UNIVERSITY OF CAMBRIDGE

ENGINEERING ADMISSIONS ASSESSMENT (ENGAA)

Content Specification

For assessment in 2020

PHYSICS

P1. Electricity

P1.1 Electrostatics:

a. Know and understand that insulators can be charged by friction.

b. Know and understand that charging is caused by gain or loss of electrons.

c. Know and understand that like charges repel and unlike charges attract.

d. Understand applications and hazards associated with electrostatics, including the role of earthing.

P1.2 Electric circuits:

a. Know and recognise the basic circuit symbols and diagrams, including: cell, battery, light source, resistor, variable resistor, ammeter, voltmeter, switch, diode.

b. Understand the difference between alternating current (ac) and direct current (dc).

c. Understand the difference between conductors and insulators, and recall examples of each type.

d. Know and be able to apply: $\text{current} = \frac{\text{charge}}{\text{time}}$, $I = \frac{Q}{t}$

e. Know and understand the use of voltmeters and ammeters.

f. Know and be able to apply: $\text{resistance} = \frac{\text{voltage}}{\text{current}}$, $R = \frac{V}{I}$

g. Recall and interpret *V*–*I* graphs for a fixed resistor and a filament lamp.

h. Know the properties of NTC (negative temperature coefficient) thermistors, LDRs (light-dependent resistors) and ideal diodes.

i. Know and understand the current and voltage rules for series and parallel circuits.

j. Calculate the total resistance for resistor combinations in series.

k. Understand that the total resistance of a parallel combination is less than that of any individual resistor.

l. Know and be able to apply: $\text{voltage} = \frac{\text{energy}}{\text{charge}}$, $V = \frac{E}{Q}$

m. Know and be able to apply: power = current × voltage, $P = IV = I^2R$

n. Know and be able to apply: energy transfer = power × time, $E = VIt$

P2. Magnetism

P2.1 Properties of magnets:

a. Know and be able to use the terms *north pole*, *south pole*, *attraction* and *repulsion*.

b. Know the magnetic field pattern around a bar magnet (including direction).

c. Understand the difference between soft and hard magnetic materials (e.g. iron and steel).

d. Qualitatively understand induced magnetism.

P2.2 Magnetic field due to an electric current:

a. Know and understand the magnetic effect of a current.

b. Know the magnetic field patterns around current-carrying wires (including direction) for straight wires and coils/solenoids.

c. Know and understand the factors affecting magnetic field strength around a wire.

d. Understand the difference between permanent magnets and electromagnets.

P2.3 The motor effect:

a. Know that a wire carrying a current in a magnetic field can experience a force.

b. Know the factors affecting the direction of a force on a wire in a magnetic field (including the left-hand rule).

c. Know the factors affecting the magnitude of the force on a wire in a magnetic field.

d. Know and be able to apply $F = BIL$ for a straight wire at right angles to a uniform magnetic field.

e. Know and understand the construction and operation of a dc motor, including factors affecting the magnitude of the force produced.

f. Understand applications of electromagnets.

P2.4 Electromagnetic induction:

a. Know and understand that a voltage is induced when a wire cuts magnetic field lines, or when a magnetic field changes.

b. Know the factors affecting the magnitude of an induced voltage.

c. Know the factors affecting the direction of an induced voltage.

d. Understand the operation of an ac generator, including factors affecting the output voltage.

e. Interpret the graphical representation of the output voltage of a simple ac generator.

f. Understand applications of electromagnetic induction.

P2.5 Transformers:

a. Know and understand the terms *step-up transformer* and *step-down transformer*.

b. Know and use the relationship between the number of turns on the primary and secondary coils, and the voltage ratio: $\frac{V_p}{V_s} = \frac{n_p}{n_s}$

c. Know that a consequence of 100% efficiency is total transfer of electrical power, and that this gives rise to the following relationship: $V_p I_p = V_s I_s$. Know and use this relationship to solve problems.

d. Understand power transmission, including calculating losses during transmission and the need for high voltage.

