Next Generation Higher National Unit Specification

Thermodynamics, Plant Systems and Fluid Mechanics (SCQF level 8)

Unit code: J7BY 48

SCQF level: 8 (24 SCQF credit points)

Valid from: session 2024 to 25

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

Unit purpose

This unit enables learners to develop knowledge and understanding of:

- heat transfer
- fluid mechanics
- mechanical plant units, sub-systems and systems used in industry

The blend of background theory and applied principles gives learners an understanding that allows them to progress to further study and employment.

The target group for the 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, and instrumental and control engineering. It is also suitable for learners doing modern apprenticeships and those who want to develop the practical, personal and professional skills they need for a successful career as an engineering technician.

Entry to the unit 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 7, for example Advanced Higher Mathematics, Advanced Higher Physics or a Higher National Certificate (HNC) in Mechanical Engineering
- relevant, equivalent workplace experience in the mechanical engineering sector

We recommend that learners complete the following SCQF level 7 units before starting this unit:

- Engineering Principles
- Mathematical Tools for Engineering

Unit outcomes

Learners who complete this unit can:

1 apply the fundamental properties of thermodynamics to a process
2 evaluate the performance of internal combustion engines
3 explain the uses of common types of pumps and fans
4 explain the function of compressed air systems
5 explain the function of air-conditioning systems
6 explain the function of steam generation and distribution systems
7 explain the function of refrigeration systems
8 produce an installation and commissioning plan for an industrial system unit
9 analyse fluid flow patterns
10 solve flow measurement problems
11 solve problems involving incompressible flow in pipe systems

Evidence requirements

You should assess this unit holistically, using written or oral recorded evidence from reviews of case study reports and mini projects. 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 to match 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

Outcome 1

- Apply the relationship between pressure (P), volume (V) and temperature (T) for polytropic and adiabatic processes.
- Calculate work transfer and heat transfer for reversible processes.
- Apply the relationship between specific heat at constant pressure and constant volume.
- Solve problems relating to change of entropy (s) for reversible processes.
- Evaluate processes using P-V and T-s diagrams.
- Solve problems relating to Avogadro’s Law.
- Solve problems relating to the universal gas constant.

Outcome 2

- Compare ideal heat engines and their thermal efficiency, and apply the second law of thermodynamics.
- Describe ideal and practical engine cycles using P-V and T-s diagrams.
- Calculate thermal efficiency, indicated and brake mean effective pressure, work done and air standard efficiency of ideal cycles.

Outcome 3

- Describe one type of pump.
- Describe two impeller designs.
- Explain common applications of two impeller designs (one or both could apply to a fan).
- State the characteristics of the type of pump described.
- Perform calculations using pump characteristic curves.
- State how the method of delivery can be varied for the type of pump described.

Outcome 4

- Annotate a block diagram for one compressed air distribution system.
- Draw and annotate two sub-system diagrams.
- Describe the layout of an air supply for a system using one type of compressor.
- Describe the layout and function of a service unit.
- Calculate maximum load and the normal working load for a compressed air distribution system.
- Determine the pipe size for a system using a nomogram diagram.

Outcome 5

- Annotate a block diagram for one air-conditioning system.
- Draw and annotate two sub-system diagrams.
- Describe the layout and operation of one type of air-conditioning system (for example, a single or multiple system).
- Describe the function of components involved in air-conditioning systems.

Outcome 6

- Annotate a block diagram for one steam distribution system.
- Draw and annotate two sub-system diagrams.
- Complete an incomplete diagram of a system generation and distribution system, showing the fluid and air flows at all points in the system, and labelling each unlabelled unit in the system.
- Describe the function of components involved in steam generation and distribution systems.

Outcome 7

- Annotate a block diagram for one refrigeration system, showing the sub-systems and flows at all points in the system.
- Describe the function of each sub-system.
- Describe the layout and operation of one type of refrigeration system.
- Describe the operation of two sub-systems.
- Calculate the coefficient of performance (COP) for one refrigeration system.

