Next Generation Higher National Unit Specification

Dynamic Engineering Systems: Modelling, Simulation and Control (SCQF level 8)

Unit code: J7BX 48

SCQF level: 8 (24 SCQF credit points)

Valid from: session 2023–24

Prototype unit specification for use in pilot delivery only (version 1.0) November 2023

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: November 2023 (version 1.0)

Unit purpose

This unit enables learners to gain knowledge about and develop skills in the fundamentals of the performance of engineering systems, and modern techniques used to control them.

They study a variety of topics, including:

- dynamic engineering systems and control systems
- mathematical models of dynamic engineering systems
- mechanical engineering systems
- electrical, electronic and electromechanical engineering systems
- response and stability of dynamic engineering systems
- basic control systems
- digital control systems

The unit is aimed at learners who want to apply dynamic engineering systems knowledge and skills to solve engineering problems, with an emphasis on modelling, analysis, simulation and control.

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

- broad understanding of engineering systems principles and mathematical skills, for example an SCQF level 7 qualification in Engineering Systems, Electrical Engineering, Instrumentation and Control, or Mechanical Engineering
- relevant, equivalent workplace experience

The unit provides learners with suitable knowledge and skills to progress to further study or employment in a wide range of engineering industries, such as utilities, renewables, chemical, pharmaceutical, food and drink, oil and gas, and other industries involving process control.

Unit outcomes

Learners who complete this unit can:

1 identify dynamic engineering systems and control systems
2 identify mathematical models of dynamic engineering systems
3 model mechanical engineering systems
4 model electrical, electronic and electromechanical engineering systems
5 analyse the response and stability of dynamic engineering systems
6 analyse control systems
7 identify digital control systems

Evidence requirements

Learners produce a portfolio consisting of written, oral and/or video recorded evidence. This should be in the form of case study reviews and/or problem-based learning (PBL) assignments. In their responses, learners must critically reflect on the knowledge and skills they have gained. Learners must produce evidence under unsupervised, open-book conditions.

Learners should produce evidence of all knowledge and skills in the context of one or more overarching engineering systems dynamics and control scenarios.

You can find more information in the ‘Additional guidance’ section.

To successfully achieve the unit, learners must provide evidence for the following outcomes.

Outcome 1

- Identify applications of control systems.
- Distinguish relevant terminology used in dynamic systems and control systems.
- Distinguish dynamic system and system dynamics.
- List types of dynamic systems.
- Identify uses of closed-loop and open-loop control systems.
- Use computer software for modelling and simulation.

Outcome 2

- Identify differential equations of dynamic engineering systems.
- Apply Laplace Transformation to obtain transfer functions.
- Identify systems input functions.
- Perform software simulations of differential equations and transfer functions.

Outcome 3

- Identify physical laws and mathematical models of translational mechanical system elements.
- Identify physical laws and mathematical models of rotational mechanical system elements.
- Identify physical laws and mathematical models of mechanical engineering systems.
- Perform software simulations of mechanical systems and their elements.

Outcome 4

- Identify physical laws and mathematical models of electrical system elements.
- Identify physical laws and mathematical models of electrical systems.
- Perform software simulation of electrical systems.
- Identify physical laws and mathematical models of electronic systems.
- Perform software simulation of electronic systems.
- Identify physical laws and mathematical models of electromechanical systems.
- Perform software simulations of electromechanical systems.

Outcome 5

- Identify types of system response.
- Analyse the transient response of dynamic engineering systems.
- Analyse the frequency response of dynamic engineering systems.
- Apply the concept of stability in linear time-invariant (LTI) systems.
- Perform software simulations of the response and stability of engineering systems.

Outcome 6

- Identify automatic control systems.
- Analyse feedback control systems.
- Identify applications of proportional, integral and derivative controllers.
- Apply the Ziegler–Nichols tuning method.
- Apply the root locus method.
- Perform software simulations of basic feedback control systems.

Outcome 7

- Identify digital control systems.
- Identify methods of digital control design.