P3. Mechanics

P3.1 Kinematics:

a. Know and understand the difference between scalar and vector quantities.

b. Know and understand the difference between distance and displacement and between speed and velocity.

c. Know and be able to apply: $\text{speed} = \frac{\text{distance}}{\text{time}}$,

$$\text{velocity} = \frac{\text{change in displacement}}{\text{time}}$$

d. Know and be able to apply: $\text{acceleration} = \frac{\text{change in velocity}}{\text{time}}$

e. Interpret distance–time, displacement–time, speed–time and velocity–time graphs.

f. Perform calculations using gradients and areas under graphs.

g. Know and be able to apply: $\text{average speed} = \frac{\text{total distance}}{\text{total time}}$

h. Know and be able to apply the equation of motion: $v^2 - u^2 = 2as$

P3.2 Forces:

a. Understand that there are different types of force, including weight, normal contact, drag (including air resistance), friction, magnetic, electrostatic, thrust, upthrust, lift and tension.

b. Know and understand the factors that can affect the magnitude and direction of the forces in 3.2a.

c. Draw and interpret force diagrams.

d. Qualitatively understand resultant force, with calculations in one dimension.

P3.3 Force and extension:

a. Interpret force–extension graphs.

b. Understand elastic and inelastic extension, and elastic limits.

c. Know and be able to apply Hooke's law ($F = kx$), and understand the meaning of the limit of proportionality.

d. Understand energy stored in a stretched spring as: $E = \frac{1}{2}Fx = \frac{1}{2}kx^2$

P3.4 Newton's laws:

a. Know and understand Newton's first law as: 'a body will remain at rest or in a state of uniform motion in a straight line unless acted on by a resultant external force'.

b. Understand mass as a property that resists change in motion (inertia).

c. Know and understand Newton's second law as: force = mass × acceleration

d. Know and understand Newton's third law as: 'if body A exerts a force on body B then body B exerts an equal and opposite force of the same type on body A'.

P3.5 Mass and weight:

a. Know and understand the difference between mass and weight.

b. Know and be able to apply gravitational field strength, *g*, approximated as $10\,\mathrm{N\,kg^{-1}}$ on Earth.

c. Know and be able to apply the relationship between mass and weight: $w = mg$

d. Understand free-fall acceleration.

e. Know the factors affecting air resistance.

f. Understand terminal velocity and the forces involved.

P3.6 Momentum:

a. Know and be able to apply: momentum = mass × velocity, $p = mv$

b. Know and be able to use the law of conservation of momentum in calculations in one dimension.

c. Know and be able to apply: force = rate of change of momentum

P3.7 Energy:

a. Know and be able to apply: work = force × distance moved (in direction of force)

b. Understand work done as a transfer of energy.

c. Know and be able to apply: gravitational potential energy = mgh, where h is the difference in height of the object.

d. Know and be able to apply: kinetic energy = $\frac{1}{2}mv^2$

e. Know and be able to apply: power = $\frac{\text{energy transfer}}{\text{time}}$

f. Know and be able to use in calculations the law of conservation of energy.

g. Understand the concepts of useful energy and wasted energy.

h. Know and be able to apply: percentage efficiency = $\frac{\text{useful output}}{\text{total input}} \times 100$

P4. Thermal physics

P4.1 Conduction:

a. Know and understand thermal conductors and insulators, with examples.

b. Know and be able to apply factors affecting rate of conduction.

P4.2 Convection:

a. Understand and be able to apply the effect of temperature on density of fluid.

b. Understand and be able to apply fluid flow caused by differences in density.

P4.3 Thermal radiation:

a. Understand thermal radiation as electromagnetic waves in the infrared region.

b. Know and be able to apply absorption and emission of radiation.

c. Know and be able to apply factors affecting rate of absorption and emission of thermal radiation.

P4.4 Heat capacity:

a. Understand the effect of energy transferred to or from an object on its temperature.

b. Know and be able to apply: specific heat capacity = $\frac{\text{thermal energy}}{\text{mass} \times \text{temperature change}}$

where temperature is measured in °C and specific heat capacity, c, is measured in $\text{J kg}^{-1}\,^{\circ}\text{C}^{-1}$.

P5. Matter

P5.1 States of matter:

a. Know the characteristic properties of solids, liquids and gases.

b. Know and be able to apply particle models of solids, liquids and gases.

c. Know and be able to explain properties of solids, liquids and gases in terms of particle motion and the forces and distances between the particles.

P5.2 Ideal gases:

a. Be able to explain pressure and temperature in terms of the behaviour of particles.

b. Understand and be able to apply the effect of pressure (P) on gas volume (V) at constant temperature, i.e. PV = constant.

P5.3 State changes:

a. Understand the terms *melting point* and *boiling point*.

b. Know and understand the terms *latent heat of fusion* and *latent heat of vaporisation*.

c. Know and be able to apply specific latent heat calculations.

