2016 Suite

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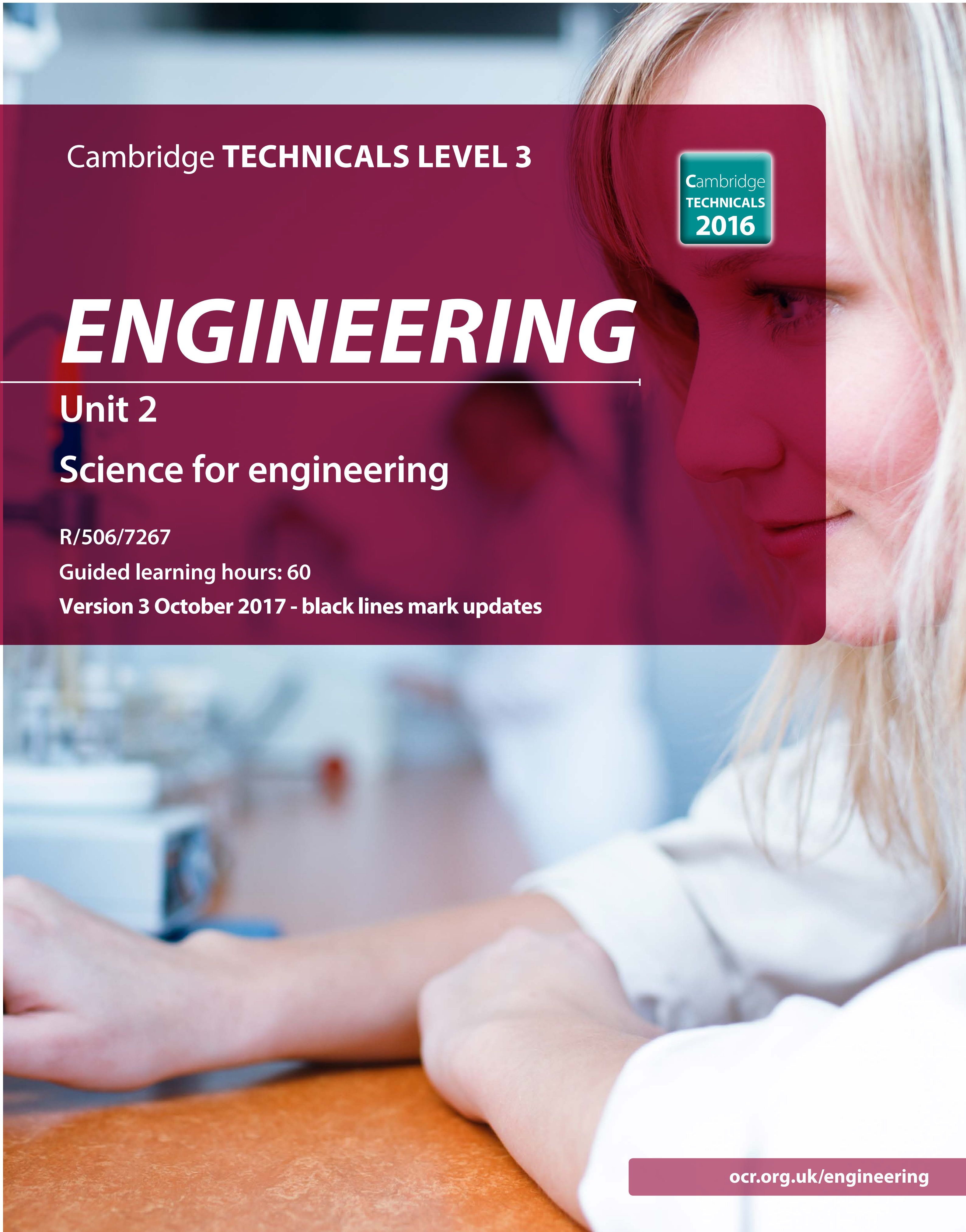