Outcome 8

- Produce an installation and commissioning plan.
- Describe multiple pre-arrival considerations within an installation and commissioning plan.

Outcome 9

- Define the terms ‘viscosity’, ‘dynamic viscosity’ and ‘kinematic viscosity’.
- Classify flow types (laminar, transitional and turbulent).
- Classify flow types in terms of the Reynolds number.
- Define the term ‘drag’.
- State the component drag forces.
- Define the term ‘flow separation’.
- Explain why flow separation occurs.
- Sketch patterns around bodies on which flow separation occurs (bluff body shape, streamlined shape, cube or rectangle).

Outcome 10

- Define total and static pressure.
- Describe the principle of operation of one of the flow measurement systems (venturi meter, orifice plate, rotameter).
- Describe the principle of operation of one velocity measuring device (pitot tube, anemometer, pitot static tube, turbine meter).
- Identify an appropriate measurement system for a defined application.
- Determine flow velocity and volumetric flow rate by applying Bernoulli’s equation to one flow measurement device (venturi meter, orifice plate, pitot tube, pitot static tube).
- Determine from given data the coefficient of discharge for either a venturi meter or orifice plate by applying Bernoulli’s equation.

Outcome 11

- Define and calculate the Reynolds number.
- Sketch velocity profiles in laminar and turbulent flow in pipes.
- Calculate friction factor in laminar flow.
- Calculate energy losses in pipe lengths for laminar flow.

- Use pipe friction (or Moody) chart.
- Calculate energy losses in pipe lengths for turbulent flow.
- Calculate pressure drop in horizontal and non-horizontal pipe lengths.
- Calculate energy losses in pipe fittings, sudden enlargements and contractions.
- Determine equivalent lengths in pipe diameters (L/D).

Knowledge and skills

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

Knowledge	Skills
Outcome 1 Learners should understand: ♦ polytropic expansion and compression processes ♦ the first law of thermodynamics ♦ thermodynamic systems and their properties	**Outcome 1** Learners can: ♦ apply the relationship between P, V and T for polytropic and adiabatic processes ♦ calculate work transfer and heat transfer for reversible processes ♦ apply the relationship between specific heat at constant pressure and constant volume ♦ solve problems relating to change of entropy for reversible processes ♦ evaluate processes using P-V and T-s diagrams ♦ solve problems relating to Avogadro's Law ♦ solve problems relating to the universal gas constant
Outcome 2 Learners should understand: ♦ the second law of thermodynamics ♦ how to compare ideal heat engines and their thermal efficiency, and apply the second law of thermodynamics ♦ describe ideal and practical engine cycles using P-V and T-s diagrams ♦ thermal efficiency, indicated and brake mean effective pressure, work done and air standard efficiency of ideal cycles	**Outcome 2** Learners can: ♦ apply the second law of thermodynamics to heat engines ♦ analyse ideal heat engine cycles ♦ describe ideal and practical heat engine cycles using P-V and T-s diagrams ♦ evaluate ideal heat engine cycles by solving problems relating to thermal efficiency, and work and heat transfer ♦ discuss methods used to improve the efficiency of internal combustion engines

Knowledge	Skills
Outcome 3 Learners should understand: ♦ the different types of pumps ♦ characteristics of pumps ♦ methods of varying delivery rates of pumps ♦ how fans differ from pumps	**Outcome 3** Learners can: ♦ describe one type of pump ♦ describe two impeller designs ♦ explain common applications of two impeller designs (one or both could apply to a fan) ♦ state the characteristics of the same type of pump described in the first requirement ♦ perform calculations using pump characteristic curves ♦ state how the method of delivery can be varied for the type of pump described
Outcome 4 Learners should understand: ♦ the basics of an air distribution system ♦ sub-systems of an air system ♦ compressors ♦ components involved in air distribution	**Outcome 4** Learners can: ♦ annotate a block diagram for one compressed air distribution system ♦ draw and annotate two sub-system diagrams ♦ describe the layout of an air supply for a system using one type of compressor ♦ describe the layout and function of a service unit ♦ calculate maximum load and the normal working load for a compressed air distribution system ♦ determine the pipe size for a system using a nomogram diagram

