UNIVERSITY OF CAMBRIDGE

ENGINEERING ADMISSIONS ASSESSMENT

CONTENT SPECIFICATION

2018

Overview

The Engineering Admissions Assessment consists of two sections:

Section 1: A multiple-choice question format consisting of 54 questions across two parts. The time allowed for Section 1 is 80 minutes. Calculators may NOT be used in Section 1.

Section 2: A multiple-choice question format consisting of approximately 20 questions. The time allowed for Section 2 is 40 minutes. Calculators may be NOT used in Section 2.

The purpose of the Engineering Admissions Assessment is to determine a candidate's potential to achieve in an academically demanding undergraduate degree course. Questions draw upon a candidate's ability to use and apply their scientific and mathematical knowledge. The assessment is designed to be challenging in order to differentiate effectively between able applicants, including those who may have achieved the highest possible grades in school examinations.

Format

Section 1 will be an 80-minute assessment, consisting of 54 multiple-choice questions. The two parts are as follows:

Part A Mathematics and Physics (28 questions)

Part B Advanced Mathematics and Advanced Physics (26 questions).

We recommend candidates spend 40 minutes on Part A and 40 minutes on Part B. Calculators may NOT be used in Section 1.

Section 2 will be a 40-minute assessment. It will consist of approximately 20 multiple-choice questions. Calculators may NOT be used in Section 2.

Example questions for Section 1 and Section 2 are given in Appendix 3.

Content

The questions in Section 1 will draw upon the topics listed in Appendix 1.

The questions in Section 2 assume knowledge of the content listed in Appendix 2, as well as knowledge of the content listed in Appendix 1. Some questions will involve the straightforward application of this knowledge, but others will require more creative thinking, problem solving and the application of principles in less familiar contexts.

Scoring

In Section 1, each correct answer will score 1 mark. No marks are deducted for incorrect answers. Results for Part A and Part B will be reported separately.

In Section 2, each correct answer will score 1 mark. No marks are deducted for incorrect answers. Space will be provided on the question paper for the candidate's working. No additional paper is permitted.

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Appendix 1: Knowledge assumed in Section 1

The following material outlines the scientific and mathematical knowledge that the Engineering Admissions Assessment Section 1 questions can draw upon. Throughout this specification it should be assumed that, where mention is made of a particular quantity, knowledge of the SI unit of that quantity is also expected (including the relationship of the unit to other SI units through the equations linking their quantities). Candidates will be expected to be familiar with the SI prefixes (for the range 10^{-9} (nano) to 10^{9} (giga)) when used in connection with any SI unit.

Part A Mathematics and Physics

A1. Number

A1.1 Order, add, subtract, multiply and divide whole numbers, integers, fractions, decimals and numbers in index form.

A1.2 Use the concepts and vocabulary of factor, multiple, common factor, highest common factor (hcf), least common multiple (lcm), composite (i.e. not prime), prime number, and prime factor decomposition.

A1.3 Use the terms ‘square’, ‘positive square root’ and ‘negative square root’, ‘cube’ and ‘cube root’.

A1.4 Use index laws to simplify, multiply, and divide integer, fractional, and negative powers.

A1.5 Interpret, order and calculate with numbers written in standard index form.

A1.6 Understand equivalent fractions.

A1.7 Convert between fractions, decimals and percentages.

A1.8 Understand and use percentage, including repeated proportional change and calculating the original amount after a percentage change.

A1.9 Understand and use direct and indirect proportion.

A1.10 Use ratio notation including dividing a quantity in a given ratio, and solve related problems (using the unitary method).

A1.11 Understand and use number operations, including inverse operations and the hierarchy of operations.

A1.12 Use surds and π in exact calculations, simplify expressions that contain surds, including rationalising the denominator.

A1.13 Calculate upper and lower bounds in contextual problems.

A1.14 Approximate to a specified and appropriate degree of accuracy, including rounding to a given number of decimal places or significant figures.

A1.15 Know and use approximation methods to produce estimations of calculations.

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A2. Algebra

A2.1 Distinguish between the different roles played by letter symbols.

A2.2 Manipulate algebraic expressions by collecting like terms; by multiplying a single term over a bracket; by expanding the product of two linear expressions.

A2.3 Use index laws in algebra for multiplication and division of integer, fractional, and negative powers.

A2.4 Set up and solve linear equations, including simultaneous equations in two unknowns.

A2.5 Factorise quadratics, including the difference of two squares. Simplify rational expressions by cancelling or factorising.

A2.6 Set up quadratic equations and solve them by factorising.