P5.4 Density:

a. Know and be able to apply: density $= \frac{\text{mass}}{\text{volume}}$, $\rho = \frac{m}{V}$

b. Understand the experimental determination of densities.

c. Be able to compare the densities of solids, liquids and gases.

P5.5 Pressure:

a. Know and be able to apply: pressure $= \frac{\text{force}}{\text{area}}$

b. Know and be able to apply: hydrostatic pressure = $h\rho g$, where h is the height, or depth, of the liquid.

P6. Waves

P6.1 Wave properties:

a. Understand the transfer of energy without net movement of matter.

b. Know and understand transverse and longitudinal waves.

c. Know and understand the terms: *peak*, *trough*, *compression* and *rarefaction*.

d. Recall examples of waves, including electromagnetic waves and sound.

e. Know and be able to use the terms: *amplitude*, *wavelength*, *frequency* and *period*.

f. Know and be able to apply: frequency $= \frac{1}{\text{period}}$, $f = \frac{1}{T}$

g. Know and be able to apply: wave speed $= \frac{\text{distance}}{\text{time}}$

h. Know and be able to apply: wave speed = frequency $\times$ wavelength, $v = f\lambda$

P6.2 Wave behaviour:

a. Know and understand reflection at a surface.

b. Know and understand refraction at a boundary.

c. Know and understand the effect of reflection and refraction on the speed, frequency, wavelength and direction of waves.

d. Know and understand the analogy of reflection and refraction of light with that of water waves.

e. Know and understand the Doppler effect.

P6.3 Optics:

a. Draw and interpret ray diagrams to describe reflection in plane mirrors.

b. Know and be able to apply: angle of incidence = angle of reflection

c. Draw and interpret ray diagrams for refraction at a planar boundary.

d. Know and be able to interpret angle of incidence and angle of refraction.

e. Know and understand the effect of refraction on wave direction (away from or towards the normal) and speed (increasing or decreasing).

P6.4 Sound waves:

a. Understand the production of sound waves by a vibrating source.

b. Understand the need for a medium.

c. Understand qualitatively the relation of loudness to amplitude and pitch to frequency.

d. Know and understand longitudinal waves.

e. Understand that reflection causes echoes.

f. Recall that the range of human hearing is 20 Hz to 20 kHz.

g. Know and understand ultrasound and its uses (sonar and medical scanning).

P6.5 Electromagnetic spectrum:

a. Know and understand the nature and properties of electromagnetic waves (they are transverse waves and travel at the speed of light in a vacuum).
b. Recall the component parts of the spectrum (radio waves, microwaves, IR, visible light, UV, X-rays, gamma).
c. Understand the distinction of the component parts by different wavelengths and/or frequencies.
d. Recall the order of the component parts by wavelength and/or frequency.
e. Understand applications and hazards of the component parts of the electromagnetic spectrum.

P7. Radioactivity

P7.1 Atomic structure:

a. Understand the atom in terms of protons, neutrons and electrons.
b. Know and be able to apply the nuclear model of atomic structure.
c. Know the relative charges and masses of protons, neutrons and electrons.
d. Understand and be able to use the terms *atomic number* and *mass number*.
e. Know and understand the term *isotope*.
f. Know and understand the term *nuclide*, and use nuclide notation.
g. Understand that ionisation is caused by the gain/loss of electrons.

P7.2 Radioactive decay:

a. Know and understand that emissions arise from an unstable nucleus.
b. Know and understand the random nature of emissions.
c. Know and understand the differences between alpha, beta and gamma emission.
d. Know and understand the nature of alpha and beta particles, and gamma radiation.
e. Be able to use and interpret nuclear equations.
f. Know the effect of decay on atomic number and mass number.

P7.3 Ionising radiation:

a. Know the relative penetrating abilities of alpha, beta and gamma radiation.
b. Know the relative ionising abilities of alpha, beta and gamma radiation.
c. Understand qualitatively the deflection of alpha, beta and gamma radiation in electric or magnetic fields.
d. Know and appreciate the existence of background radiation.
e. Understand the applications and hazards of ionising radiation.

P7.4 Half-life:

a. Be able to interpret graphical representations of radioactive decay (including consideration of decay products).

b. Understand the meaning of the term *half-life*.

c. Understand and be able to apply half-life calculations.

ADVANCED MATHEMATICS

AM1. Algebra and functions

AM1.1 Laws of indices for all rational exponents.

AM1.2 Use and manipulation of surds.

Simplifying expressions that contain surds, including rationalising the denominator.