Cambridge **TECHNICALS LEVEL 3**

Cambridge TECHNICALS 2016

ENGINEERING

Unit 2

Science for engineering

R/506/7267

Guided learning hours: 60

Version 3 October 2017 - black lines mark updates

ocr.org.uk/engineering

LEVEL 3

UNIT 2: Science for engineering

R/506/7267

Guided learning hours: 60

Essential resources required for this unit: Formula Booklet for Level 3 Cambridge Technicals in Engineering, scientific calculator, protractor and ruler (cm/mm)

This unit is externally assessed by an OCR set and marked examination.

UNIT AIM

Different branches of science underpin the teaching and learning of a number of engineering disciplines. In this unit we focus on the science which supports mechanical engineering, electrical and electronic engineering, fluid dynamics, thermal physics and material science for engineering.

This unit will develop the learner's knowledge and understanding of principles of engineering science and consider how these can be applied to a range of engineering situations.

By completing this unit learners will:

- understand applications of SI units and measurement
- understand fundamental scientific principles of mechanical engineering
- understand fundamental scientific principles of electrical and electronic engineering
- understand properties of materials
- know the basic principles of fluid mechanics
- know the basic principles of thermal physics

TEACHING CONTENT

The teaching content in every unit states what has to be taught to ensure that learners are able to access the highest grades.
Anything which follows an i.e. details what must be taught as part of that area of content. Anything which follows an e.g. is illustrative.

For externally assessed units, where the teaching content column contains i.e. and e.g. under specific areas of content, the following rules will be adhered to when we set questions for an exam:

- a direct question may be asked about unit content which follows an i.e.
- where unit content is shown as an e.g. a direct question will not be asked about that example.

Learning outcomes		Teaching content		Exemplification
The Learner will:		**Learners must be taught:**		

1. Understand applications of SI units and measurement	1.1	SI units
		• the seven SI base units, i.e.
		  o metre for length
		  o kilogram for mass
		  o second for time
		  o ampere for electric current
		  o kelvin for temperature
		  o candela for luminous intensity
		  o mole for amount of substance
		• SI derived units with special names and symbols
		• SI prefixes
		• SI derived quantities
			1.1	See ASE publication Signs, Symbols and Systematics (The ASE Companion to 16-19 Science 2000)

Learning outcomes		Teaching content		Exemplification
The Learner will:		**Learners must be taught:**		
	1.2	definitions of measurement and terms related to measurement, i.e. • accuracy • accuracy class • absolute error • calibration • correction • error • intrinsic error • percentage error • precision • relative error • true value and uncertainty	1.2	**Accuracy** is a quality denoting how close a measured value is to the true value. **Accuracy class** is the percentage of the inherent error of a measuring device with respect to full scale deflection. **Intrinsic error** is the error of a measuring instrument determined under reference conditions. **Precision** is a quality denoting the consistency of measured values obtained by repeated measurements.
	1.3	the formulae for: • relative error • absolute error • absolute correction • relative correction	1.3	**Relative error** = absolute error ⁄ true value **Absolute error** = indicated value – true value **Absolute correction** = true value – indicated value **Relative correction** = absolute correction ⁄ true value
	1.4	how to calculate the standard deviation and the standard error of the mean	1.4	
	1.5	how to use instruments for taking measurements	1.5	Use of instruments in electrical engineering, mechanical engineering, electronic engineering, materials science, fluid mechanics and thermal physics.