A2.7 Set up and use equations to solve problems involving direct and indirect proportion.

A2.8 Derive a formula, substitute into a formula.

A2.9 Change the subject of a formula.

A2.10 Solve linear inequalities in one or two variables.

A2.11 Generate terms of a sequence using 'term-to-term' and 'position-to-term' definitions.

A2.12 Use linear expressions to describe the n^{th} term of a sequence.

A2.13 Use Cartesian coordinates in all 4 quadrants.

A2.14 Recognise the equations of straight lines; understand $y = mx + c$ and the gradients of parallel lines.

A2.15 Understand that the intersection of graphs can be interpreted as giving the solutions to simultaneous equations.

A2.16 Solve simultaneous equations, where one is linear and one is quadratic.

A2.17 Recognise and interpret graphs of quadratic functions, simple cubic functions, the reciprocal function, trigonometric functions, and the exponential function $y = k^x$ for simple positive values of k.

A2.18 Construct linear functions from real-life problems; interpret graphs modelling real situations.

A3. Geometry

A3.1 Recall and use properties of angles at a point, on a straight line, perpendicular lines and opposite angles at a vertex.

A3.2 Understand and use the angle properties of parallel lines, intersecting lines, triangles and quadrilaterals.

A3.3 Calculate and use the sums of the interior and exterior angles of polygons.

A3.4 Recall the properties and definitions of special types of quadrilateral.

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A3.5 Recognise and use reflectional and rotational symmetry of 2-dimensional shapes.

A3.6 Understand congruence and similarity.

A3.7 Use Pythagoras' theorem in 2-dimensions and 3-dimensions.

A3.8 Understand and construct geometrical proofs, including using circle theorems:

- **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 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.

A3.9 Use 2-dimensional representations of 3-dimensional shapes.

A3.10 Describe and transform 2-dimensional shapes using single or combined rotations, reflections, translations, or enlargements, including the use of vector notation.

A4. Measures

A4.1 Calculate perimeters and areas of shapes made from triangles, rectangles and other shapes.

A4.2 Find circumferences and areas of circles, including arcs, segments and sectors.

A4.3 Calculate the volumes and surface areas of right prisms, pyramids, spheres, cylinders, cones, and solids made from cubes and cuboids (formulae will be given for the sphere and cone).

A4.4 Use vectors, including the sum of two vectors, algebraically and graphically.

A4.5 Use and interpret maps and scale drawings.

A4.6 Understand and use the effect of enlargement for perimeter, area, and volume of shapes and solids.

A4.7 Convert measurements from one unit to another, including between imperial and metric (conversion factors will be given for imperial/metric conversions).

A4.8 Know the SI prefixes for the range 10^{-9} (nano) to 10^{9} (giga) when used in connection with any SI unit.

A4.9 Recognise the inaccuracy of measurement.

A4.10 Understand and use three-figure bearings.

A4.11 Understand and use compound measures.

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A5. Statistics

A5.1 Identify possible sources of bias.

A5.2 Identify flaws in data collection sheets and questionnaires in a survey or an experiment.

A5.3 Group, and understand, discrete and continuous data.

A5.4 Extract data from lists and tables.

A5.5 Design and use two-way tables.

A5.6 Interpret bar charts, pie charts, grouped frequency diagrams, line graphs, and frequency polygons.

A5.7 Interpret cumulative frequency tables, graphs, and histograms (including unequal class width).

A5.8 Calculate and interpret mean, median, mode, modal class, range, and inter-quartile range, including the estimated mean of grouped data.

A5.9 Calculate average rates when combining samples or events, including solving problems involving average rate calculations (e.g. average survival rates in different wards of different sizes; average speed of a car over a journey where it has travelled at different speeds).

A5.10 Interpret scatter diagrams and recognise correlation; using lines of best fit.

A5.11 Compare sets of data by using statistical measures or by interpreting graphical representations of their distributions.

A6. Probability

A6.1 Understand and use the vocabulary of probability and the probability scale.

A6.2 Understand and use estimates or measures of probability, including relative frequency and theoretical models.

A6.3 List all the outcomes for single and combined events.

A6.4 Identify different mutually exclusive outcomes and know that the sum of the probabilities of all these outcomes is 1.

A6.5 Construct and use Venn diagrams to solve union and intersection categorisation problems and determine probabilities when required. Familiarity with the meaning and use of the terms ‘union’, ‘intersection’, and ‘complement’ is required.

A6.6 Know when to add or multiply two probabilities.

A6.7 Understand the use of tree diagrams to represent outcomes of combined events:

- **a.** when the probabilities are independent of the previous outcome
- **b.** when the probabilities are dependent on the previous outcome.