For example: simplifying $\frac{\sqrt{5}}{3+2\sqrt{5}}$ and $\frac{3}{\sqrt{7}-2\sqrt{3}}$

AM1.3 Quadratic functions and their graphs; the discriminant of a quadratic function; completing the square; solution of quadratic equations.

AM1.4 Simultaneous equations: analytical solution by substitution, e.g. of one linear and one quadratic equation.

AM1.5 Solution of linear and quadratic inequalities.

AM1.6 Algebraic manipulation of polynomials, including:

a. expanding brackets and collecting like terms

b. factorisation and simple algebraic division (by a linear polynomial, including those of the form $ax + b$, and by quadratics, including those of the form $ax^2 + bx + c$)

c. use of the Factor Theorem and the Remainder Theorem

AM1.7 Qualitative understanding that a function is a many-to-one (or sometimes just a one-to-one) mapping.

Familiarity with the properties of common functions, including $f(x) = \sqrt{x}$ (which always means the 'positive square root') and $f(x) = |x|$.

AM2. Sequences and series

AM2.1 Sequences, including those given by a formula for the n^{th} term and those generated by a simple recurrence relation of the form $x_{n+1} = f(x_n)$

AM2.2 Arithmetic series, including the formula for the sum of the first n natural numbers.

AM2.3 The sum of a finite geometric series.

The sum to infinity of a convergent geometric series, including the use of $|r| < 1$

AM2.4 Binomial expansion of $(1 + x)^n$ for positive integer n, and for expressions of the form $(a + f(x))^n$ for positive integer n and simple $f(x)$.

The notations $n!$ and $\binom{n}{r}$.

AM3. Coordinate geometry in the (x, y)-plane

AM3.1 Equation of a straight line, including:

a. $y - y_1 = m(x - x_1)$

b. $ax + by + c = 0$

Conditions for two straight lines to be parallel or perpendicular to each other.

Finding equations of straight lines given information in various forms.

AM3.2 Coordinate geometry of the circle, using the equation of a circle in the forms:

a. $(x - a)^2 + (y - b)^2 = r^2$

b. $x^2 + y^2 + cx + dy + e = 0$

AM3.3 Use of the following circle properties:

a. The perpendicular from the centre to a chord bisects the chord.

b. The tangent at any point on a circle is perpendicular to the radius at that point.

c. The angle subtended by an arc at the centre of a circle is twice the angle subtended by the arc at any point on the circumference.

d. The angle in a semicircle is a right angle.

e. Angles in the same segment are equal.

f. The opposite angles in a cyclic quadrilateral add to 180°.

g. The angle between the tangent and chord at the point of contact is equal to the angle in the alternate segment.

AM4. Trigonometry

AM4.1 The sine and cosine rules, and the area of a triangle in the form $\frac{1}{2}ab\sin C$.

The sine rule includes an understanding of the 'ambiguous' case (angle–side–side).

Problems might be set in 2 or 3 dimensions.

AM4.2 Radian measure, including use for arc length and area of sector and segment.

AM4.3 The values of sine, cosine and tangent for the angles: 0°, 30°, 45°, 60°, 90°.

AM4.4 The sine, cosine and tangent functions; their graphs, symmetries, and periodicity.

AM4.5 Knowledge and use of the equations:

a. $\tan\theta = \dfrac{\sin\theta}{\cos\theta}$

b. $\sin^2\theta + \cos^2\theta = 1$

AM4.6 Solution of simple trigonometric equations in a given interval (this may involve the use of the identities in 4.5).

For example: $\tan\theta = -\dfrac{1}{\sqrt{3}}$ for $-\pi < x < \pi$ $\qquad$ $\sin^2(2x + \frac{\pi}{3}) = \frac{1}{2}$ for $-2\pi < x < 2\pi$

$$12\cos^2 x + 6\sin x - 10 = 2 \quad \text{for } 0° < x < 360°$$

AM5. Exponentials and logarithms

AM5.1 $y = a^x$ and its graph, for simple positive values of a.

AM5.2 Laws of logarithms:

a. $a^b = c \Leftrightarrow b = \log_a c$

b. $\log_a x + \log_a y = \log_a (xy)$

c. $\log_a x - \log_a y = \log_a \left(\frac{x}{y} \right)$

d. $k \log_a x = \log_a (x^k)$

including the special cases:

e. $\log_a \left(\frac{1}{x} \right) = - \log_a x$

f. $\log_a a = 1$

Questions requiring knowledge of the change of base formula will not be set.

