# Next Generation Higher National Unit Specification

## Engineering Systems Principles (SCQF level 7)

**Unit code:** J6D4 47

**SCQF level:** 7 (24 SCQF credit points)

**Valid from:** session 2024 to 2025

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

# Unit purpose

This unit provides learners with knowledge and skills specific to systems engineering. They learn about the principles underlying systems, including:

- electrical principles
- mechanical principles
- electronics principles
- instrumentation principles

The target group for this unit is learners who want to develop their core engineering design and analysis skills to support a career in systems engineering.

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

- broad knowledge and understanding of electrical, electronic and mechanical concepts and theorems at SCQF level 6, for example in subjects related to electrical engineering, electronics or mechanical principles
- an appreciation of manufacturing principles, and project and risk management at SCQF level 6, for example, in subjects related to manufacturing principles, or project and risk management
- relevant, equivalent workplace experience or SCQF level 6 qualifications, for example Higher Physics or a National Certificate (NC) in Engineering Systems

This unit provides learners with suitable knowledge and skills to progress to further study, or employment in a wide range of engineering industries.

# Unit outcomes

Learners who complete this unit can:

1. apply electrical principles to solve problems encountered in engineering systems
2. apply mechanical principles to solve problems encountered in engineering systems
3. apply fluids and heat transfer principles to solve problems encountered in engineering systems
4. apply instrumentation principles to solve problems encountered in engineering systems

## 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 seven of the ten required items:

- Use the correct electrical quantities and standard international units to perform calculations, including the use of complex numbers and phasors for alternating current (AC) circuit calculations.
- Apply circuit reduction techniques to solve problems in one direct current (DC) circuit and one AC circuit containing parallel and series resistors, inductors and capacitors.
- Apply Kirchhoff's current and voltage laws to solve a problem in a DC circuit with parallel components and multiple circuit loops.
- Apply Kirchhoff's current and voltage laws to solve a problem in an AC circuit with parallel components and multiple circuit loops.
- Use voltage and current dividers to calculate voltage and current in one DC and one AC circuit containing resistors, inductors and capacitors.

- Calculate active power and energy consumed by one DC and one AC circuit containing resistors, inductors and capacitors.
- Calculate reactive and apparent power consumed by an AC circuit containing resistors, inductors and capacitors.
- Accurately measure DC and AC voltage, current, and power in one DC and one AC circuit with parallel components and multi-loops, containing resistors, inductors and capacitors.
- Explain transient responses in DC resistive-inductive and resistive-capacitive circuits.
- Explain the per unit (PU) system as applied to electrical power systems.

## Outcome 2

Sample any 16 of the 27 required items:

- Use the equations of static equilibrium to calculate reactions and moments in a simply supported beam.
- Use nodal analysis to solve a framework problem.
- Use vector analysis to solve a framework problem.
- Draw one shear force and one bending moment diagram.
- Determine the position of maximum shear and maximum tensile and compressive bending for a simply supported beam and a cantilever.
- Calculate stress and strain.
- Draw a stress-strain graph and use it to calculate modulus of elasticity.
- Solve a problem using the bending and torque equations.
- Explain compressive and tensile forces in structural members.
- Explain stress and strain and the relationship between them.
- Explain the stress-strain curve for elastic and plastic materials.
- Solve a problem using each of the angular equations of motion and each of the angular to linear bridging equations.
- Solve a projectile motion problem.
- Calculate tension in a two-rope system under steady state and acceleration.
- Solve a linear and an angular momentum problem.
- Calculate work done during motion and overcoming friction for one object.
- Solve a problem involving moment of inertia.
- Explain the velocity–time graph and other quantities that can be calculated from it (such as acceleration, displacement).
- Explain the conservation of linear and angular momentum.
- Calculate values of two material properties from experimental data.
- Carry out two tensile and two hardness tests.
- Summarise the common material properties of toughness, malleability and tensile strength.
- Summarise the properties of common metals.
- Summarise the properties of common non-metals.
- Explain the structure of metals.
- Explain the structure of non-metals.

- Explain heat treatment and cold working.

**Outcome 3**

Sample any six of the nine required items:

- Solve a problem using each of the ideal gas laws.
- Solve two problems using the combined gas laws.
- Solve a problem involving calculation of heat energy and enthalpy.
- Calculate heat energy transferred during a thermodynamic process.
- Explain the relationship between heat and work.
- Summarise energy transfer principles in boilers.
- Explain flow through pipes and vanes.
- Summarise absolute, atmospheric and gauge pressure.
- Calculate gauge pressure for two situations.