Knowledge	Skills
Outcome 5 Learners should understand: ♦ the basics of an air-conditioning system ♦ sub-systems of an air-conditioning system ♦ the layout and operation of a specific air-conditioning system ♦ components involved in air conditioning	**Outcome 5** Learners can: ♦ annotate a block diagram for one air-conditioning system ♦ draw and annotate two sub-system diagrams ♦ describe the layout and operation of one type of air-conditioning system (for example, a single or multiple system) ♦ describe the function of two sub-systems
Outcome 6 Learners should understand: ♦ the basics of a steam distribution system ♦ sub-systems of a steam distribution system ♦ the operation of a steam boiler ♦ components involved in steam generation and distribution	**Outcome 6** Learners can: ♦ annotate a block diagram for one steam distribution system ♦ draw and annotate two sub-system diagrams ♦ with the aid of an incomplete diagram of a system generation and distribution system, complete the diagram showing the fluid and air flows at all points in the system and label each unlabelled unit in the system ♦ describe the function of two items
Outcome 7 Learners should understand: ♦ the basics of a refrigeration system ♦ sub-systems of a refrigeration system ♦ refrigeration system types ♦ components involved in a refrigeration system ♦ COP	**Outcome 7** Learners can: ♦ annotate a block diagram for one refrigeration system, showing the sub-systems and flows at all points in the system ♦ describe the function of each sub-system ♦ describe the layout and operation of one type of refrigeration system ♦ describe the operation of two sub-systems ♦ calculate the COP for one refrigeration system

Knowledge	Skills
Outcome 8 Learners should understand: ♦ installation and commissioning plans ♦ pre-arrival considerations	**Outcome 8** Learners can: ♦ produce an installation and commissioning plan ♦ describe multiple pre-arrival considerations within an installation and commissioning plan
Outcome 9 Learners should understand: ♦ viscosity, dynamic viscosity and kinematic viscosity ♦ flow types (laminar, transitional and dynamic) ♦ the Reynolds number ♦ the relationship between the Reynolds number and dynamic and kinematic viscosity ♦ drag ♦ component drag forces ♦ flow separation ♦ patterns around bodies on which flow separation occurs (bluff body shape, streamlined shape, cube or rectangle)	**Outcome 9** Learners can: ♦ define the terms ‘viscosity’, ‘dynamic viscosity’ and ‘kinematic viscosity’ ♦ classify flow types (laminar, transitional and turbulent) ♦ classify flow types in terms of the Reynolds number ♦ define the term ‘drag’ ♦ state the component drag forces ♦ define the term ‘flow separation’ ♦ explain why flow separation occurs ♦ sketch patterns around bodies on which flow separation occurs (bluff body shape, streamlined shape, cube or rectangle)

Knowledge	Skills
Outcome 10 Learners should understand: ♦ dynamic, static and hydrostatic pressure ♦ principle of operation of flow measurement systems (venturi meter, orifice plate, rotameter) ♦ principle of operation of velocity measuring devices (pitot tube, anemometer, pitot static tube, turbine meter) ♦ appropriate measurement system for defined applications ♦ determination of flow velocity and volumetric flow rate by applying Bernoulli's equation to flow and velocity measurement devices (venturi meter, orifice plate, pitot tube and pitot static tube) ♦ determination of coefficient of discharge for venturi meters and orifice plates by applying Bernoulli's equation	**Outcome 10** Learners can: ♦ define total and static pressure ♦ describe the principle of operation of one of the flow measurement systems (venturi meter, orifice plate, rotameter) ♦ describe the principle of operation of one velocity measuring device (pitot tube, anemometer, pitot static tube, turbine meter) ♦ identify an appropriate measurement system for a defined application ♦ determine flow velocity and volumetric flow rate by applying Bernoulli's equation to one flow measurement device (venturi meter, orifice plate, pitot tube and pitot static tube) ♦ determine from given data the coefficient of discharge for either a venturi meter or orifice plate by applying Bernoulli's equation
Outcome 11 Learners should understand: ♦ how to define the Reynolds number ♦ velocity profiles in laminar and turbulent flow ♦ friction factor in laminar flow ♦ energy losses in pipe lengths for laminar flow ♦ pipe friction (or Moody) chart ♦ energy losses in pipe lengths for turbulent flow ♦ pressure drop in horizontal and non-horizontal pipe lengths ♦ energy losses in pipe fittings, sudden enlargements and contractions ♦ equivalent lengths in pipe diameters (L/D)	**Outcome 11** Learners can: ♦ define and calculate the Reynolds number ♦ sketch velocity profiles in laminar and turbulent flow in pipes ♦ calculate friction factor in laminar flow ♦ calculate energy losses in pipe lengths for laminar flow ♦ use pipe friction (or Moody) chart ♦ calculate energy losses in pipe lengths for turbulent flow ♦ calculate pressure drop in horizontal and non-horizontal pipe lengths ♦ calculate energy losses in pipe fittings, sudden enlargements and contractions ♦ determine equivalent lengths in pipe diameters (L/D)

