Next Generation Higher National Unit Specification

Thermodynamics and Fluid Mechanics (SCQF level 7)

Unit code: J6CX 47

SCQF level: 7 (24 SCQF credit points)

Valid from: session 2024 to 2025

Prototype unit specification for use in pilot delivery only (version 2.0) August 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: August 2024 (version 2.0)

Unit purpose

This unit enables learners to develop knowledge, understanding and skills in mechanical engineering principles, with a focus on engineering heat and flow principles including:

- thermodynamics
- heat transfer
- fluid mechanics
- pneumatics and hydraulics

The blend of background theory and applied principles gives learners a better understanding of the subject matter, and allows them to progress to further study and employment.

The target group 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

We recommend that learners complete the Engineering Principles unit at SCQF level 6 and the Engineering Mathematics 1 unit at SCQF level 6 before starting this unit.

Unit outcomes

Learners who complete this unit can:

1. apply the concepts of temperature and heat to resolve engineering problems
2. apply aspects of the first law of thermodynamics to resolve engineering problems
3. define the various properties and energy transfers for vapours relating to engineering problems
4. apply the principles of heat transfer to resolve engineering problems
5. analyse problems relating to hydrostatic pressures on vertical submerged plane surfaces
6. solve problems involving the application of the mass continuity and Bernoulli's equation to incompressible flow in pipes
7. apply fluid principles in the design, construction and testing of pneumatic and hydraulic systems related to 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.

Outcome 1

Sample any three of the four required items:

- Define the terms 'thermal equilibrium' and 'temperature'.
- Explain the empirical temperature scales (Fahrenheit, Celsius, Kelvin).
- State three thermometric properties from length, density, electrical resistance, volume and colour, and describe a temperature-measuring device based on any one of these properties.

- Use thermal expansion theory to calculate expansion coefficients and perform at least one practical experiment to apply the concepts of temperature and heat to determine thermal expansion parameters.

Outcome 2

Sample any six of the nine required items:

- Calculate gas properties using the gas laws:
  - ideal gas law
  - combined gas law
  - characteristic gas equation
- Define isothermal, adiabatic and polytropic processes.
- Draw isothermal, adiabatic and polytropic process diagrams.
- Calculate specific heat capacities of a gas at constant pressure and constant volume.
- Calculate change in internal energy.
- Evaluate work done on non-flow processes.
- Calculate unknowns in a steady flow process.
- Sketch and explain ideal cycles associated with heat engines, and compare ideal and practical cycles.
- Calculate the work of expansion and contraction for the following thermodynamic processes: isothermal, isobaric and adiabatic conditions.

Outcome 3

Sample any two of the three required items:

- Calculate internal energy and enthalpy.
- Use tables of properties.
- Basic steam terminology:
  - dry steam
  - wet steam
  - superheated steam
  - specific volume
  - internal energy
  - dryness fraction
  - degree of superheat

Outcome 4

Sample any five of the seven required items:

- Describe the terms used in conduction heat transfer.
- Describe the terms used in natural convection and forced convection heat transfer.
- Define the terms ‘thermal conductivity’ and ‘thermal resistance’.
- Apply the Fourier equation to solve problems involving either single or composite plane walls.
- Calculate heat energy transfer, mean temperature differences, and heat transfer area.
- Define black body radiation and define or calculate emissivity.
- Apply the Stefan–Boltzmann law to solve radiation problems.

Outcome 5

Sample any three of the four required items:

- Define density and unit weight.
- Calculate pressure at varying depth.
- Calculate pressure differential in a U-tube manometer using differing fluids.
- Calculate the resultant force and centre of pressure on a vertical submerged plane surface.

Outcome 6

Sample any two of the three required items:

- Solve problems involving mass and volumetric flow rates.
- Solve problems involving Bernoulli’s equation in pipes of constant and varying cross-section and involving change of height.
- Solve problems involving motion in pipe bends, stationary flat plates and stationary curved vanes.

Outcome 7

- Identify the operation of the main features of a pneumatic system; identify the operation of the main features of a hydraulic system; explain the properties of air as a working fluid; and explain the properties of hydraulic fluids.
- Describe the operation and performance of air compressors; and describe the operation and performance of hydraulic pumps.
- Design a fluid power and control circuit to satisfy a given performance specification; select appropriate components to assemble the circuit; prepare drawings and a parts list for the circuit; and assemble the circuit.
- Explain the safety precautions required when operating or working with pneumatic and hydraulic systems.