Knowledge and skills

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

Knowledge	Skills
Outcome 1 Learners should understand: ♦ applications of control systems ♦ terminology used in dynamic systems and control systems ♦ dynamic system and system dynamics ♦ types of dynamic systems ♦ closed-loop and open-loop control systems ♦ computer software for modelling and simulation	**Outcome 1** Learners can: ♦ identify a wide range of real-life applications of control systems ♦ distinguish relevant terminologies used in dynamic systems and control systems ♦ distinguish the difference between dynamic system and system dynamics ♦ list the main types of dynamic systems ♦ identify the main features of closed-loop and open-loop control systems ♦ use computer software for modelling and simulation
Outcome 2 Learners should understand: ♦ differential equations of dynamic engineering systems ♦ Laplace Transformation and transfer functions ♦ software simulations of differential equations and transfer functions	**Outcome 2** Learners can: ♦ identify differential equations to model and simulate engineering systems ♦ apply Laplace Transformation to obtain transfer functions ♦ perform computer simulations of differential equations and transfer functions

Knowledge	Skills
Outcome 3 Learners should understand: ♦ translational mechanical system elements ♦ rotational mechanical system elements ♦ mechanical systems ♦ software simulations of mechanical systems	**Outcome 3** Learners can: ♦ identify physical laws and mathematical models of translational mechanical system elements ♦ identify physical laws and mathematical models of rotational mechanical system elements ♦ identify physical laws and mathematical models of mechanical systems ♦ perform software simulations of mechanical systems and their elements
Outcome 4 Learners should understand: ♦ electrical system elements ♦ electrical systems ♦ software simulations of electrical systems ♦ electronic systems ♦ software simulations of electronic systems ♦ electromechanical systems ♦ software simulations of electromechanical systems	**Outcome 4** Learners can: ♦ identify physical laws and mathematical models of electrical system elements ♦ identify physical laws and mathematical models of electrical systems ♦ perform software simulations of electrical systems ♦ identify physical laws and mathematical models of electronic systems ♦ perform software simulations of electronic systems ♦ identify physical laws and mathematical models of electromechanical systems ♦ perform software simulations of electromechanical systems

Knowledge	Skills
Outcome 5 Learners should understand: ♦ types of system response ♦ the transient response of dynamic engineering systems ♦ the frequency response of dynamic engineering systems ♦ stability in LTI systems ♦ software simulations of the response and stability of engineering systems	**Outcome 5** Learners can: ♦ identify transient and steady-state response ♦ analyse transient response of dynamic engineering systems ♦ analyse frequency response of dynamic engineering systems ♦ apply the concept of stability in LTI systems ♦ apply stability theory in the frequency domain ♦ perform computer simulations of system response and stability
Outcome 6 Learners should understand: ♦ automatic control systems ♦ feedback control systems ♦ proportional, integral and derivative controllers ♦ the Ziegler–Nichols tuning method ♦ the root locus method ♦ computer simulations of the stability of dynamic engineering systems	**Outcome 6** Learners can: ♦ identify automatic control systems ♦ analyse closed-loop control systems ♦ list ways to use proportional, integral and derivative controllers ♦ apply the Ziegler–Nichols tuning method to proportional, integral and derivative controllers ♦ analyse the transient response using the root locus method ♦ perform computer simulations of the performance of control systems
Outcome 7 Learners should understand: ♦ digital control systems ♦ digital controllers design	**Outcome 7** Learners can: ♦ identify practical issues of how controllers and feedback structures are implemented ♦ identify methods of digital controllers design

Meta-skills

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

Self-management

Learners develop the meta-skills of integrity (self-awareness, ethics and self-control) and adapting (critical reflection and self-learning) when making their portfolio or project assignments. They also develop initiative (decision-making, self-motivation and responsibility) during learning activities and when they elaborate reports.

Social intelligence

Learners develop communication skills (receiving information, listening and giving information) by accessing unit material through a virtual learning environment (VLE), keeping an e-portfolio and completing technical reports. They also develop their collaborative skills (team working and collaboration) when engaging with lecturers and other learners throughout the unit.

Innovation

Learners develop the meta-skills of curiosity (observation, questioning, information sourcing and problem recognition); creativity (imagination, idea generation, visualising and maker mentality); sense-making (pattern recognition, holistic thinking, synthesis, opportunity recognition and analysis); and critical thinking (deconstruction, logical thinking, judgement and computational thinking) during learning activities and assignments, working either individually or in groups.