Learning outcomes		Teaching content		Exemplification
The Learner will:		**Learners must be taught:**		
2. Understand fundamental scientific principles of mechanical engineering	2.1	force and motion, i.e. • the difference between scalar and vector quantities • how to determine the resultant of two coplanar vectors by using a vector triangle • how to calculate the resultant of two perpendicular vectors • how to resolve a vector into two perpendicular vectors • definitions of the terms: displacement, speed, velocity and acceleration • use of graphical methods to represent: o distance travelled o displacement o speed o velocity o acceleration	2.1	Vectors have direction and magnitude, scalars have magnitude only. **Displacement** - distance in a given direction, and is a vector quantity **Speed** - ratio of distance to time taken by a moving body and is a scalar quantity **Velocity** - the change in displacement divided by the time taken for that change and is a vector quantity **Acceleration** - the rate of change of velocity
	2.2	kinematics, i.e. • determination of: o distance travelled by calculating the area under a speed – time graph o velocity by using the gradient of a displacement – time graph o speed by using the gradient of a distance – time graph o acceleration by using the gradient of a velocity – time graph	2.2	

Learning outcomes		Teaching content		Exemplification
The Learner will:		**Learners must be taught:**		
		• the equations which represent uniformly accelerated motion in a straight line • that mass is the property of a body which resists change in velocity • the formula for density (ρ) of a material		$v = u + at$, $v^2 = u^2 + 2as$, $s = ut + \frac{1}{2}at^2$, $s = \frac{1}{2}(u + v)t$ $\rho = \frac{m}{V}$, the density (ρ) of a material is the mass (m) divided by volume (V)
	2.3	dynamics • the formula for force (F) • definition of the term Newton (N) • application of the concept of weight as the effect of a gravitational field on mass • use of the formula for weight (W) • that the weight of a body may be considered as acting at a single point called the centre of gravity • that a couple is a pair of equal parallel forces which produce rotational motion only • the moment of a force and the torque of a couple • that for a system in equilibrium there is no resultant force and no resultant torque	2.3	$F = ma$ **Newton (N)** – the derived SI unit of force; 1 N is the force required to give a mass of 1 kg an acceleration of 1 ms^{-2} $W = mg$, where g is the acceleration due to gravity Moment of a force = force x perpendicular distance from pivot. Torque of a couple = force x perpendicular distance between the forces

Learning outcomes		Teaching content		Exemplification
The Learner will:		**Learners must be taught:**		
	2.4	force, work and power • the Joule and use of the formula for work done (W) • meaning of and formula for: o kinetic energy o gravitational potential energy o the relationship between mechanical power, work done and time o the Watt and use of the formula for energy or work done (W)	2.4	The **Joule** is the SI unit of energy of work done where one Joule of work is done when a force of 1 Newton moves its point of application by one metre in the direction of the force. **Work done** = force x distance moved in the direction of the force. **Kinetic energy** $E_k = \frac{1}{2}mv^2$ **Gravitational Potential Energy** $E_p = mgh$ **Power** is the rate of doing work or converting energy from one form to another. $P = \frac{W}{t}$, where P is power, W is the work done in time t **Watt** - the derived SI unit of power, equal to a rate of working of 1 joule per second
3. Understand fundamental scientific principles of electrical and electronic engineering	3.1	atomic structure and electric current	3.1	An atom consists of a nucleus surrounded by electrons. Current is the rate of flow of charge
	3.2	the term Coulomb and use of the formula for charge	3.2	**Coulomb** – the derived SI unit of electric charge, is that charge that crosses a section of the circuit in 1 second when a current of 1 ampere flows. $Q = It$, where Q is the charge, I is the current and t is time.

Learning outcomes		Teaching content		Exemplification
The Learner will:		**Learners must be taught:**		
	3.3	electron flow and current flow in conductors, semi-conductors and insulators	3.3	Understand the idea of conventional current
	3.4	potential difference (V) relating to: • energy and charge • power and current	3.4	**Potential difference** – the energy converted from electrical energy to some other form when unit charge passes from one point to another. $V = \frac{W}{Q}$, where W is energy and Q is charge. $P = VI$, where P is power and I is current.
	3.5	current-potential difference characteristics for: • a metallic conductor at constant temperature • a filament lamp • a semiconductor diode	3.5	
	3.6	resistance and Ohm's law for resistive circuits	3.6	**Resistance** R is the opposition to the flow of electrons and is defined as the ratio of the potential difference V across a component to the current I through it. $R = \frac{V}{I}$ **Ohm's law** – the current through a conductor is proportional to the potential difference across it, provided its temperature remains constant.
	3.7	how to calculate the total resistance and total current for a circuit that is a combination of resistors connected in series and parallel	3.7	
	3.8	use of the formulae for electrical power (P) and energy (W)	3.8	$P = VI$, $P = I^2R$, $P = \frac{V^2}{R}$ $W = Pt$

