Unit 1: Engineering Principles

Level: **3**

Unit type: **External**

Guided learning hours: **120**

Unit in brief

Learners apply mathematical and physical science principles to solve electrical-, electronic- and mechanical-based engineering problems.

Unit introduction

Modern life depends on engineers to develop, support and control the products and systems that are all around us. For example, cars, heart rate monitors and manufacturing and transport systems. To make a contribution as an engineer you must be able to draw on an important range of principles developed by early engineering scientists, such as Newton, Young, Faraday and Ohm. There is an increasing demand for 'multi-skilled' engineers who can apply principles from several engineering disciplines to develop solutions.

This unit will develop your mathematical and physical scientific knowledge and understanding to enable you to solve problems set in an engineering context. You will explore and apply the algebraic and trigonometric mathematical methods required to solve engineering problems. The mechanical problems you will encounter cover static, dynamic, fluids and thermodynamic systems. The electrical and electronic problems you will encounter cover static and direct current (DC) electricity, DC circuit theory and networks, magnetism, and single-phase alternating current theory. You will apply these engineering principles to solve problems involving more than one of these topic areas.

This unit is externally assessed. It sits at the heart of the qualification and gives you a foundation to support you in any engineering technician role, an engineering apprenticeship or in higher education.

Summary of assessment

The unit will be assessed through one paper of 80 marks lasting two hours that will be set and marked by Pearson.

Learners will be assessed through a number of short- and long-answer problem-solving questions. Learners will need to explore and relate to the engineering contexts and data presented. Assessment will focus on learners' ability to solve problems that require individual and combined application of mathematical techniques, and electrical, electronic and mechanical principles to solve engineering problems.

The assessment availability is twice a year in January and May/June. The first assessment availability is May/June 2017.

Sample assessment materials will be available to help centres prepare learners for assessment.

Assessment outcomes

AO1 Recall basic engineering principles and mathematical methods and formulae

Command words: calculate, describe, explain

Marks: ranges from 1 to 5 marks

AO2 Perform mathematical procedures to solve engineering problems

Command words: calculate, find, solve

Marks: ranges from 1 to 10 marks

AO3 Demonstrate an understanding of electrical, electronic and mechanical principles to solve engineering problems

Command words: find, calculate, describe, draw, explain

Marks: ranges from 1 to 5 marks

AO4 Analyse information and systems to solve engineering problems

Command words: calculate, draw

Marks: ranges from 1 to 5 marks

AO5 Integrate and apply electrical, electronic and mechanical principles to develop an engineering solution

Command words: calculate, draw, explain

Marks: ranges from 1 to 10 marks

Essential content

The essential content is set out under content areas. Learners must cover all specified content before the assessment.

A Algebraic and trigonometric mathematical methods

A1 Algebraic methods

- Indices and logarithms:
  - laws of indices: $a^m \times a^n = a^{m+n}$, $\frac{a^m}{a^n} = a^{m-n}$, $(a^m)^n = a^{mn}$
  - laws of logarithms: $\log A + \log B = \log AB$, $\log A^n = n\log A$, $\log A - \log B = \log\frac{A}{B}$
  - common logarithms (base 10), natural logarithms (base e).
- Application to problems involving exponential growth and decay.
- Linear equations and straight line graphs:
  - linear equations of the form $y = mx + c$
  - straight-line graph (coordinates on a pair of labelled Cartesian axes, positive or negative gradient, intercept, plot of a straight line)
  - pair of simultaneous linear equations in two unknowns.
- Factorisation and quadratics:
  - multiply expressions in brackets by a number, symbol or by another expression in a bracket
  - extraction of a common factor $ax + ay$, $a(x + 2) + b(x + 2)$
  - grouping $ax - ay + bx - by$
  - quadratic expressions $a^2 + 2ab + b^2$
  - roots of an equation, including quadratic equations with real roots by factorisation, and by the use of formula.

A2 Trigonometric methods

- Circular measure:
  - radian
  - conversion of degree measure to radian measure and vice versa
  - angular rotations (multiple number (n) of radians)
  - problems involving areas and angles measured in radians
  - length of arc of a circle $s = r\theta$
  - area of a sector $A = \frac{1}{2}r^2\theta$
- Triangular measurement:
  - functions (sine, cosine and tangent)
  - sine/cosine wave over one complete cycle
  - graph of $\tan A$ as A varies from 0° and 360° confirming $\tan A = \frac{\sin A}{\cos A}$
  - values of the trigonometric ratios for angles between 0° and 360°
  - periodic properties of the trigonometric functions
  - the sine and cosine rule
  - application of vectors:
    - calculation of the phasor sum of two alternating currents
    - diagrammatic representation of vectors
    - resolution of forces/velocities.