Literacies

Learners develop core skills in the following literacies:

Numeracy

Learners develop numeracy skills by:

- working with physical laws models of engineering systems
- performing operations with advanced mathematical equations

Communication

Learners develop communication skills by:

- studying the course material
- keeping an individual portfolio
- elaborating reflective reports
- engaging with lecturers, other learners and other interested parties

Digital

Learners develop digital skills and computer literacy by:

- using appropriate engineering software packages to model and simulate the dynamics of engineering systems
- accessing the course material through a VLE
- using information and communication technology (ICT) to elaborate reports and display data and information

Delivery of unit

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

While the exact time allocated to the unit is at your centre's discretion, the notional design length is 120 hours.

The amount of time you allocate to each outcome is also at your discretion, however, we suggest spending approximately 17 hours on each outcome, including assessment.

Additional guidance

The guidance in this section is not mandatory.

Content and context for this unit

This unit gives learners the knowledge and skills they need to progress to higher study or employment in a wide range of engineering industries in the field of engineering systems, automation and control engineering.

Identify dynamic engineering systems and control systems (outcome 1)

This outcome introduces learners to dynamic engineering systems and control systems. Learners study the fundamentals of control systems, dynamic systems and system dynamics. This enables them to identify a wide range of practical applications of control systems, and distinguish relevant technical terminologies used in dynamic systems and control systems. They learn to distinguish dynamic system and system dynamics, and types of dynamic systems. They also learn and identify the main features of basic closed-loop and open-loop control systems. Finally, learners look at the main features of and how to run appropriate software for modelling and simulating engineering systems.

Identify mathematical models of dynamic engineering systems (outcome 2)

This outcome introduces learners to the basic mathematical methods for modelling dynamic engineering systems. Learners identify and apply differential equations that they could use to describe engineering systems. They learn how to use the Laplace Transformation method to transform simple differential equations into transfer functions. They learn and apply relevant input functions used for modelling and simulation of engineering systems, and learn how to perform computer simulations of both differential equations and transfer functions.

Model mechanical engineering systems (outcome 3)

This outcome introduces learners to the fundamentals of mathematical modelling and simulation of mechanical engineering systems and their elements. They identify and apply the fundamental physical laws and the mathematical models of translational and rotational motion mechanical systems. The mathematical models include both differential equations and transfer functions. Learners use appropriate software to model and simulate the physical laws, differential equations and transfer functions of mechanical systems.

Model electrical, electronic and electromechanical engineering systems (outcome 4)

This outcome introduces learners to the fundamentals of mathematical modelling and simulation of electrical, electronic and electromechanical engineering systems. Learners identify and apply the physical laws and mathematical models of electrical and electronic engineering systems and their elements. They learn to identify the physical laws and mathematical models that describe the performance of electromechanical systems. They use appropriate software to simulate the physical laws, differential equations and transfer functions of electrical, electronic and electromechanical systems.

Analyse the response and stability of dynamic engineering systems (outcome 5)

This outcome introduces learners to analysing the response and stability of engineering systems. Learners can identify different types of system response using both time domain and frequency response of engineering systems. They learn the concept of stability in linear control systems. Learners use the Routh–Hurwitz criterion, the root locus method and the frequency-domain stability criterion to analyse the stability of engineering systems. They use appropriate software to simulate and analyse the response and stability of engineering systems under various input and system parameter conditions.

Analyse control systems (outcome 6)

This outcome introduces learners to the basics of control systems. They learn how to analyse closed-loop feedback control systems. They also learn and identify different ways to use proportional, integral and derivative controllers. They learn and apply the Ziegler–Nichols tuning method and use the root locus method of a basic feedback control system. They also learn how to determine the steady-state accuracy of closed-loop controls, apply the concept of closed-loop stability, and analyse the transient response using the root locus method. Finally, they learn to quantify margins using Bode plots, and use appropriate software to perform simulations of the performance of control systems.

Identify digital control systems (outcome 7)

This outcome introduces learners to the fundamentals of digital control systems. They learn about modern digital computer control systems and how to identify how industrial controllers and feedback control loops are implemented. They also learn and identify methods of digital controller design.

Required resources

Your centre must have appropriate engineering modelling and simulation software to deliver this unit. Learners should have opportunities to use this software throughout the unit.

