Fundamentals

Fundamentals year 12 & 13 Cambridge Technicals: Engineering

Mathematics for Engineering	
Knowledge	**Skills**
Application of algebra	• multiplication by constant • binomial expansion • removing a common factor • factorisation • using the principle of the lowest common multiple (LCM)
Simplification of polynomials	• factorising a cubic • algebraic division • the remainder and factor theorems
How to simplify and solve equations	
Transposition of formulae	• containing two like terms • containing a root or a power
How to solve linear simultaneous equations with two unknowns	• graphical interpretation • algebraic method, i.e.: o elimination method o substitution method
How to solve quadratic equations	• sketching of quadratic graphs • factorisation method • completing the squares • using the formula
How to use co-ordinate geometry	• straight line equations i.e. o equation of a line through two points o gradient of parallel lines o gradient of perpendicular lines o mid-point of a line o distance between two points • curve sketching i.e. o graphs o graphical solution of cubic functions • graphical transformations i.e. o translation by addition o translation by multiplication i.e.: - stretches

	- reflections
Problem solving using exponentials and logarithms	• applying logarithms to base 10
How to use inverse function and log laws	
Angles and radians	• define the terms angle and radian • the formulae
Problem solving with arcs, circles and sectors	• the formula for the length of an arc of a circle • the formula for the area of a sector of a circle • the co-ordinate equation of a circle
Problem solving involving right-angled triangles	• what is meant by the term "solution of a triangle" • Pythagoras' Theorem • use of sine, cosine and tangent rule for right-angled triangles • the formulae for the area of a right-angled triangle
Problem solving involving non-right angled triangles	• sine rule • cosine rule • area
Common trigonometric values	
Common trigonometric identities	
Cine, cosine and tangent operations i.e.	determine the sine, cosine and tangent of any angle between 0^0 and 360^0
Problem solving involving differentiation	• determine gradients of a simple curve using graphical methods • the rule to differentiate simple algebraic functions • determine the maximum and minimum turning points and the co-ordinates of the turning points by differentiating the equation twice • differentiate functions of the form
Solve problems involving indefinite integration	• define indefinite integration • recognise the symbol $\int$ for integration • the rule to integrate functions of the form

problem solving involving definite integrals	• the rule for a definite integral • the notation for definite integration • the interpretation of a definite integral • integrate functions of the form
the terms "data handling" and "sampling"	
problem solving involving histograms, frequency polygons and cumulative frequency curves	
Science for Engineering	
Understand applications of SI units and measurement	- SI units - Definitions of measurement and terms related to measurement. - Applying the formulae for: • relative error • absolute error • absolute correction • relative correction - How to calculate the standard deviation and the standard error of the mean. - How to use instruments for taking measurements.
Understand fundamental scientific principles of mechanical engineering	- Applying the formulae for force and motion. - Explaining the terms associated to kinematics - Explaining the terms associated to dynamics - Applying the formulae for force, work and power
Understand fundamental scientific principles of electrical and electronic engineering	- To be able to do and explain the following: - atomic structure and electric current - the term Coulomb and use of the formula for charge - electron flow and current flow in conductors, semi-conductors and insulators - potential difference (*V*) relating to: • energy and charge • power and current - current-potential difference characteristics for: • a metallic conductor at constant temperature • a filament lamp • a semiconductor diode

	- resistance and Ohm's law for resistive circuits - how to calculate the total resistance and total current for a circuit that is a combination of resistors connected in series and parallel - use of the formulae for electrical power (*P*) and energy (*W*) - that the kilowatt-hour is a unit of energy - that the efficiency of a system is the ratio of work output to work input - the term resistivity and use of the formula for resistivity (*ρ*) - the term temperature coefficient of resistance - use of graphs to show the variation with temperature of a pure resistor and of a negative temperature coefficient thermistor - use of the formula for the magnitude of the uniform electric field strength (*E*) between charged parallel plates - the terms capacitance (*C*) and farad (F) - use of the formula capacitance (*C*) and the formula for the energy () of a charged capacitor *W* - how to draw a graph for a capacitor discharging through a resistor of (a) potential difference against time and (b) current against time - the significance of a time constant for the discharge of a capacitor and use of the formula for time constant () τ - use of the formula for the discharge of a capacitor - the terms inductance (*L*) and henry (H) - use of the formula for the self-inductance (*L*) of a coil and the formula for energy () stored in the magnetic field of a coil. *LW*
Understand properties of materials	- To be able to identify and explain the following: - elastic deformation, in terms of the separation of atoms in a solid material - that the resultant force between two atoms in a crystal is the vector sum of an attractive force and a repulsive force