- Mensuration:
  - o standard formulae to solve surface areas and volumes of regular solids
    - – volume of a cylinder $V = \pi r^2 h$
    - – total surface area of a cylinder $TSA = 2\pi rh + 2\pi r^2$
    - – volume of sphere $V = \frac{4}{3}\pi r^3$
    - – surface area of a sphere $SA = 4\pi r^2$
    - – volume of a cone $V = \frac{1}{3}\pi r^2 h$
    - – curved surface area of cone $CSA = \pi rl$

B Static engineering systems

B1 Static engineering systems

Recall, perform procedures, demonstrate an understanding of and analyse information and systems, involving:

- Non-concurrent coplanar forces:
  - o representation of forces using space and free body diagrams
  - o moments
  - o resolution of forces in perpendicular directions $F_x = F\cos\theta$, $F_y = F\sin\theta$
  - o vector addition of forces – resultant, equilibrant and line of action
  - o conditions for static equilibrium $\Sigma F_x = 0$, $\Sigma F_y = 0$, $\Sigma M = 0$
- Simply supported beams:
  - o concentrated loads
  - o uniformly distributed loads (UDL).
- Reactions:
  - o support reactions
  - o pin reaction forces
  - o roller reaction forces.

B2 Loaded components

Recall, perform procedures, demonstrate an understanding of and analyse information and systems involving:

- direct stress and strain: direct stress $\sigma = \frac{F}{A}$, direct strain $\varepsilon = \frac{\Delta L}{L}$
- shear stress and strain: shear stress $\tau = \frac{F}{A}$, shear strain $\gamma = \frac{a}{b}$
- tensile and shear strength
- elastic constants: modulus of elasticity $E = \frac{\sigma}{\varepsilon}$; modulus of rigidity $G = \frac{\tau}{\gamma}$

C Dynamic engineering systems

C1 Dynamic engineering systems

Recall, perform procedures, demonstrate an understanding of and analyse information and systems involving:

- kinetic parameters and principles:
  - o displacement (s)
  - o velocity – initial velocity (u), final velocity (v)
  - o acceleration (a)
  - o equations for linear motion with uniform acceleration
    $v = u + at$, $s = ut + \frac{1}{2}at^2$, $v^2 = u^2 + 2as$, $s = \frac{1}{2}(u + v)t$

- dynamic parameters and principles:
  - force
  - inertia
  - torque (T)
  - mechanical work $W = Fs$, mechanical power (average and instantaneous)
  - mechanical efficiency
  - energy: gravitational potential energy $PE = mgh$, kinetic energy $KE = \frac{1}{2}mv^2$
  - Newton's Laws of Motion
  - principles of conservation of momentum
  - principles of conservation of energy.
- angular parameters:
  - angular velocity (ω)
  - centripetal acceleration $a = \omega^2 r = \frac{v^2}{r}$
  - uniform circular motion power $P = T\omega$
  - rotational kinetic energy $KE = \frac{1}{2}I\omega^2$
- lifting machines, including inclined planes, scissor jacks, pulleys:
  - velocity ratio
  - mechanical advantage
  - effort and load motion
  - friction effects.

D Fluid and thermodynamic engineering systems

D1 Fluid systems

Recall, perform procedures, demonstrate an understanding of and analyse information and systems involving:

- submerged surfaces in fluid systems:
  - hydrostatic pressure and hydrostatic thrust on an immersed plane surface $F = \rho gAx$
  - centre of pressure of a rectangular retaining surface with one edge in the free surface of a liquid
- immersed bodies:
  - Archimedes' principle
  - determination of density using floatation methods
  - relative density
- fluid flow in a gradually tapering pipe:
  - flow rate (volumetric and mass)
  - flow velocities (input and output)
  - input and output pipe diameters
  - incompressible fluid flow (continuity of volumetric flow $A_1v_1 = A_2v_2$ and mass flow $\rho A_1v_1 = \rho A_2v_2$)