Meta-skills

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

Self-management

Learners develop the meta-skill of focusing as they concentrate on complex concepts such as the first and second laws of thermodynamics, the Reynolds number and Bernoulli's equation. This requires the ability to focus and maintain attention on tasks over a period of time.

They develop the meta-skill of adapting through the wide range of topics and skills they cover, from understanding thermodynamic principles to describing the operation of various systems. Learners need to be able to adjust to new conditions and learn new concepts and skills.

Learners must produce an installation and commissioning plan, which involves demonstrating the meta-skill of initiative to start and follow through on tasks.

Social intelligence

Learners develop the meta-skill of communicating through describing and explaining various concepts, such as the layout and operation of air-conditioning systems, the principle of operation of flow measurement systems, and the characteristics of pumps. This involves clearly and effectively expressing ideas and information.

Innovation

Learners develop the meta-skill of curiosity as they must understand and apply a wide range of concepts, which requires a desire to learn.

They also develop the meta-skill of sense-making by considering complex concepts and systems, such as understanding the relationship between pressure, volume and temperature for polytropic and adiabatic processes, or understanding the operation of a steam boiler. This requires the ability to determine the deeper meaning or significance of what is being expressed.

Literacies

Numeracy

Learners develop numeracy skills through calculations and problem-solving tasks. For example:

- Calculating work transfer and heat transfer for reversible processes.
- Applying the relationship between specific heat at constant pressure and constant volume.

- Solving problems relating to change of entropy for reversible processes.
- Evaluating processes using P-V and T-s diagrams.
- Solving problems relating to Avogadro's Law and the universal gas constant.
- Calculating thermal efficiency, indicated and brake mean effective pressure, work done, and air standard efficiency of ideal cycles.
- Performing calculations using pump characteristic curves.
- Calculating maximum load and the normal working load for a compressed air distribution system.
- Calculating the COP for one refrigeration system.
- Determining flow velocity and volumetric flow rate by applying Bernoulli's equation to one flow measurement device.
- Calculating energy losses in pipe lengths for laminar and turbulent flow.
- Calculating pressure drop in horizontal and non-horizontal pipe lengths.

Communication

Learners develop communication skills through tasks that require them to describe and explain. For example:

- Describing one type of pump and two impeller designs.
- Explaining common applications of two impeller designs.
- Annotating a block diagram for one compressed air distribution system.
- Describing the layout of an air supply for a system using one type of compressor.
- Describing the layout and operation of one type of air-conditioning system.
- Describing the function of components involved in air-conditioning systems.
- Describing the function of components involved in steam generation and distribution systems.
- Describing the layout and operation of one type of refrigeration system.
- Defining the terms 'viscosity', 'dynamic viscosity' and 'kinematic viscosity'.
- Classifying flow types (laminar, transitional and turbulent).
- Defining the terms 'drag' and 'flow separation'.