Learning outcomes		Teaching content		Exemplification
The Learner will:		**Learners must be taught:**		
	3.9	that the kilowatt-hour is a unit of energy	3.9	
	3.10	that the efficiency of a system is the ratio of work output to work input	3.10	**Efficiency** $\eta = \frac{work\ output}{work\ input} \times 100\%$
	3.11	the term resistivity and use of the formula for resistivity (ρ)	3.11	**Resistivity** ρ is a relationship between the dimensions of a specimen of a material and its resistance. $\rho = \frac{RA}{l}$, where R is resistance, A is cross sectional area and l is length.
	3.12	the term temperature coefficient of resistance		
	3.13	use of graphs to show the variation with temperature of a pure resistor and of a negative temperature coefficient thermistor		
	3.14	use of the formula for the magnitude of the uniform electric field strength (E) between charged parallel plates		An electric field is a region of space where a force acts on a stationary charge. $E = \frac{V}{d}$, where V is the potential difference across plates of separation d.
	3.15	the terms capacitance (C) and farad (F)		**Capacitance** is the property of a conductor to store an electric charge and is defined as the ratio of charge Q on a conductor, to its potential V. $C = \frac{Q}{V}$ One **farad** is the capacitance of a conductor which is at a potential of 1 volt when it carries a charge of 1 coulomb.

Learning outcomes		Teaching content		Exemplification
The Learner will:		**Learners must be taught:**		
	3.16	the relationship between capacitance and energy stored in a capacitor	3.16	$W_{\text{charging}} = \frac{1}{2}QV = \frac{1}{2}CV^2 = W_{\text{stored}}$
	3.17	how to draw a graph for a capacitor discharging through a resistor of (a) potential difference against time and (b) current against time	3.17	
	3.18	the significance of a time constant for the discharge of a capacitor and use of the formula for time constant (τ)	3.18	The time required for a **capacitor** to discharge is defined by the term Resistor Capacitor Time Constant (RC) A capacitor takes about 5 **time constants** or 5T to discharge. The 'transient response **time'** T, is measured in seconds $\tau = RC$, where R is the value of the **resistor** in ohms and C is the value of the **capacitor** in Farads.
	3.19	use of the formula for the discharge of a capacitor	3.19	e.g. $v = v_0 e^{-\frac{t}{RC}}$, where the potential difference at time t is v and at t = 0, the p.d. is v_0
	3.20	the terms inductance (L) and the unit of inductance - henry (H)	3.20	A coil has a self-inductance (L) of 1 henry (H) if an e.m.f. of 1 volt (V) is induced in the coil when the current through the coil changes at the rate of 1 ampere per second.
	3.21	use of the formula for the self-inductance (L) of a coil and the formula for energy (W_L) stored in the magnetic field of a coil	3.21	$L = \frac{\Phi N}{I}$, $W_L = \frac{1}{2}LI^2$