AM5.3 The solution of equations of the form $a^x = b$, and equations which can be reduced to this form, including those that need prior algebraic manipulation.

For example: $3^{2x} = 4$ and $25^x - 3 \times 5^x + 2 = 0$

AM6. Differentiation

AM6.1 The derivative of $f(x)$ as the gradient of the tangent to the graph $y = f(x)$ at a point.

a. Interpretation of a derivative as a rate of change.

b. Second-order derivatives.

c. Knowledge of notation: $\frac{\mathrm{d}y}{\mathrm{d}x}$, $\frac{\mathrm{d}^2 y}{\mathrm{d}x^2}$, $f'(x)$, and $f''(x)$

Differentiation from first principles is excluded.

AM6.2 Differentiation of x^n for rational n, and related sums and differences. This might require some simplification before differentiating.

For example, the ability to differentiate an expression such as $\frac{(3x+2)^2}{x^{\frac{1}{2}}}$

AM6.3 Applications of differentiation to gradients, tangents, normals, stationary points (maxima and minima only), increasing functions [$f'(x) \geq 0$] and decreasing functions [$f'(x) \leq 0$]. Points of inflexion will not be examined, although a qualitative understanding of points of inflexion in the curves of simple polynomial functions is expected.

AM7. Integration

AM7.1 Definite integration as related to the 'area between a curve and an axis'. The difference between finding a definite integral and finding the area between a curve and an axis is expected to be understood.

AM7.2 Finding definite and indefinite integrals of x^n for n rational, $n \neq 1$, and related sums and differences, including expressions which require simplification prior to integrating.

For example: $\int (x+2)^2 \, \mathrm{d}x$ and $\int \frac{(3x-5)^2}{x^{\frac{1}{2}}} \, \mathrm{d}x$

AM7.3 An understanding of the Fundamental Theorem of Calculus and its significance to integration. Simple examples of its use may be required in the forms:

a. $\int_a^b f(x)\mathrm{d}x = F(b) - F(a)$, where $F'(x) = f(x)$

b. $\frac{\mathrm{d}}{\mathrm{d}x}\int_a^x f(x)\mathrm{d}x = f(x)$

AM7.4 Combining integrals with either equal or contiguous ranges.

For example: $\int_2^5 f(x)\mathrm{d}x + \int_2^5 g(x)\mathrm{d}x = \int_2^5 [f(x)+g(x)]\mathrm{d}x$

$$\int_2^4 f(x)\mathrm{d}x + \int_4^3 f(x)\mathrm{d}x = \int_2^3 f(x)\mathrm{d}x$$

AM7.5 Approximation of the area under a curve using the trapezium rule; determination of whether this constitutes an overestimate or an underestimate.

AM7.6 Solving differential equations of the form $\frac{\mathrm{d}y}{\mathrm{d}x} = f(x)$

AM8. Graphs of functions

AM8.1 Recognise and be able to sketch the graphs of common functions that appear in this specification: these include lines, quadratics, cubics, trigonometric functions, logarithmic functions, exponential functions, square roots, and the modulus function.

AM8.2 Knowledge of the effect of simple transformations on the graph of $y = f(x)$ with positive or negative value of a as represented by:

a. $y = af(x)$

b. $y = f(x) + a$

c. $y = f(x + a)$

d. $y = f(ax)$

Compositions of these transformations.

AM8.3 Understand how altering the values of m and c affects the graph of $y = mx + c$

AM8.4 Understand how altering the values of a, b and c in $y = a(x + b)^2 + c$ affects the corresponding graph.

AM8.5 Use differentiation to help determine the shape of the graph of a given function, including:

a. finding stationary points (excluding inflexions)

b. when the graph is increasing or decreasing

AM8.6 Use algebraic techniques to determine where the graph of a function intersects the coordinate axes; appreciate the possible numbers of real roots that a general polynomial can possess.

AM8.7 Geometric interpretation of algebraic solutions of equations; relationship between the intersections of two graphs and the solutions of the corresponding simultaneous equations.

ADVANCED PHYSICS

AP1. Forces and equilibrium

AP1.1 Understand the nature of scalars and vectors:

a. Examples include velocity, speed, mass, momentum, force, weight, acceleration, displacement and distance.

b. Know and be able to interpret vector notation.

AP1.2 Components and resultants of vectors:

a. Be able to resolve a vector into two components at right angles to each other by drawing and by calculation.

b. Find the resultant of two coplanar vectors at any angle to each other by drawing.

c. Find the resultant of two coplanar vectors at right angles to each other by calculation.