Digital

Learners develop digital literacy by using digital tools and resources to learn, understand and apply concepts. For example:

- Using digital resources to research and understand complex concepts such as the first and second laws of thermodynamics, the Reynolds number and Bernoulli's equation.
- Using digital tools to create diagrams and annotate them, such as block diagrams for air distribution systems, steam distribution systems, and refrigeration systems.
- Using digital tools to perform calculations and solve problems.
- Using digital communication tools to discuss and explain concepts with peers or instructors.

- Using digital platforms to access and interpret data, such as pump characteristic curves or the pipe friction (or Moody) chart.

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. We suggest the following distribution of time, including assessment:

Outcome 1 — Apply the fundamental properties of thermodynamics to a process (8 hours)
Outcome 2 — Evaluate the performance of internal combustion engines (8 hours)
Outcome 3 — Explain the uses of common types of pumps and fans (10 hours)
Outcome 4 — Explain the function of compressed air systems (12 hours)
Outcome 5 — Explain the function of air-conditioning systems (12 hours)
Outcome 6 — Explain the function of steam generation and distribution systems (13 hours)
Outcome 7 — Explain the function of refrigeration systems (14 hours)
Outcome 8 — Produce an installation and commissioning plan for an industrial system unit (15 hours)
Outcome 9 — Analyse fluid flow patterns (7 hours)
Outcome 10 — Solve flow measurement problems (5.5 hours)
Outcome 11 — Solve problems involving incompressible flow in pipe systems (15.5 hours)

Additional guidance

Content and context for this unit

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

Apply the fundamental properties of thermodynamics to a process (outcome 1)

You should set questions related to real-life examples. Topics include:

- differing pressures, volumes and temperatures in real-world engine cylinders
- differing pressures, volumes and temperatures in air receivers
- gases in closed vessels
- gas flow through nozzles

Evaluate the performance of internal combustion engines (outcome 2)

For this outcome, we recommend that:

- calculation questions relate to ideal cycles
- descriptive answers explain how real cycles differ from ideal ones
- practical cycles relate to those found in real-world applications

Explain the uses of common types of pumps and fans (outcome 3)

This outcome covers:

- types of pumps and their characteristics:
  - reciprocating: layout, working fluids, series and parallel connections
  - rotational: layout, working fluids, series and parallel connection
- delivery: factors affecting delivery rates, for example speed, restrictors, variable blade angles on impellers or guide vanes, cutting out cylinders
- pipe sizes: duct or pipe sizing using charts and calculations
- how pumps and fans differ:
  - how they are used
  - their descriptions

Explain the function of compressed air systems (outcome 4)

We recommend you use a systems approach for the knowledge and skills requirements. Use block diagrams to explain causes of change in the variables and how the sub-systems are affected by these changes.

This outcome covers:

- block diagrams:
  - for both overall system and sub-system diagrams, describe each element, stating its purpose and its interaction with the other elements
- compressors:
  - describe several current types of compressors, where they are used and their characteristics
  - techniques to vary pressure and delivery rates
- other system elements:
  - describe current equipment
  - explain function
  - where appropriate, consider the characteristics of different types
  - only decide pipe work sizes where the techniques or sources of information are different from the work completed in outcome 1
  - consider alternatives to a particular unit or sub-system

Explain the function of air-conditioning systems (outcome 5)

We recommend you use a systems approach for the knowledge and skills requirements. Use block diagrams to explain causes of change in the variables and how the sub-systems are affected by these changes.

You can use this outcome to prepare learners for outcome 7 by introducing refrigeration system components as a sub-system of the overall air-conditioning system.

Explain the function of steam generation and distribution systems (outcome 6)

We recommend you use a systems approach for the knowledge and skills requirements. Use block diagrams to explain causes of change in the variables and how the sub-systems are affected by these changes.

You should avoid describing too many types of boilers, or matching generator capacity to outputs using calculations.

Explain the function of refrigeration systems (outcome 7)

We recommend you use a systems approach for the knowledge and skills requirements. Use block diagrams to explain causes of change in the variables and how the sub-systems are affected by these changes.

You do not need to restrict calculations using information extracted from charts and thermodynamic tables to COP; they could involve, for example, the volumetric efficiency of the compressor.