**Outcome 4**

Sample any seven of the nine required items:

- Select and use a sensor for the measurement of any two of the following: displacement, velocity, temperature, flow, level, pressure, strain or light, for specific applications.
- Select and use an actuator for the variation of any two of the following: displacement, velocity, temperature, flow, level, pressure, strain or light, for specific applications.
- Select components to build and test a transducer interfacing circuit using electronic components and explain the role of the electronic components selected.
- Select and use instrumentation to accurately measure voltage, current and power.
- Select and use instrumentation to accurately measure any three of displacement, velocity, temperature, flow, level and pressure.
- Calculate measurement errors caused by instrument inaccuracies, for one electrical and one mechanical measurement.
- Calibrate an instrumentation system used to measure displacement, velocity, temperature, flow, level or pressure.
- Interpret a process flow diagram.
- Interpret a circuit diagram.

# Knowledge and skills

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

| Knowledge | Skills |
|---|---|
| Learners should understand how to explain:<br><br>♦ transient responses in DC resistive-inductive and resistive-capacitive circuits<br>♦ the PU system as applied to electrical power systems<br>♦ metallic and non-metallic material structure<br>♦ heat, energy, work and pressure, and the relationships between them<br>♦ the operation of transducer interfacing circuits | Learners can:<br><br>♦ solve problems involving DC principles<br>♦ solve problems involving AC principles<br>♦ solve problems involving power and energy principles<br>♦ solve problems involving statics principles<br>♦ solve problems involving dynamics principles<br>♦ solve problems involving materials principles<br>♦ solve problems involving fluids principles<br>♦ solve problems involving heat transfer principles<br>♦ select and use transducers for the measurement and control of physical variables<br>♦ select components, build and test transducer interfacing circuits<br>♦ select and use instrumentation for accurate measurements<br>♦ interpret instrumentation diagrams |

# Meta-skills

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

## Self-management

Learners develop the skill of integrity. They can provide evidence of this in their reflective reports.

## Social intelligence

Learners develop their ability to collaborate by taking part in a group project.

## Innovation

Learners develop their sense-making skills. They could provide evidence of this by evaluating multiple system performance.

# Literacies

Learners develop core skills in the following literacies:

## Numeracy

Learners develop their numeracy skills by performing engineering calculations.

## 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 by accessing the course material through a virtual learning environment, collaborating online and producing an e-portfolio.

# 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 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 recommended holistic approach). We suggest the following distribution of time, including assessment:

**Outcome 1** — Apply electrical principles to solve problems encountered in engineering systems (20 hours)

**Outcome 2** — Apply mechanical principles to solve problems encountered in engineering systems (30 hours)

**Outcome 3** — Apply fluids and heat transfer principles to solve problems encountered in engineering systems (30 hours)

**Outcome 4** — Apply instrumentation principles to solve problems encountered in engineering systems (40 hours)

# Additional guidance

The guidance in this section is not mandatory.

## Content and context for this unit

This unit gives learners some of the knowledge and skills they need to support an industrial career in an engineering field such as:

- electrical engineering
- mechanical engineering
- systems engineering
- manufacturing engineering
- measurement and control engineering

The unit takes an integrated approach, combining principles theory with mathematical underpinning knowledge, practical experimentation and using digital technology. You can combine this unit with some of the learning in the Engineering Principles unit at SCQF level 6, the Professional Practice in Engineering unit at SCQF level 7, and the Engineering Systems: Practical Skills unit at SCQF level 7. We also encourage contextualisation — using real industry examples and case studies.

### Apply electrical principles to solve problems encountered in engineering systems (outcome 1)

Learners develop the ability to calculate and measure current, voltage and power in a variety of AC and DC passive circuits. Where practicable, they should use a variety of instruments for measurement, for example oscilloscopes, multimeters, wattmeters, power sources, signal sources, current probes and remotely connected equipment. You should encourage learners to use digital technologies, such as industry standard mathematical and simulation software, to help them develop meta-skills and compound their knowledge and skills.

### Apply mechanical principles to solve problems encountered in engineering systems (outcome 2)

Learners develop skills and knowledge relating to statics, dynamics and materials. Where possible, they should gather data by carrying out experimentation and testing, such as tensile tests, structural testing and air track momentum experiments. In structural testing, learners carry out stress and strain calculations, and calculate compressive and tensile forces in simple structures. In dynamics and materials, they should work with the range of criteria specified in the evidence requirements. You should encourage learners to use digital simulation alongside this to help them develop their meta-skills and further reinforce their learning.

### Apply fluids and heat transfer principles to solve problems encountered in engineering systems (outcome 3)

Learners develop knowledge and skills relating to thermodynamics and fluids, including the ability to calculate heat and work. They learn the important theories of heat transfer and working fluids. Where possible, learners should gather their own data for processing, for example by taking pressure measurements. Where experimentation is not possible, they should use digital technologies instead, which allows them to develop meta-skills and reinforce their knowledge.