AP1.3 Moments:

a. Understand moment defined as force × perpendicular distance from the point to the line of action of the force.

b. Be able to calculate the moment of a force about a point (2 dimensions only).

c. Know and be able to apply the principle of moments.

AP1.4 Understand the use of normal and frictional components of contact forces between two surfaces. The distinction between static and dynamic friction is not included.

AP1.5 Understand and use the condition for a particle to be in equilibrium in simple situations. Equilibrium may involve a stationary particle or one moving at constant velocity.

AP1.6 Understand and use the terms *smooth* and *rough*.

AP1.7 Understand and be able to apply the concept of centre of gravity (centre of mass):

a. Understand that the weight of a body acts through its centre of gravity.

b. Identify the position of the centre of gravity of simple planar bodies using symmetry.

AP1.8 Solve problems involving equilibrium of rigid bodies under coplanar forces (zero resultant force and zero resultant moment):

a. These problems could involve an object on an inclined plane, with or without friction.

b. Understand and apply the representation of forces using a triangle of forces.

AP2. Kinematics

AP2.1 Understand graphical methods involving distance, displacement, speed, velocity, acceleration and time.

AP2.2 Use graphical representation of 1-dimensional motion to make various deductions (for example, find the displacement from a velocity–time graph).

AP2.3 Solve questions involving the equations of motion:

a. $v = u + at$

b. $s = ut + \frac{1}{2}at^2$

c. $s = \frac{(u+v)t}{2}$

d. $v^2 = u^2 + 2as$

AP2.4 Know and be able to apply the equation: power = force × velocity

AP3. Newton's laws

AP3.1 Apply Newton's laws to linear motion of point masses moving under the action of forces, including friction and drag (the resistive force experienced by an object travelling through a fluid).

a. Understand that drag force increases with speed.

b. Understand and apply the explanation of terminal velocity in terms of forces acting.

AP3.2 Model a body moving vertically, or on an inclined plane, with constant acceleration.

AP3.3 Solve problems involving projectile motion as the independent effect of motion in horizontal and vertical directions in a uniform gravitational field.

a. Problems will be solvable using the equations of motion.

b. Be able to consider qualitatively the effect of air resistance on projectile motion.

AP3.4 Solve simple problems involving two bodies connected by a light inextensible string or rod.

a. For example, two bodies connected by a string over a light smooth pulley or a car towing a caravan.

b. Interpret and use free body diagrams.

AP4. Momentum

AP4.1 Understand and use the definition of linear momentum.

AP4.2 Understand and use the principle of conservation of momentum in 1-dimensional situations, including coalescence involving elastic collisions (where there is no loss of kinetic energy) and inelastic collisions (where there is a loss of kinetic energy).

AP4.3 Understand how to relate conservation of momentum to Newton's laws of motion.

Know and be able to apply the equation: force = rate of change of momentum

AP4.4 Understand and be able to apply the impulse of a force: impulse = $F\Delta t$

AP5. Energy

AP5.1 Understand and use the concepts of:

gravitational potential energy, $\Delta E_p = mg\Delta h$

kinetic energy, $E_k = \frac{1}{2}mv^2$

a. Be able to apply the quantitative and qualitative use of energy conservation to examples involving gravitational potential energy, kinetic energy, and work done against resistive forces.

b. Understand and apply the principle of conservation of energy.

AP5.2 Know and be able to apply the equation:

power = rate of doing work = rate of energy transfer, $P = \frac{\Delta W}{\Delta t}$

AP5.3 Know and be able to apply the equation:

$$\text{efficiency} = \frac{\text{useful energy transfer}}{\text{total energy input}} \times 100\%$$

AP6. Materials

AP6.1 Know and be able to apply the equation: $\text{density} = \frac{\text{mass}}{\text{volume}}$

AP6.2 Know and be able to apply the equation: $\text{pressure} = \frac{\text{normal force}}{\text{area}}$

AP6.3 Understand and be able to use the concepts of tensile and compressive deformation.

AP6.4 Know and be able to describe the behaviour of springs in terms of load, extension and elastic limit.

AP6.5 Know and be able to apply Hooke's law (force is proportional to extension):

a. Know and be able to apply the equation:

spring constant = force per unit extension

b. Understand graphical methods involving force and extension.

AP6.6 Understand and be able to use the terms *stress*, *strain* and *ultimate tensile strength*.