	- basic material properties: • ductility • brittleness • toughness • stiffness • resilience • endurance • hardness • malleability - what is meant by the term equilibrium separation - plastic deformation: • in terms of slip • why plastic deformation happens more easily when dislocations are present in a solid material - 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 - application of the formula for current (*I*) - that deformation is caused by a tensile or compressive force - Hooke's law - what is meant by the terms: • elastic limit • stress • strain • Young's modulus - the difference between elastic and plastic deformation of a material - how to calculate the strain energy in a deformed material from a force – extension graph - the term ultimate tensile stress - how to draw force-extension graphs for typical brittle, ductile and polymeric materials showing that there is a difference for various materials - what is meant by the terms non-destructive testing and destructive testing.
Know the basic principles of fluid mechanics	- To be able to explain the following: - fluids at rest - pressure, gauge pressure, absolute pressure

	- pressure exerted on any point on a surface in a fluid is always at right angles to the surface - pressure at any point in a fluid is the same in all directions at that point - pressure due to a column of liquid - Archimedes' principle - fluid flow: • ideal fluid • streamline or laminar • turbulent flow • boundary layers - definition of viscosity
Know the basic principles of thermal physics	To know and be able to apply: - the non-flow energy equation - the steady flow energy equation - 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 - 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 - Boyle's law and its equation - Charles' law and its equation - Pressure law and its equation - combined gas law and its equation - characteristic gas equation - the term specific heat capacity and the formula heat energy or sensible heat (Q) - the efficiency equation - what is meant by the terms sensible heat and latent heat - application of sensible
Principles of Mechanical Engineering	
Understand systems of forces and types of loading on mechanical components	- Learners should appreciate the different types of loading identified, and how they can be applied to a mechanical component. - Methods of trigonometry should be used to resolve forces. - Learners should understand situations in which assumptions of particle and rigid body mechanics can be applied.

	- Learners should be able to use and draw force diagrams to represent engineering problems to aid visualisation and analysis. - Learners should be aware of horizontal and vertical equilibrium for systems of concurrent forces (particle mechanics), and horizontal, vertical and rotational equilibrium for non-concurrent forces (rigid body mechanics). - For systems of concurrent forces, the resultant or equilibrant force should be defined in terms of magnitude and direction. - For systems of non-concurrent forces the learner must be able to define the resultant or equilibrant both in terms of: 1. magnitude and line of action (point and direction) 2. magnitude and direction, and moment acting at a specific point - Learners should be aware of the assumptions made for calculations of direct stress and strain in axially loaded components. They should know appropriate units for stress and Young's modulus and be able to use the formulae listed to carry out calculations for components in direct tension or compression. - Learners must know the term of the modulus of elasticity (Young's modulus), and that this represents the stiffness of a material.
Understand fundamental geometric properties	- To be able to apply calculation of the area of irregular 2D shapes - calculation of the volume of a regular prism of known cross sectional area and length - calculation of the mass of a body of known volume and uniform density - he significance of the centroid of a body as its centre of gravity/centre of mass - the use of axes of symmetry of a uniform 2D figure to find its centroid