D2 Thermodynamic systems

Recall, perform procedures, demonstrate an understanding of and analyse information and systems involving:

- heat transfer parameters in thermodynamic systems – temperature, pressure, mass, linear dimensions, time, thermal conductivity and surface finish
- heat transfer processes – conduction, convection and radiation
- linear expansivity; phases (solid, liquid and gas) $\Delta L = \alpha L\Delta T$
- heat transfer principles – specific heat capacity, sensible and latent heat transfer $Q = mc\Delta T$ and $Q = ml$

- thermal efficiency of heat transfer systems (heat engines and heat pumps)
- entropy and enthalpy $H = U + pV$, change of enthalpy to mechanical work (heat engines)
- thermodynamic process equations
  - process parameters: absolute temperature and absolute pressure, volume, mass and density
  - Gas laws – Boyle's law pV = constant, Charles's law $\frac{V}{T}$ = constant, general gas equation $\frac{pV}{T}$ = constant

E Static and direct current electricity and circuits

E1 Static and direct current electricity

Recall, perform procedures, demonstrate an understanding of and analyse information and systems, in the context of electrical circuits (networks) and devices, including:

- conductance
- conventional current flow
- charge/electron flow $I = \frac{q}{t}$
- voltage
- Coulomb's law $F = \frac{q_1 q_2}{4\pi\varepsilon_o r^2}$
- factors affecting resistance, including conductor length, cross sectional area, resistivity, and temperature coefficient of resistance $R = \frac{\rho l}{A}$, $\frac{\Delta R}{R_0} = \alpha\Delta T$
- resistors, including function, fixed, variable, values
- electric field strength, including uniform electric fields $E = \frac{F}{q}$, $E = \frac{v}{d}$
- factors affecting capacitance, including plate spacing, plate area, permittivity $C = \frac{\varepsilon A}{d}$
- capacitors – typical capacitance values and construction, including plates, dielectric materials and strength, flux density, permittivity.

E2 Direct current circuit theory

Recall, perform procedures, demonstrate an understanding of and analyse information and systems involving:

- Ohm's law $I = \frac{V}{R}$
- Power $P = IV$, $P = I^2V$, $P = \frac{V^2}{R}$
- efficiency $E = \frac{P_{out}}{P_{in}}$
- Kirchoff's voltage and current laws $V = V_1 + V_2 + V_3$ or $\Sigma PD = \Sigma IR$, $I = I_1 + I_2 + I_3$
- charge, voltage, capacitance and energy stored in capacitors

  $Q = CV$, $W = \frac{1}{2}CV^2$
- RC transients (capacitor/resistor), charge and discharge, including exponential growth and decay of voltage and current, and time constant $\tau = RC$
- Diodes, including forward and reverse bias characteristics:
  - forward mode applications, including rectification, clamping, circuit/component protection
  - reverse mode applications, including zener diode for voltage regulation

E3 Direct current networks

Recall, perform procedures, demonstrate an understanding of and analyse information and systems involving:

- DC sources, including cell, battery, stabilised power supply, photovoltaic cell/array and internal resistance
- at least five resistors in series and parallel combinations

  $R_T = R_1 + R_2 + R_3$

  $$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

- series resistors and diodes
- DC power source with at least two capacitors connected (series, parallel, combination).

F Magnetism and electromagnetic induction

F1 Magnetism

Recall, perform procedures, demonstrate an understanding of and analyse information and systems involving:

- magnetic field:
  - flux density $B = \frac{\phi}{A}$
  - magnetomotive force (mmf) and field strength (H), $F_m = NI$, $H = \frac{NI}{l}$
  - permeability $\frac{B}{H} = \mu_0 \mu_r$
  - B/H curves and loops
  - ferromagnetic materials
  - reluctance $S = \frac{F_m}{\phi}$
  - magnetic screening
  - hysteresis
- electromagnetic induction and applications:
  - induced electromotive force (emf)
  - relationship between induced emf, magnetic field strength, number of conductor turns and rate of change of flux
  - relationship between number of turns, magnetic length, permeability, and inductance
  - eddy currents
  - principle of operation of electric motors and generators
  - self inductance, including inductance of a coil, energy stored in an inductor, induced emf

    $$L = \frac{N\phi}{I},\ W = \frac{1}{2}LI^2,\ E = BLv,\ E = -N\frac{d\phi}{dt} = -L\frac{dl}{dt}$$

  - mutual inductance (transformers – step up/down, primary and secondary current and voltage ratios)

    $$\frac{V_1}{V_2} = \frac{N_1}{N_2}$$

  - application of Faraday's and Lenz's laws.