### Apply instrumentation principles to solve problems encountered in engineering systems (outcome 4)

Learners develop knowledge and skills in the application and use of instrumentation and associated subjects. Learners should develop knowledge of a variety of different types of transducers, and skills in using these, along with both analogue and digital interfacing circuits, in a variety of instrumentation systems and instruments. Other key skills in this outcome are determining measurement accuracy and calibrating to achieve best accuracy. Where practicable, learners should use modern instruments, remotely connected equipment and smart sensors. You should encourage them to use digital technologies, such as industry standard mathematical and simulation software, to help them develop meta-skills and compound their knowledge and skills. You should deliver and assess this outcome as one or more group projects, to develop collaboration skills.

## Approaches to delivery

We advise that learners study outcomes 1 to 3 first. These introduce learners to key concepts that they would benefit from understanding before they move on to the topics in outcome 4.

You should deliver the outcomes in a learning space or virtual learning environment. Choose a holistic approach of active learning to encourage learners to consider the deeper context of the theory.

You could enhance this unit with guest lectures from industry specialists and industrial visits.

## Approaches to assessment

In line with the approach to delivery, you should take a holistic approach to assessment. This consists of a review of case study reports, mini projects and group work.

For case studies and mini projects, you can assess knowledge and skills through coursework exercises. In particular, you can use reflective reports to assess integrity. You can assess learners' ability to collaborate in a group project by their contribution to and reflection on group work.

Learners could demonstrate evidence of all knowledge and skills in the context of one or more overarching complex systems engineering scenarios. They must produce product evidence, for example in the form of reports. They should collate all evidence in their individual portfolio, which they produce in open-book, unsupervised and untimed conditions.

Learners could keep a linear 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 coursework, making use of oral questioning, and using originality-checking software.

## 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 Systems Principles (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 forms part of the Higher National Certificate (HNC) in Engineering. It provides you with knowledge and skills specific to systems engineering, and is aimed at learners wishing to become engineering technicians.

In this unit, you learn about the principles underlying systems, including:

- electrical principles
- mechanical principles
- electronics principles
- instrumentation principles

### Unit outcomes

On completion of this unit, you can:

1 apply electrical principles to solve problems encountered in engineering systems
2 apply mechanical principles to solve problems encountered in engineering systems
3 apply fluids and heat transfer principles to solve problems encountered in engineering systems
4 apply instrumentation principles to solve problems encountered in engineering systems

**Outcome 1** — you learn how to solve problems using the electrical principles of direct current (DC) and alternating current (AC). By applying these principles, you calculate current, voltage, power and energy for a variety of series and parallel multi-loop circuits. These circuits consist of electrical sources and loads containing passive components: resistors, inductors and capacitors.

**Outcome 2** — you learn how to apply knowledge of statics, dynamics and materials principles to solve mechanical engineering problems. You can perform practical testing such as tensile tests, structural testing and air track momentum experiments. You also learn how to use simulation software to solve mechanical problems.

**Outcome 3** — you learn how to apply knowledge of thermodynamics and fluids principles to solve engineering problems. You learn the important theories of heat transfer and working fluids, using this knowledge to calculate heat and work. You use experimentation or digital technologies (such as simulation software) to compound your knowledge.

**Outcome 4** — you learn how to use instrumentation and how to interpret measurement results. You learn about a variety of different types of transducers, and analogue and digital interfacing circuits. You use this knowledge to build and test circuits and systems, either using digital technologies (such as simulation software) or by workshop activities, such as calibrating an instrumentation system.

You are assessed in a variety of ways. You produce reports that investigate and review case studies (using real-life examples) and complete mini projects. For outcome 4, you may also be assessed by producing reports on work you have done in a group. You should collate all your assessment evidence in your individual portfolio, along with reflective reports on what you have learned.

When you have completed this unit, you are able to apply the principles of electrical, mechanical, fluids and instrumentation engineering to solve problems in engineering systems.

## Meta-skills

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

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

### Self-management

You develop the skill of integrity, which is assessed through your reflective reports.

### Social intelligence

You develop your ability to collaborate, which is assessed by a group project.

### Innovation

You develop your sense-making skills when you think about different aspects of engineering systems.

# Administrative information

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**Superclass:** XA

## History of changes

| Version | Description of change | Date |
|---|---|---|
| 2.0 | ♦ In 'Evidence requirements', wording edited for clarity and consistency with other units; wording added to clarify sampling; and changes made to outcome 4 knowledge and skills items.<br>♦ Style and punctuation edits made to 'Knowledge and skills' section for clarity and consistency.<br>♦ In 'Additional guidance' section, minor punctuation edits for clarity and readability.<br>♦ In 'Information for learners' section, changed 'section' to 'information', and updated wording of meta-skills, for consistency across units. | August 2023 |
| 3.0 | Additional wording to clarify conditions of assessment. | August 2024 |
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Note: please check SQA's website to ensure you are using the most up-to-date version of this document.