Knowledge and skills

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

Knowledge	Skills
Outcome 1 Learners should understand how to: ♦ explain and describe thermal equilibrium and temperature ♦ explain and describe values using empirical temperature scales (Fahrenheit, Celsius, Kelvin) ♦ explain and describe values using thermometric properties ♦ explain and describe values of thermal expansion	**Outcome 1** Learners can: ♦ calculate values using empirical temperature scales (Fahrenheit, Celsius, Kelvin) ♦ calculate values using thermometric properties ♦ calculate values of thermal expansion
Outcome 2 Learners should understand how to: ♦ explain and describe the ideal gas law ♦ explain and describe isothermal, adiabatic and polytropic processes and draw process diagrams ♦ explain and describe specific heat capacities of a gas at constant pressure and at constant volume ♦ explain and describe non-flow processes ♦ explain and describe steady flow processes ♦ explain and describe ideal and practical cycles ♦ explain and describe thermal changes and work done	**Outcome 2** Learners can: ♦ calculate values using ideal gas laws ♦ calculate values using specific heat capacities of a gas at constant pressure and at constant volume ♦ calculate values using non-flow processes ♦ calculate values using steady flow processes ♦ calculate values using ideal and practical cycles ♦ calculate values using thermal changes and work done

Knowledge	Skills
Outcome 3 Learners should understand how to: ♦ explain and describe internal energy and enthalpy ♦ use steam terminology: dry steam, wet steam, superheated steam, specific volume, internal energy, dryness fraction and degree of superheat	**Outcome 3** Learners can: ♦ calculate values using internal energy and enthalpy ♦ use tables of properties for calculations ♦ calculate basic steam terminology: dry steam, wet steam, superheated steam, specific volume, internal energy, dryness fraction and degree of superheat
Outcome 4 Learners should understand how to: ♦ explain and describe conduction ♦ explain and describe convection ♦ explain and describe thermal conductivity and thermal resistance ♦ explain and describe the Fourier equation to plane walls ♦ explain and describe black body radiation and emissivity ♦ explain the Stefan–Boltzmann law	**Outcome 4** Learners can: ♦ calculate values using the Fourier equation to plane walls ♦ calculate overall heat transfer ♦ calculate black body radiation and emissivity ♦ calculate values using the Stefan–Boltzmann law
Outcome 5 Learners should understand how to: ♦ explain and define densities and unit weights of different fluids ♦ explain and define pressure at various depths owing to static fluid	**Outcome 5** Learners can: ♦ calculate densities and unit weights of different fluids ♦ calculate pressure at various depths owing to static fluid ♦ calculate pressures at various depths owing to two fluids of different densities ♦ calculate resultant forces and centres of pressure on vertical submerged plane surfaces

Knowledge	Skills
Outcome 6 Learners should understand how to: ♦ define the principles of the equation of mass continuity for the flow of an incompressible fluid to calculate various quantities ♦ define the principle of Bernoulli's equation for the flow of an incompressible fluid through a tapered pipe with a change in height ♦ define the mass continuity and Bernoulli's principles to flow through pipes	**Outcome 6** Learners can: ♦ apply the principles of the equation of mass continuity for the flow of an incompressible fluid to calculate various quantities ♦ apply the principle of Bernoulli's equation for the flow of an incompressible fluid through a tapered pipe with a change in height to calculate various quantities ♦ apply the mass continuity and Bernoulli's principles to flow through pipes and vanes to calculate various quantities
Outcome 7 Learners should understand how to: ♦ identify and correctly explain the function of pneumatic and hydraulic components, using appropriate symbols that conform to current standards ♦ identify the various types, and describe the operation and calculate performance quantities of both air compressors and hydraulic pumps	**Outcome 7** Learners can: ♦ design and simulate a power circuit to meet a set specification ♦ identify safety regulations for the assembly and testing of a fluid power system

Meta-skills

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

Self-management

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

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, and engaging with other learners and their teacher or lecturer.

Digital

Learners develop their digital literacy skills by using information and communication technology (ICT) throughout the unit.

Delivery of unit

This unit is part of the Higher National Certificate (HNC) in Engineering. The framework includes a number of mandatory and optional units, and you can tailor the selected combination of units specific to the 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. We suggest the following distribution of time, including assessment:

Outcome 1 — Apply the concepts of temperature and heat to resolve engineering problems (18 hours)

Outcome 2 — Apply aspects of the first law of thermodynamics to resolve engineering problems (21 hours)

Outcome 3 — Define the various properties and energy transfers for vapours relating to engineering problems (18 hours)

Outcome 4 — Apply the principles of heat transfer to resolve engineering problems (18 hours)

Outcome 5 — Analyse problems relating to hydrostatic pressures on vertical submerged plane surfaces (6 hours)

Outcome 6 — Solve problems involving the application of the mass continuity and Bernoulli’s equation to incompressible flow in pipes (9 hours)

Outcome 7 — Apply fluid principles in the design, construction and testing of pneumatic and hydraulic systems related to engineering problems (30 hours)

Additional guidance

The guidance in this section is not mandatory.