Learning outcomes		Teaching content		Exemplification
The Learner will:		**Learners must be taught:**		
4. Understand properties of materials	4.1	elastic deformation, in terms of the separation of atoms in a solid material	4.1	
	4.2	that the resultant force between two atoms in a crystal is the vector sum of an attractive force and a repulsive force	4.2	
	4.3	basic material properties: • ductility • brittleness • toughness • stiffness • resilience • endurance • hardness • malleability	4.3	**Ductility** – ability of a material to plastically deform without breaking e.g. to be drawn into wires. **Brittleness** – tendency for materials to break without undergoing any plastic deformation. **Toughness** – a measure of the amount of energy stored in a material before failure. **Stiffness** – the ratio of force to extension **Resilience/elasticity** – the ability to spring back into shape **Endurance** – the ability to withstand repeated stress cycling. **Hardness** – the ability to resist surface abrasion **Malleability** – the ability to undergo deformation in compression before failure.
	4.4	what is meant by the term equilibrium separation	4.4	

Learning outcomes		Teaching content		Exemplification
The Learner will:		**Learners must be taught:**		
	4.5	plastic deformation: • in terms of slip • why plastic deformation happens more easily when dislocations are present in a solid material	4.5	**Dislocation** – an extra partial plane of atoms present in a crystal structure
	4.6	the difference between the drift velocity and root mean square (r.m.s) speed of an electron which forms part of an electric current in a solid	4.6	
	4.7	application of the formula for current (I)	4.7	$I = nAve$, where n is the number of conduction electrons per unit volume, A the cross-sectional area of the conductor, v the average drift velocity and e the charge on the electron
	4.8	that deformation is caused by a tensile or compressive force	4.8	
	4.9	Hooke's law	4.9	
	4.10	what is meant by the terms: • elastic limit • stress • strain • Young's modulus	4.10	**Elastic limit** – the maximum stress which can be applied such that, when the stress is removed, the object returns to its original shape and size. **Stress** σ = force/cross sectional area **Strain** ε = extension/original length **Young's modulus** = stress/strain
	4.11	the difference between elastic and plastic deformation of a material	4.11	
	4.12	how to calculate the strain energy in a deformed material from a force – extension graph	4.12	Strain energy is equal to the area under a Force-extension graph

Learning outcomes		Teaching content		Exemplification
The Learner will:		**Learners must be taught:**		
	4.13	the term ultimate tensile stress	4.13	Ultimate tensile stress (or strength) is sometimes called breaking stress and is the maximum stress that can be applied to a material before it breaks.
	4.14	how to draw force-extension graphs for typical brittle, ductile and polymeric materials showing that there is a difference for various materials	4.14	
	4.15	what is meant by the terms non-destructive testing and destructive testing	4.15	
5. Know the basic principles of fluid mechanics	5.1	fluids at rest	5.1	Two forms of fluid: liquid and gases
	5.2	the terms: • pressure • gauge pressure • absolute pressure	5.2	**Pressure** (*p*) - Forces acting on a surface/plane due to intermolecular collisions within the fluid $p = \frac{F}{A}$ **Gauge Pressure** – pressure indicated on a gauge above that due to the atmosphere **Absolute pressure** = gauge pressure + atmospheric pressure
	5.3	pressure exerted on any point on a surface in a fluid is always at right angles to the surface	5.3	
	5.4	pressure at any point in a fluid is the same in all directions at that point	5.4	
	5.5	pressure due to a column of liquid	5.5	$p = hg\rho$ where *h* is height of the column, *g* is the acceleration due to gravity, and ρ is the density of the liquid

Learning outcomes		Teaching content		Exemplification
The Learner will:		**Learners must be taught:**		
	5.6	Archimedes' principle	5.6	The up-thrust force acting on an immersed object is equal to the weight of fluid displaced Up-thrust force $= Vg\rho$ where V is the volume of displaced fluid, g is the acceleration due to gravity, and ρ is the density of the liquid
	5.7	fluid flow: • ideal fluid • streamline or laminar • turbulent flow • boundary layers	5.7	**Ideal fluid** is one with assumed zero viscosity **Streamline (or laminar) flow** happens when particles of the fluid move along in layers (and successive particles passing any given point have the same velocity). **Turbulent flow** happens when particles move in very irregular paths (and the velocity of particles at any given point varies randomly)
	5.8	definition of viscosity	5.8	Viscosity- Fluid's ability to resist shear forces. Dynamic viscosity- ratio of shear stress to velocity gradient. Kinematic Viscosity- ratio of dynamic viscosity to density.
6. Know the basic principles of thermal physics	6.1	the non-flow energy equation	6.1	From the principle of conservation of energy $U_1 + Q = U_2 + W$ So $Q = (U_2 - U_1) + W$ Where: Q = energy entering the system W = energy leaving the system U_1 = initial energy in the system U_2 = final energy in the system
	6.2	the steady flow energy equation	6.2	$Q = (W_2 - W_1) + W$ Where: Q = heat energy supplied to the system W_2 = energy leaving the system W_1 = energy entering the system W = work done by the system