AP6.7 Recall and be able to use the equation: Young modulus $= \dfrac{\text{stress}}{\text{strain}}$

where stress $= \dfrac{\text{force}}{\text{cross - sectional area}}$ and strain $= \dfrac{\text{extension}}{\text{unstretched length}}$

AP6.8 Recall and be able to use the concept of strain energy:

a. as the area under the force–extension graph

b. recall and be able to use the equation: strain energy $= \frac{1}{2}Fx = \frac{1}{2}kx^2$

AP6.9 Understand and be able to use the concepts of elastic and plastic deformation.

AP7. Waves

AP7.1 Know and be able to describe wave motion as illustrated by vibration in ropes, springs and ripple tanks.

AP7.2 Know and understand the terms *displacement*, *amplitude*, *wavelength*, *frequency*, *period*, *speed*, *path difference* and *phase difference*.

AP7.3 Recall and be able to use the equation: frequency $= \dfrac{1}{\text{period}}$

AP7.4 Recall and be able to use the equation: speed = frequency × wavelength

AP7.5 Understand and be able to compare transverse and longitudinal waves.

a. Understand and be able to interpret graphical representations of transverse and longitudinal waves.

AP7.6 Understand and be able to use the principle of superposition.

AP7.7 Understand and be able to describe the formation of stationary waves using a graphical method.

AP7.8 Be able to identify nodes and antinodes.

AP7.9 Understand and be able to use the concepts of reflection and refraction of waves.

AP7.10 Recall and be able to use the equations: refractive index, $n = \dfrac{v_1}{v_2} = \dfrac{\sin\theta_1}{\sin\theta_2}$

AP7.11 Understand and be able to use the concepts of total internal reflection and critical angle (*C*).

a. Recall and be able to use the equation: $n = \dfrac{1}{\sin C}$

AP8. Electricity

AP8.1 Recall and be able to use the equation: charge = current × time

AP8.2 Recall and be able to use the equation: potential difference, pd = $\frac{\text{work done}}{\text{charge}}$

AP8.3 Know and be able to apply Ohm's law.

AP8.4 Recall and be able to use the equation: $V = IR$

AP8.5 Recall and be able to use the equations:

a. $P = VI$

b. $P = I^2R$

c. $P = \frac{V^2}{R}$

AP8.6 Understand and be able to interpret the *V*–*I* characteristics of an ohmic resistor, a filament lamp and a semi-conductor diode.

AP8.7 Know the behaviour of LDRs and NTC thermistors.

AP8.8 Recall and be able to use the equation: resistivity = resistance × $\frac{\text{cross-sectional area}}{\text{length}}$

AP8.9 Recall and be able to use standard circuit symbols.

AP8.10 Draw and be able to interpret circuit diagrams.

AP8.11 Understand electromotive force (emf) as the work done in driving unit charge around a complete circuit.

a. Distinguish between emf and pd in terms of energy considerations.

b. Understand internal resistance and its effect on the terminal pd of a supply.

AP8.12 Recall and be able to apply Kirchhoff's laws:

a. Understand Kirchhoff's first law in terms of conservation of charge.

b. Understand Kirchhoff's second law in terms of conservation of energy.

c. Be able to apply Kirchhoff's laws to circuit problems.

AP8.13 Understand and be able to apply formulae for combined resistance of two (or more) resistors:

a. in series

b. in parallel

AP8.14 Understand the principle of a potential divider circuit, including the equations:

a. $V_{\text{out}} = \frac{R_1}{R_1 + R_2}$

b. $\frac{V_1}{V_2} = \frac{R_1}{R_2}$

APPENDIX 2: EXAMPLE QUESTIONS

In the following questions, the correct answer has been underlined.

Section 1 Part A: Mathematics and Physics

A ball is thrown vertically upwards and leaves the thrower's hand with a speed of $12\,m\,s^{-1}$. It can be assumed that all of the initial kinetic energy of the ball has been converted into gravitational potential energy when the ball reaches its highest point.

To what height does the ball rise?