	- the position of the centroid of common non-symmetrical 2D shapes i.e. • right-angled triangle • semi-circle - the use of moment of area of uniform regular 2D shapes to find the position of the centroid of more complex uniform irregular shapes
Understand levers, pulleys and gearing	- To know concepts of mechanical advantage (MA) and velocity ratio (VR) applied to: • levers • systems of pulleys • gears - the three classes of lever - different types of gears and gear systems, and their applications - calculation of MA and VR for spur gears - calculation of MA and VR for simple compound spur gear systems - different types of pulley and belt drive systems and their applications - calculation of the MA and VR for the named belt drive systems.
Understand properties of beams	- To be able to accurately complete questions involving calculations will be restricted to statically determinate beams only (i.e. simply supported and cantilever beams). - Learners should understand that uniformly distributed loads can be imposed loads e.g. pedestrians or dead loads from the weight of the beam.
Understand principles of dynamic systems	- To know how to apply Newton's Laws of Motion in a mechanical engineering context - how to apply the constant acceleration formulae to problems set in a mechanical engineering context - the principle of conservation of energy and how to apply this principle to problems involving kinetic and gravitational potential energy - the relationship between work done on a body and the change in energy of that body

	- application of equations for energy and work done to problems set in a mechanical engineering context - use of the equations for power to solve problems set in a mechanical engineering context - the action of a friction force between a body and a rough surface and how to apply the equation $F \leq \mu N$ - to apply the principle of conservation of momentum to bodies experiencing elastic collisions
Principles of electrical and electronic engineering	
Understand fundamental electrical principles	- application of the defining equations for: - measurement of voltage, current and resistance in a circuit. - Circuit theory
Understand alternating voltage and current	- what is meant by a simple generator - what is meant by an alternating current (AC) and generated electromotive force (e.m.f.) - diagrammatic representations of a sine wave - to determine frequency and amplitude of a sine wave - to determine the phase difference and phase angle in alternating quantities - circuit diagrams and phasor diagrams for: • a pure resistance being supplied by an alternating current • a pure inductance being supplied by an alternating current • a pure capacitance being supplied by an alternating current • a pure resistance and inductor in series • a pure resistance and capacitor in series - application of the defining equation for reactance (X) and impedance (Z) for: • pure resistance • pure inductance • pure capacitance

	- application of the defining equation for impedance for: • pure resistance and inductor in series • pure resistance and capacitor in series
Understand electric motors and generators	- To know the difference between motors and generators - application of the defining equation for - the type of field winding and action - application of the defining equations - applications for a: • separately excited DC generator • series wound self-excited DC generator • shunt-wound self-excited DC generator • series-wound DC motor • shunt-wound DC motor - DC motor starters to include a no-volt trip coil and an overload current trip coil - how the speed of a DC shunt motor and a series DC motor can be changed
Understand power supplies and power system protection	- To know the meaning of: • an alternating current supply • a direct current supply - the distribution of electrical energy to consumers by a: • single-phase 2-wire system • single phase 3-wire system • three phase 3- wire Delta connected system • three phase 4-wire Star connected system - an alternating current can be rectified to a half wave direct current using a single diode - full wave rectification can be obtained by using two diodes - full wave rectification can be obtained by using four diodes in a bridge configuration - the capability of load regulation to maintain a constant voltage or current level on the output of a power supply regardless of changes in the supply load

Understand analogue electronics	- To be able to express the definition of an analogue circuit - how to explain with the aid of a labelled diagram the characteristics of an operational amplifier (op-amp) - how to draw a labelled diagram of an op-amp - characteristic properties of an ideal op-amp - how to draw a labelled diagram and explain the function of: • an inverting amplifier • a non-inverting amplifier • a summing amplifier - application of the defining equation for gain in: • an inverting amplifier • a non-inverting amplifier • a summing amplifier out*V* - state and apply the formula for a summing amplifier out*V*
Understand digital electronics	- To be able to express the definition of a digital electronic circuit - how to draw a labelled diagram and explain the function of the logic gates - how to construct truth tables for: • AND • NAND • OR • NOR • NOT • XOR - how to solve simple combinational logic problems - how to recognise simple Boolean expressions - how to explain with the aid of a circuit symbol the function of: • T type bi-stable flip-flop • D type bi-stable flip-flop - to explain the behaviour of a rising-edge triggered D flip-flop