem-based-learning (PBL) techniques such as case studies and mini projects, supported by other methods. The holistic teaching format of PBL encourages them to consider the deeper context of the theory.

You could enhance this unit with guest lecturers, for example industry specialists, and industrial visits.

Approaches to assessment

There are opportunities to assess this unit in conjunction with other units in the Higher National Certificate (HNC) in Engineering qualification, (including the Thermodynamics and Fluid Mechanics unit at SCQF level 7 and the Engineering Principles unit at SCQF level 6), in the form of real-world engineering problems.

In line with the approach to the delivery, you should take a holistic approach to assessment. This consists of a review of case studies, mini projects and group work, focusing on carrying out real-life engineering scenario-based problems, case studies and mini projects. Learners should collate all evidence in their individual portfolio.

For case studies and mini projects, you can assess knowledge and skills through coursework exercises. Learners must produce product evidence (for example, in the form of a coursework report), which they do under controlled or supervised open-book conditions.

Learners could keep a reflective account to measure their meta-skills, digital literacies, professional skills and wider employer-desired skills. They should record this in their portfolio.

You should provide learners with support, guidance and feedback on areas of development, and signpost developmental opportunities. Because of the open-book nature of the assessment, you must take care to ensure authenticity. You can do this by using variable values in the coursework, making use of oral questioning and using originality-checking software, as appropriate.

Opportunities for e-assessment

Assessment that is supported by information and communication technology (ICT), such as e-testing or the use of e-portfolios or social software, may be appropriate for some assessments in this unit.

If you want to use e-assessment, you must ensure that you apply the national standard to all evidence and that conditions of assessment (as specified in the evidence requirements) are met, regardless of the mode of gathering evidence.

Equality and inclusion

This unit is designed to be as fair and as accessible as possible with no unnecessary barriers to learning or assessment.

You should take into account the needs of individual learners when planning learning experiences, selecting assessment methods or considering alternative evidence.

Guidance on assessment arrangements for disabled learners and/or those with additional support needs is available on the assessment arrangements web page: www.sqa.org.uk/assessmentarrangements.

Information for learners

Engineering Mechanics and Materials (SCQF level 7)

This information explains:

- what the unit is about
- what you should know or be able to do before you start
- what you need to do during the unit
- opportunities for further learning and employment

Unit information

This unit provides you with knowledge and skills specific to mechanical engineering. It forms part of the Higher National Certificate in Engineering, which aims to provide you with opportunities to progress into industry in a mechanical engineering technician role.

It also provides a career development opportunity for those already in industry, as well as the opportunity for you to build the engineering knowledge, skills and experience required to progress to further study at either Higher National Diploma (HND) level or university.

Before starting this unit, you should already have broad knowledge and understanding of mathematics and mechanical engineering concepts and theorems, or relevant workplace experience.

You learn about the fundamental mechanical engineering principles of statics and dynamics, as well as material properties and their importance in the selection of materials related to engineering problems.

Unit outcomes

On completion of this unit, you can:

1 understand the relationship between the structure and properties of materials in relation to mechanical engineering problems
2 apply the principles and laws that relate to engineering dynamics to resolve mechanical engineering problems
3 apply the principles and laws that relate to static equilibrium and strength of materials to resolve mechanical engineering problems

Outcome 1 — introduces you to the mechanical properties of engineering materials and their importance when selecting materials for engineering applications. You learn how these properties can change through various processes and carry out testing processes to determine material properties.

Outcome 2 — introduces you to Newton’s laws of motion and their application in relation to linear and angular dynamics. You apply mathematics principles in solving various dynamic

problems, including applying the energy balance equations, and centripetal and centrifugal forces.

Outcome 3 — introduces you to static equilibrium and the study of applied forces within structures and beams to determine the strength of materials within various engineering applications. You also learn about the stress–strain relationship and the applications of Hooke's law, which develops into an understanding of torsion theory. There is an emphasis on applied mathematics throughout this outcome, which builds on the Mathematical Tools for Engineering unit at SCQF level 6.

Assessment

There is a holistic approach to assessment, where you are assessed by a variety of means, including project-based learning, case studies and lab exercises. You generate evidence through an individual portfolio.

Meta-skills

Throughout the unit, you can develop meta-skills to enhance your employability in the engineering sector.

Meta-skills include self-management, social intelligence and innovation.

Self-management

As you work through the course material and case studies, you develop the skills of adapting and initiative through critical reflection and independent thinking.

Social intelligence

You develop the skills of communicating and collaborating as you work with other learners on case studies and assignments.

Innovation

You develop a number of skills including critical thinking, curiosity and sense-making as you analyse problems relating to mechanical engineering principles.

Administrative information

Published: October 2024 (version 3.0)

Superclass: XH

History of changes

Version	Description of change	Date
2.0	Evidence requirements updated to clarify sampling and conditions of assessment.	August 2024
3.0	♦ Evidence requirements updated regarding sampling items. ♦ Knowledge and skills updated. ♦ Approaches to assessment updated.	October 2024

Note: please check SQA's website to ensure you are using the most up-to-date version of this document.