Content and context for this unit

This unit gives learners knowledge and skills in mechanical engineering principles, with a focus on engineering heat and flow principles.

Apply the concepts of temperature and heat to resolve engineering problems (outcome 1)

This introduces learners to the base units, descriptions and terminology of heat and, by extension, thermodynamics.

Apply aspects of the first law of thermodynamics to resolve engineering problems (outcome 2)

This introduces learners to the first law of thermodynamics and its application in relation to heat and work. They also apply the energy balance equation in steady flow situations of an applied and practical nature.

Define the various properties and energy transfers for vapours relating to engineering problems (outcome 3)

This introduces learners to steam terminology and, using data tables, they apply and calculate energy values, underpinning and further developing the knowledge they gained in outcomes 1 and 2.

Apply the principles of heat transfer to resolve engineering problems (outcome 4)

This introduces learners to heat transfer. They use the Fourier equation to calculate intermediate temperatures and total heat loss. This furthers their knowledge from outcomes 1, 2 and 3.

Analyse problems relating to hydrostatic pressures on vertical submerged plane surfaces (outcome 5)

This introduces learners to hydrostatics. They apply this theory to find pressures at depth on various practical applications.

Solve problems involving the application of the mass continuity and Bernoulli’s equation to incompressible flow in pipes (outcome 6)

This introduces learners to fluid mechanics. They apply mass continuity and Bernoulli’s theory, combined with velocity ratios, to practical applications to calculate pressures and velocities in pipe sections.

Apply fluid principles in the design, construction and testing of pneumatic and hydraulic systems related to engineering problems (outcome 7)

This introduces learners to pneumatics and hydraulics. They calculate pressures, velocities of stroke, system capacities and power requirements. They also get the chance to either physically build the required pneumatic circuits or simulate them using applicable software.

If required, you can use simulation software instead of physical equipment, or to supplement the physical equipment.

Approaches to delivery

You should take a sequential approach to delivery, where learners study and complete the outcomes in order. However, outcomes 2 and 3 could be completed together, as could outcomes 5 and 6.

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

Approaches to assessment

You can assess learners using a variety of holistic ways. This principally consists of a hybrid assessment for outcomes 1, 2, 3, 4, 5 and 6, involving a case study-type scenario that allows for a combined assessment with the Engineering Mechanics and Materials unit at SCQF level 7. You should assess outcome 7 as a practical task.

Learners should generate evidence under open-book conditions and collate all evidence in their individual portfolio.

For case studies and mini projects, you can assess knowledge and skills through coursework exercises. Learners must generate product evidence (for example, in the form of a coursework report), which they should produce under open-book, unsupervised and untimed 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 could 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 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

Thermodynamics and Fluid Mechanics (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 a depth of knowledge in a principal area of mechanical engineering. It is one of two principal units in the Higher National Certificate (HNC) in Engineering.

This unit is for learners who are:

- in a variety of industry-level jobs such as technical or design and development posts
- looking to build on their engineering knowledge to progress to higher education

Before you begin, you should have a broad knowledge and understanding of mathematics and mechanical engineering concepts and theorems. For example, you may have completed Higher Mathematics or Physics, or a National Certificate (NC) in Mechanical Engineering at SCQF level 6.

If you have an experience-based background, you should have a good understanding and working knowledge from your experience.

Unit outcomes

On completion of this unit, you can:

1. apply the concepts of temperature and heat
2. apply aspects of the first law of thermodynamics
3. define the various properties and energy transfers for vapours
4. apply the principles of heat transfer
5. analyse problems relating to hydrostatic pressures on vertical submerged plane surfaces
6. solve problems involving the application of the mass continuity and Bernoulli's equation to incompressible flow in pipes
7. apply fluid principles in the design, construction and testing of pneumatic and hydraulic systems related to engineering problems

Outcomes 1, 2, 3 and 4 — introduce you to thermodynamic principles, then build up your knowledge to cover the laws of thermodynamics and applying thermodynamic theory, including energy in steam and heat transfer conditions.

Outcomes 5 and 6 — the focus moves from thermodynamics to fluid mechanics, starting with hydrostatics and then moving on to fluid flow conditions in practical applications.

Outcome 7 — applies many of the above principles in the form of pneumatics and hydraulics. The theory of pressure and flow are shown in practical application using pneumatic equipment or simulation packages.

In this unit, you are assessed by a combination of projects and labs, along with a holistic-style assessment that is carried out in conjunction with the Mechanical Engineering: Engineering Mechanics and Materials unit. In this assessment, a realistic scenario is used to assess the criteria for both units.

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: August 2024 (version 2.0)

Superclass: RC

History of changes

Version	Description of change	Date
02	Evidence requirements updated to clarify sampling and conditions of assessment.	August 2024

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