A6.8 Compare experimental and theoretical probabilities.

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A6.9 Understand that if an experiment is repeated, the outcome may be different.

A7. Electricity

A7.1 Electric current:

- **a.** conductors and insulators
- **b.** current = charge / time
- **c.** use of voltmeter and ammeter
- **d.** resistance = voltage / current
- **e.** V-I graphs for a fixed resistor and a filament lamp
- **f.** series and parallel circuits – current and voltage rules
- **g.** resistor combinations in series (but not parallel)
- **h.** voltage = energy / charge.

A7.2 Basic circuit symbols and diagrams.

A7.3 Power and energy:

- **a.** power = current × voltage
- **b.** energy transfer = power × time = VIt.

A8. Motion and energy

A8.1 Kinematics:

- **a.** speed = distance / time
- **b.** difference between speed and velocity
- **c.** acceleration = change in velocity / time
- **d.** distance-time and velocity-time graphs
- **e.** calculations using gradients and areas under graphs
- **f.** average speed.

A8.2 Forces and motion:

- **a.** inertia and Newton's first law
- **b.** momentum = mass × velocity
- **c.** conservation of momentum
- **d.** Newton's second law: force = mass × acceleration
- **e.** force = rate of change of momentum
- **f.** resultant force
- **g.** difference between mass and weight, and the relationship between them ($W = mg$)
- **h.** gravitational field strength (approximated as 10 N / kg on Earth)
- **i.** free-fall acceleration
- **j.** terminal velocity and forces involved

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k. Newton's third law.

A8.3 Energy:

a. work = force × distance moved in direction of force

b. appreciation of work done as a transfer of energy

c. potential energy = mgh

d. kinetic energy = $\frac{1}{2}mv^2$

e. applications to crumple zones and road safety – stopping distances

f. power = energy transfer / time.

A8.4 Energy conversion:

a. law of conservation of energy

b. forms of energy

c. ideas of useful energy and wasted energy

d. percentage efficiency = (useful output / total input) × 100.

A9. Thermal physics

A9.1 Conduction:

a. thermal conductors and insulators

b. factors affecting rate of conduction.

A9.2 Convection:

a. fluid flow caused by differences in density

b. factors affecting rate of convection.

A9.3 Radiation:

a. infrared radiation (see **A10.** Waves)

b. absorption and emission of radiation

c. factors affecting rate of absorption or emission.

A9.4 Matter:

a. density = mass / volume

b. experimental determination of densities

c. comparison of densities of the three states.

A10. Waves

A10.1 Wave nature:

a. transfer of energy without net movement of matter

b. examples (including electromagnetic waves, sound, seismic)

c. amplitude, wavelength, frequency and period

d. frequency = 1 / period, and the SI unit of frequency is hertz (Hz), 1 Hz means 1 wave per second

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e. speed = distance / time

f. wave speed = frequency × wavelength.

A10.2 Sound waves:

a. ultrasound and uses (sonar, scanning, animals).

A11. Electromagnetic spectrum

A11.1 EM waves:

a. nature and properties of electromagnetic waves (transverse, travel at speed of light in vacuum).

A11.2 The spectrum:

a. parts of the spectrum (radio waves, microwaves, IR, visible light, UV, X-rays, gamma)

b. distinction by different wavelengths, frequencies

c. order of component parts by wavelength, frequency

d. applications

e. dangers.

A12. Radioactivity

A12.1 Atomic structure:

a. protons, neutrons and electrons

b. popular models of atomic structure

c. relative charges and masses of sub-atomic particles

d. atomic number, atomic mass

e. isotopes

f. ionisation caused by gain or loss of electrons.

A12.2 Radioactive decay:

a. emissions from the nucleus

b. random and spontaneous nature

c. alpha, beta and gamma emission

d. nature of alpha and beta particles, gamma radiation

e. radioactive decay equations

f. effect of decay on atomic number and mass

g. activity of a radioactive sample.

A12.3 Ionising radiation:

a. penetrating abilities of alpha, beta and gamma

b. ionising abilities of alpha, beta and gamma

c. background radiation – existence and origins

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d. applications, dangers and hazards of ionising radiation.

A12.4 Half-life:

a. decrease in activity over time

b. graphical representation of decay (including of decay products)

c. meaning of half-life.

A12.5 Nuclear fission:

a. caused by absorption of neutrons

b. fission of uranium-235, including equation

c. chain reaction.

A12.6 Nuclear fusion:

a. fusion of hydrogen to form helium

b. need for high temperatures

c. significance as energy source.