Produce an installation and commissioning plan for an industrial system unit (outcome 8)

This outcome allows learners to apply their knowledge and understanding from the other outcomes.

- Pre-arrival considerations:
  - you should emphasise that these form an important part of the commissioning procedure
  - ideally, learners should look at three different types of sub-system replacement, one each of a different plant system, perhaps treating each replacement due to different circumstances, such as breakdown, planned replacement or increased capacity requirement
- Documents:
  - you could look at several 'real' administrative systems and compare their strengths and weaknesses
  - you could then consider several scenarios, perhaps related to the sub-systems already considered; you could divide learners into teams to work on a scenario each, prepare the necessary paperwork and give a presentation on it, followed by critical class discussion

Analyse fluid flow patterns (outcome 9)

Defining viscosity terms

Start with the basic definition of viscosity as a measure of a fluid's resistance to flow. Explain that dynamic viscosity is a measure of internal friction when a layer of fluid is made to move in relation to another layer. Kinematic viscosity, on the other hand, is the ratio of dynamic viscosity to the density of the fluid. Use real-world examples to illustrate these concepts, such as comparing the flow of honey (high viscosity) versus water (low viscosity).

Classifying flow types

Explain that flow types can be classified as laminar, transitional or turbulent based on the flow behaviour of fluids. Laminar flow is smooth and orderly, while turbulent flow is chaotic. Transitional flow is the state between laminar and turbulent. Use visual aids or simulations to help learners visualise these different types of flow.

Reynolds number

Explain that the Reynolds number is a dimensionless quantity that predicts flow patterns in different fluid flow situations. It can be used to predict the onset of turbulence. Discuss the formula for calculating the Reynolds number and what each variable represents.

Defining drag

Define drag as the force that opposes an object's motion through a fluid (such as air or water). Discuss the two main types of drag: form drag (resistance related to the shape of an object), and skin friction drag (resistance related to the surface texture of an object).

Component drag forces

Discuss the different components of drag forces, such as pressure drag and viscous drag. Use diagrams to illustrate how these forces act on an object moving through a fluid.

Defining and explaining flow separation

Define flow separation as the phenomenon where the flow of a fluid around a body detaches from the body's surface. Explain why flow separation occurs, typically due to the fluid slowing down and the pressure increasing. Discuss the effects of flow separation, such as increased pressure drag.

Sketching flow separation patterns

Demonstrate how to sketch patterns around different body shapes where flow separation occurs. Use a variety of shapes such as a bluff body shape, streamlined shape, cube or rectangle. Explain how the shape of the body can affect the point of flow separation and the resulting flow patter.

Solve flow measurement problems (outcome 10)

Defining total and static pressure

Start with the basic definition of pressure as the force exerted by a fluid per unit area. Explain that static pressure is the pressure exerted by a fluid at rest, while total pressure is the sum of the static pressure and the dynamic pressure (which is associated with the movement of the fluid). Use real-world examples or demonstrations to illustrate these concepts.

Describing flow measurement systems

Discuss the principles of operation of different flow measurement systems such as the venturi meter, orifice plate and rotameter. For example, a venturi meter measures fluid flow rate by reducing the cross-sectional flow area in the flow path, causing a change in pressure. An orifice plate, on the other hand, measures flow rate by introducing a restriction in the path of the flow, while a rotameter measures flow rate based on the vertical displacement of a float in a tapered tube. Use diagrams or animations to help learners visualise how these systems work.

Describing velocity measuring devices

Discuss the principles of operation of different velocity measuring devices such as the pitot tube, anemometer, pitot static tube and turbine meter. For example, a pitot tube measures fluid flow velocity by converting the kinetic energy in a fluid flow to potential energy. An anemometer measures the speed of fluid flow, typically air, by capturing the wind with cups or propellers. Use visual aids or demonstrations to help learners understand these devices.

Identifying appropriate measurement systems

Discuss how to identify the most appropriate measurement system for a given application. This could be based on factors such as the type of fluid, the required accuracy, the flow rate and the environmental conditions. Encourage learners to think critically and consider all relevant factors when making their selection.