Approaches to delivery

We recommend you deliver the outcomes in order, from outcome 1 to outcome 7, as they progress gradually from the basics to more advanced concepts and principles.

You should deliver the unit in a learning space or through a VLE. You should teach primarily using PBL and gradual release of responsibility models, supported by other appropriate learner-centred methods. PBL and gradual release of responsibility approaches enable learners to develop their critical thinking, communication skills and problem-solving abilities.

You should deliver the unit by a combination of lectures, software modelling demonstrations and software simulation exercises.

Approaches to assessment

In line with the approach to delivery, you should take a holistic approach to assessment by reviewing case study reports and PBL assignments. Learners produce written and/or oral evidence under unsupervised, open-book conditions, and collate all evidence in their individual portfolios.

For case studies and PBL assignments, you can assess learners' knowledge and skills through coursework exercises. Learners' evidence could take the form of modelling, analysis or software simulation results reports.

You should combine assessment for:

- outcomes 1 and 2
- outcomes 3, 4 and 5
- outcomes 6 and 7

Learners' evidence for all three assessments should comprise:

- their results from modelling, analysis and software simulation
- their interpretation of the results

The assessments must be open book, with learners able to access software manuals, online help facilities and other appropriate support materials, such as books and class notes. Learners complete these assessments in their own time.

For the assessment of outcomes 6 and 7, it could be helpful to use the same engineering system used to assess outcomes 3, 4 and 5. This enables learners to experience continuity of learning from initial systems modelling, through the tuning of controllers, to the implementation of digital control systems.

You could create a checklist to confirm learners have satisfied the knowledge and skills requirements for all outcomes.

Learners can keep a linear reflective account to assess their meta-skills, digital literacies, communication skills and wider employer-desired skills. They should record this in their individual portfolio. You should provide learners with support, guidance and feedback on areas of development, and signpost development opportunities.

As assessment is open-book, you must take care to ensure authenticity. You can do this by using variable values in the PBL assignments, making use of oral questioning and using originality-checking software.

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

Dynamic Engineering Systems: Modelling, Simulation and Control (SCQF level 8)

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

In this unit, you gain knowledge and develop skills specific to dynamic engineering systems and control engineering. It is part of the Higher National Diploma (HND) in Engineering, which is aimed at learners who want to become engineering technicians or, after further study, engineers.

The unit equips you with the fundamental knowledge and skills you need to progress to higher study levels or employment in a wide range of engineering industries, such as utilities, renewables, chemical, pharmaceutical, food and drink, oil and gas, and other industries involving process control.

Before starting the unit, we recommend that you have a broad knowledge and understanding of engineering, and the fundamentals of mathematics. You should have a broad understanding of mechanical, electrical, electronics and control engineering principles. For example, you may have an SCQF level 7 qualification in an engineering discipline such as mechanical, electrical, electronics or engineering systems.

On completion of the unit, you can:

1. identify dynamic engineering systems and control systems
2. identify mathematical models of dynamic engineering systems
3. model mechanical engineering systems
4. model electrical, electronic and electromechanical engineering systems
5. analyse the response and stability of dynamic engineering systems
6. analyse control systems
7. identify digital control systems

You learn about dynamic engineering systems and control, and the mathematical models used to describe and simulate engineering systems. You gain knowledge and develop skills in how to model and simulate mechanical, electrical, electronics and electromechanical engineering systems. You also learn how to analyse the response, stability and feedback control of engineering systems. Finally, you learn the basics of modern digital control systems.

You are assessed in various ways, including by review of case study reports and problem-based learning (PBL) assignments. There is a holistic approach to assessment, where you demonstrate evidence of all knowledge and skills in the context of one or more overarching dynamic engineering systems and control systems scenarios. You produce evidence under open-book, unsupervised conditions. You should collate all evidence in your 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

You develop the meta-skills of focusing, adapting and initiative as you study the course material, and complete learning activities and assignments.

Social intelligence

You develop your communication skills during group work, and when engaging with lecturers and other learners throughout the unit.

Innovation

You develop the meta-skills of curiosity, sense-making, creativity and critical thinking when carrying out basic mathematical modelling and simulation activities.

Administrative information

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Superclass: VF

History of changes

Version	Description of change	Date

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