Learning outcomes		Teaching content		Exemplification
The Learner will:		**Learners must be taught:**		
	6.3	that the internal energy of a system is the sum of a random distribution of kinetic and potential energy concerned with the molecules of the system	6.3	
	6.4	what is meant by the term thermodynamic scale and state that on the Kelvin scale, absolute zero is the temperature at which all substances have a minimum internal energy	6.4	
	6.5	Boyle's law and its equation	6.5	**Boyle's law equation** $pV = C(\text{constant}) \quad p_1V_1 = p_2V_2$
	6.6	Charles' law and its equation	6.6	**Charles law equation** $\frac{V}{T} = C(\text{constant}) \quad \frac{V_1}{T_1} = \frac{V_2}{T_2}$
	6.7	Pressure law and its equation	6.7	**Pressure law equation** $\frac{p}{T} = C(\text{constant}) \quad \frac{p_1}{T_1} = \frac{p_2}{T_2}$
	6.8	combined gas law and its equation	6.8	**Combined gas law equation:** $\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$

Learning outcomes		Teaching content		Exemplification
The Learner will:		**Learners must be taught:**		
	6.9	ideal and characteristic gas equations	6.9	**Ideal gas equation:** $pV = (constant)T$ $pV = nRT$ Where n is the number of moles of a gas and R is the molar gas constant. **Characteristic gas equation:** The ideal gas equation can be rewritten in terms of the mass of gas m; in this case R would need to equal the specific gas constant for the particular gas. $pV = mRT$
	6.10	the term specific heat capacity and the equation for heat energy or sensible heat (Q)	6.10	**Sensible heat formula** heat energy, $Q = mc\Delta T$ specific heat capacity is the energy required to raise the temperature of 1kg of a material by 1 °C.
	6.11	the efficiency equation	6.11	**Efficiency equation** $\eta = \frac{\text{work output}}{\text{work input}}$
	6.12	what is meant by the terms sensible heat and latent heat	6.12	Sensible heat is heat energy which results in a change of temperature. Latent heat is heat energy absorbed or emitted during a change of state Specific latent heat is the energy change resulting in the change of state of 1 kg of substance.
	6.13	application of sensible and latent heat formulae	6.13	**Latent heat formula** $Q = mL$

ASSESSMENT GUIDANCE

All Learning Outcomes are assessed through externally set written examination papers, worth a maximum of 60 marks and 1 hour and 30 minutes in duration. Learners should study the design requirements, influences and user needs within the taught content in the context of a range of real engineered products. Exam papers for this unit will use engineered products as the focus for some questions, however it is not a requirement of this unit for learners to have any detailed prior knowledge or understanding of particular products used. Questions will provide sufficient product information to be used, applied and interpreted in relation to the taught content. During the external assessment, learners will be expected to demonstrate their understanding through questions that require the skills of analysis and evaluation in particular contexts.

LEARNING OUTCOME WEIGHTINGS

Each learning outcome in this unit has been given a percentage weighting. This reflects the size and demand of the content you need to cover and its contribution to the overall understanding of this unit. See table below:

LO1	10-20%
LO2	10-20%
LO3	10-20%
LO4	10-20%
LO5	10-20%
LO6	10-20%

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