Applying Bernoulli's equation

Explain Bernoulli's equation and how it can be used to determine flow velocity and volumetric flow rate. Bernoulli's equation describes the conservation of energy principle for flowing fluids and is used to relate the pressure, velocity and elevation in a flowing fluid. Work through some example problems with learners to demonstrate how to apply the equation.

Determining the coefficient of discharge

Discuss how to determine the coefficient of discharge for a venturi meter or orifice plate using Bernoulli's equation. The coefficient of discharge accounts for energy losses in the fluid flow and is used to correct the theoretical flow rate to the actual flow rate. Provide some example problems for learners to practise this calculation.

Solve problems involving incompressible flow in pipe systems (outcome 11)

Defining and calculating the Reynolds number

Start by defining the Reynolds number as a dimensionless quantity that predicts the onset of turbulence in fluid flow. Discuss the formula for calculating the Reynolds number and what each variable represents. Work through some example problems with learners to demonstrate how to calculate the Reynolds number.

Sketching velocity profiles

Explain what velocity profiles are and how they differ for laminar and turbulent flow in pipes. For laminar flow, the velocity profile is parabolic, with the highest velocity at the centre of the pipe. For turbulent flow, the velocity profile is flatter due to mixing. Demonstrate how to sketch these profiles and provide opportunities for learners to practise.

Calculating friction factor and energy losses in laminar flow

Discuss how to calculate the friction factor in laminar flow using the formula $f = 64 / \mathrm{Re}$ where Re is the Reynolds number. Then, explain how to calculate energy losses in pipe lengths for laminar flow using the Darcy-Weisbach equation. Provide some example problems for learners to practise these calculations.

Using the pipe friction (or Moody) chart

Demonstrate how to use the Moody chart to find the friction factor for turbulent flow. The Moody chart is a graph that plots the Darcy-Weisbach friction factor against the Reynolds number for various relative roughness values. Explain how to read the chart and use it to find the friction factor.

Calculating energy losses in turbulent flow and pressure drop

Discuss how to calculate energy losses in pipe lengths for turbulent flow using the Darcy-Weisbach equation and the friction factor obtained from the Moody chart. Then, explain how to calculate pressure drop in horizontal and non-horizontal pipe lengths using the formula $\Delta P = f * (L / D) * (pv^2 / 2)$, where ΔP is the pressure drop, f is the friction factor, L is the pipe length, D is the pipe diameter, ρ is the fluid density and v is the fluid velocity.

Calculating energy losses in pipe fittings, sudden enlargements and contractions

Discuss how to calculate energy losses due to pipe fittings, sudden enlargements and contractions using appropriate loss coefficients. These coefficients can often be found in engineering handbooks or manufacturer data.

Determining equivalent lengths in pipe diameters (L/D)

Explain what equivalent length is and how it's used to account for energy losses due to fittings and valves in a pipe system. The equivalent length is the length of straight pipe that would cause the same amount of head loss as the fitting or valve. Show learners how to calculate the equivalent length in pipe diameters (L/D) using the formula $L / D = K / f$, where K is the loss coefficient and f is the friction factor.

Approaches to delivery

You can deliver the unit using lectures, reading assignments, practice problems, group work, online resources and hands-on projects. It is important to use a combination of these methods to ensure that learners have a well-rounded understanding of the material and opportunities to engage with it in different ways.

You should deliver the unit in a learning space or through a virtual learning environment (VLE). You should teach 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

We recommend that you assess this unit holistically by reviewing case studies, mini projects and group work in which learners carry out real-life scenario-based engineering problems.

Assessment methods could include written exams, practical assessments, oral presentations, group work and portfolios. It is important to use a combination of assessment methods to evaluate learners' knowledge and skills, and provide feedback to help them improve.

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

Learners should 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.

As the assessment is open book, 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.