G Single-phase alternating current

G1 Single-phase alternating current theory

Recall, perform procedures, demonstrate an understanding of and analyse information and systems involving:

- waveform characteristics:
  - o sinusoidal and non-sinusoidal waveforms
  - o amplitude, time period, frequency
  - o instantaneous values:
    - – peak/peak-to-peak
    - – root mean square (RMS):

      $$\text{RMS voltage} = \frac{\text{peak voltage}}{\sqrt{2}}$$

    - – average values:

      $$\text{average value} = \frac{2}{\pi} \times \text{maximum value}$$

    - – form factor:

      $$\text{form factor} = \frac{\text{RMS value}}{\text{average value}}$$

- AC principles:
  - o determination of values using phasor and trigonometric representation of alternating quantities
  - o graphical and phasor addition of two sinusoidal voltages
  - o reactance and impedance of pure R, L and C components

    $$X_C = \frac{1}{2\pi fC},\ X_L = 2\pi fL$$

  - o total impedance of an inductor in series with a resistance $z = \sqrt{X_L{}^2 + R^2}$
  - o total impedance of a capacitor in series with a resistance $z = \sqrt{X_C{}^2 + R^2}$
  - o rectification, including half wave, full wave.

Grade descriptors

To achieve a grade a learner is expected to demonstrate these attributes across the essential content of the unit. The principle of best fit will apply in awarding grades.

Level 3 Pass

Learners are able to use and apply basic electrical, electronic, mechanical and mathematical principles to solve simple and familiar engineering and mathematical problems directly. They can provide responses showing understanding and analysis of basic and familiar engineering problems. They can interpret and analyse diagrams, graphical information and systems, using their knowledge and understanding to solve basic and familiar problems. They can select and implement appropriate basic procedures to provide solutions for given mathematical and engineering situations. They often use appropriate engineering and mathematical terminology and units. Learners can propose synoptic solutions to problems, drawing on their knowledge and understanding of basic electrical, electronic, mechanical and principles.

Level 3 Distinction

Learners are able to use and apply advanced electrical, electronic, mechanical and mathematical principles to solve complex and unfamiliar engineering and mathematical problems directly, indirectly and synoptically. They can provide balanced responses showing developed understanding and evaluation of complex familiar and unfamiliar engineering problems. They can interpret and evaluate diagrams, graphical information and systems, using their knowledge and understanding to solve complex familiar and unfamiliar problems. They can select and implement appropriate advanced procedures to provide justified and optimised solutions for given engineering and mathematical situations. They use appropriate and technically accurate engineering and mathematical terminology consistently. Learners can propose justified synoptic solutions to problems, drawing on their knowledge and understanding of electrical, electronic, mechanical and mathematical principles.

Key terms typically used in assessment

The following table shows the key terms that will be used consistently by Pearson in our assessments to ensure students are rewarded for demonstrating the necessary skills.

Please note: the list below will not necessarily be used in every paper/session and is provided for guidance only.

Command or term	Definition
Calculate	Learners judge the number or amount of something by using the information they already have, and add, subtract, multiply, or divide numbers. For example, 'Calculate the reaction forces...'
Draw	Learners make a graphic representation of data by hand (as in a diagram). For example, 'Draw a diagram to represent...'
Describe	Learners give a clear, objective account in their own words showing recall, and in some cases application, of the relevant features and information about a subject. For example, 'Describe the process of heat transfer...'
Explain	Learners make something clear or easy to understand by describing or giving information about it. For example, 'Explain one factor affecting...'

Command or term	Definition
Find	Learners discover the facts or truth about something. For example, 'Find the coordinates where…'
Identify	Learners recognise or establish as being a particular person or thing; verify the identity of. For example, 'Identify the energy loss…'
Label	Learners affix a label to; mark with a label. For example, 'Label the diagram to show…'
Solve	Learners find the answer or explanation to a problem. For example, 'Solve the equation to…'
State	Learners declare definitely or specifically. For example, 'State all three conditions for…'

Links to other units

This unit has links to all other units in the qualification.

Employer involvement

Centres may involve employers in the delivery of this unit if there are local opportunities. There is no specific guidance related to this unit.