(gravitational field strength = $10\,N\,kg^{-1}$)

A 7.2 m

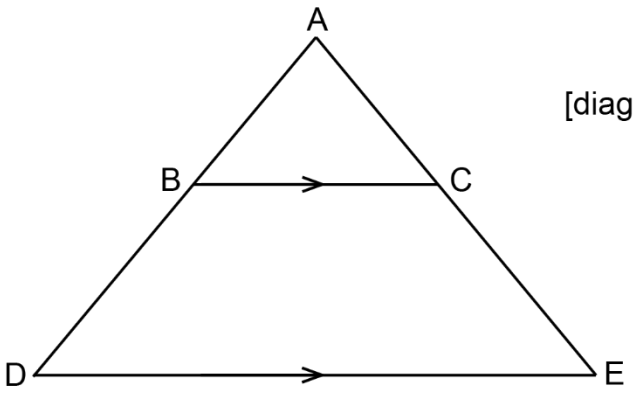
B 14.4 m

C 24 m

D 60 m

E 120 m

A shape is formed by drawing a triangle *ABC* inside the triangle *ADE*.



[diagram not to scale]

BC is parallel to *DE*.

$AB = 4\,\text{cm}$ $BC = x\,\text{cm}$ $DE = (x+3)\,\text{cm}$ $DB = (x-4)\,\text{cm}$

What is the length, in cm, of *DE*?

A 5

B 7

C 9

D $4+2\sqrt{7}$

E $7+2\sqrt{7}$

Section 1 Part B: Advanced Mathematics and Advanced Physics

A particle of weight 5.0 N is held in position by two light ropes.

One of the ropes makes an angle of 60° with the upward vertical, the other is horizontal.

What is the tension in the horizontal rope?

A $5.0\sqrt{3}$ N

B $1.25\sqrt{3}$ N

C $10\sqrt{3}$ N

D 10 N

E 5 N

What is the smallest possible value of $\int_0^1 (x-a)^2 \, \mathrm{d}x$ as a varies?

A $\frac{1}{12}$

B $\frac{1}{3}$

C $\frac{1}{2}$

D $\frac{7}{12}$

E 2

Section 2

A seismic wave causes the surface of the Earth to vibrate. The vibration at a building some distance from the epicentre of the earthquake has a period of 2.0 s.

A second building is 1.0 km farther from the epicentre. The vibration at the second building is $\frac{\pi}{3}$ radians out of phase with that at the first building.

What is the speed of the wave?

(Assume that the wavelength is greater than the separation of the buildings.)

A $\frac{1.5}{\pi}\,\text{km s}^{-1}$

B $\frac{3.0}{\pi}\,\text{km s}^{-1}$

C $1.5\,\text{km s}^{-1}$

D $\frac{6.0}{\pi}\,\text{km s}^{-1}$

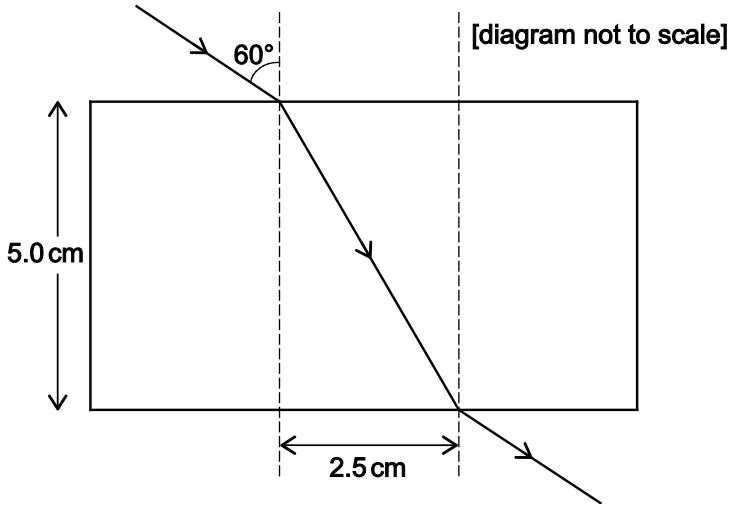
E $3.0\,\text{km s}^{-1}$

F $\frac{12.0}{\pi}\,\text{km s}^{-1}$

G $6.0\,\text{km s}^{-1}$

H $12\,\text{km s}^{-1}$

A ray of light in air strikes the surface of a rectangular transparent block at an angle of 60° to the normal. The ray passes through the block and exits from the far side as shown. The width of the block is 5.0 cm and the distance between the normal at the point of entry to the block and the normal at the point of exit from the block is 2.5 cm.



What is the refractive index of the block?

A $\frac{2}{\sqrt{15}}$

B $\frac{1}{\sqrt{3}}$

C $\frac{1}{\sqrt{2}}$

D $\frac{2}{\sqrt{5}}$

E $\frac{\sqrt{5}}{2}$

F $\sqrt{2}$

G $\sqrt{3}$

H $\frac{\sqrt{15}}{2}$

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