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

Plant Systems and Fluid Mechanics (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

This unit provides you with a depth of knowledge in a principal area of mechanical engineering. It enables you to develop knowledge and understanding of:

- heat transfer
- fluid mechanics
- mechanical plant units, sub-systems and systems used in industry

The unit is suitable for you if you are:

- in an industry-level job, such as a technical, or design and development post
- looking to build on your engineering knowledge to progress to higher education

Before starting the unit, we recommend that you have a broad knowledge and understanding of mathematics, and mechanical engineering concepts and theorems. For example, you may have completed Advanced Higher Mathematics or Physics, or a Higher National Certificate (HNC) in Mechanical Engineering.

You may also have this gained this knowledge and understanding from work experience, rather than from a formal qualification.

Unit outcomes

On completion of the unit, you can:

1. apply the fundamental properties of thermodynamics to a process
2. evaluate the performance of internal combustion engines
3. explain the uses of common types of pumps and fans
4. explain the function of compressed air systems
5. explain the function of air-conditioning systems
6. explain the function of steam generation and distribution systems
7. explain the function of refrigeration systems
8. produce an installation and commissioning plan for an industrial system unit
9. analyse fluid flow patterns

10 solve flow measurement problems

11 solve problems involving incompressible flow in pipe systems

In outcomes 1 and 2, you build on your existing understanding of thermodynamic principles, then apply the laws of thermodynamics to combustion engines.

In outcomes 4 to 8 you use a systems approach (input → process → output) to describe plant systems and their parts, and explain the function and behaviour of each sub-system, as well as how changes in one part of the system affect the other parts. You learn how to decide the capacity of each sub-system, and the pipe and duct sizes used in cyclical systems.

Finally, you consider planning the replacement of sub-systems of a plant, how it will be done, and requirements such as manpower and tooling, testing to check the replacement is working satisfactorily, and preparing the necessary paperwork.

Outcomes 9 to 11 provide you with an opportunity to study fluid flow patterns and give you an understanding of the following fluid mechanics terms:

- viscosity
- dynamic viscosity
- kinematic viscosity
- the Reynolds number
- drag and drag forces
- flow separation

You also learn about the principle of operation of the following flow measuring systems:

- venturi meter
- orifice plate
- rotameter
- anemometer
- pitot static tube
- turbine meter

You also find out how to identify appropriate flow measurement systems for defined applications.

You have the opportunity to develop the necessary knowledge and skills to solve problems involving incompressible flow in pipe systems. From this, you learn how to:

- classify flow types by correctly calculating and applying the Reynolds number
- correctly use the pipe friction chart to relate the Reynolds number, relative roughness and friction factor
- correctly determine energy losses for given situations
- correctly determine flow rates in pipe systems

You are assessed holistically by a combination of methods, including reviews of case study reports and mini projects. Assessments can include written exams, practical assessments, oral presentations, group work and portfolios.

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-skill of focusing as you concentrate on complex concepts such as the first and second laws of thermodynamics, the Reynolds number and Bernoulli’s equation. This requires the ability to focus and maintain attention on tasks over a period of time.

You develop the meta-skill of adapting though the wide range of topics and skills you cover, from understanding thermodynamic principles to describing the operation of various systems. This involves being able to adjust to new conditions and learn new concepts and skills.

You develop the meta-skill of initiative by producing an installation and commissioning plan, which involves starting and following through on tasks.

Social intelligence

You develop the meta-skill of communicating through describing and explaining various concepts, such as the layout and operation of air-conditioning systems, the principle of operation of flow measurement systems, and the characteristics of pumps. This involves clearly and effectively expressing ideas and information.

Innovation

You develop the meta-skill of curiosity as you understand and apply a wide range of concepts, which requires a desire to learn.

You also develop the meta-skill of sense-making by considering complex concepts and systems, such as understanding the relationship between pressure, volume and temperature for polytropic and adiabatic processes, or understanding the operation of a steam boiler. This requires the ability to determine the deeper meaning or significance of what is being expressed.

Administrative information

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Superclass: XH

History of changes

Version	Description of change	Date
02	♦ Evidence requirements updated to clarify conditions of assessment. ♦ Approaches to assessment updated.	Dec 2024

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