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Part B Advanced Mathematics and Advanced Physics

B1. Algebra and functions

B1.1 Laws of indices for all rational exponents.

B1.2 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 $\frac{3}{\sqrt{7}-2\sqrt{3}}$.

B1.3 Quadratic functions and their graphs; the discriminant of a quadratic function; completing the square; solution of quadratic equations.

B1.4 Simultaneous equations: analytical solution by substitution, e.g. of one linear and one quadratic equation.

B1.5 Solution of linear and quadratic inequalities.

B1.6 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 $ax + b$)
- **c.** use of the Factor Theorem and the Remainder Theorem.

B2. Sequences and series

B2.1 Sequences, including those given by a formula for the nth term and those generated by a simple recurrence relation of the form $x_{n+1} = f(x_n)$.

B2.2 Arithmetic series, including the formula for the sum of the first n natural numbers.

B2.3 The sum of a finite geometric series; the sum to infinity of a convergent geometric series, including the use of $|r| < 1$.

B2.4 Binomial expansion of $(1 + x)^n$ for positive integer n; the notations $n!$ and $\binom{n}{r}$.

B3. Coordinate geometry in the (x,y) plane

B3.1 Equation of a straight line, including $y - y_1 = m(x - x_1)$ and $ax + by + c = 0$; conditions for two straight lines to be parallel or perpendicular to each other; finding equations of straight lines given information in various forms.

B3.2 Coordinate geometry of the circle: using the equation of a circle in the forms $(x - a)^2 + (y - b)^2 = r^2$, and $x^2 + y^2 + cx + dy + e = 0$.

B3.3 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

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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.

B4. Trigonometry

B4.1 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.

B4.2 Radian measure, including use for arc length and area of sector and segment.

B4.3 The values of sine, cosine and tangent for the angles $0°,\ 30°,\ 45°,\ 60°,\ 90°$.

B4.4 The sine, cosine, and tangent functions; their graphs, symmetries, and periodicity.

B4.5 Know and use of $\tan\theta = \frac{\sin\theta}{\cos\theta}$ and $\sin^2\theta + \cos^2\theta = 1$.

B4.6 Solution of simple trigonometric equations in a given interval (this may involve the use of the identities in **B4.5**); for example: $\sin x = -\frac{1}{\sqrt{3}}$ for $-\pi < x < \pi$;

$\sin^2\left(x + \frac{\pi}{3}\right) = \frac{1}{2}$ for $-2\pi < x < 2\pi$; $12\cos^2 x + 6\sin x - 10 = 2$ for $0° < x < 360°$.

B5. Exponentials and logarithms

B5.1 $y = a^x$ and its graph, for simple positive values of a.

B5.2 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. $\log_a\frac{1}{x} = -\log_a x$

f. $\log_a a = 1$

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

B5.3 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 $25^x - 3\times 5^x + 2 = 0$.

B6. Differentiation

B6.1 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

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

Differentiation from first principles is excluded.

B6.2 Differentiation of x^n for rational n, and related sums and differences. This might include some simplification before differentiating; for example, the ability to differentiate an expression such as $\frac{(3x+2)^2}{x^{\frac{1}{2}}}$ could be required.

B6.3 Applications of differentiation to gradients, tangents, normals, stationary points (maxima and minima only), increasing and decreasing functions. Points of inflexion will not be examined.

B7. Integration

B7.1 Definite integration as finding the 'area under a curve.'

B7.2 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, $\int (x+2)^2 dx$, and $\int \frac{(3x-5)^2}{x^{\frac{1}{2}}} dx$.

B7.3 An understanding of the Fundamental Theorem of Calculus and its significance to integration. Simple examples of its use may be required in the two forms:

$\int_a^b f(x)dx = F(b) - F(a)$, where $F'(x) = f(x)$, and $\frac{d}{dx}\int_a^x f(t)dt = f(x)$.

B7.4 Combining integrals with either equal or contiguous ranges;

for example, $\int_2^5 f(x)dx + \int_2^5 g(x)dx = \int_2^5 [f(x) + g(x)]\,dx$,

and $\int_2^4 f(x)dx + \int_4^3 f(x)dx = \int_2^3 f(x)dx$.

B7.5 Approximation of area under a curve using the trapezium rule; determination of whether this constitutes an overestimation or an underestimation.

B7.6 Solving differential equations of the form $\frac{dy}{dx} = f(x)$.

B8. Graphs of functions

B8.1 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, and exponential functions.

B8.2 Know the effect of simple transformations on the graph of $y = f(x)$ as represented by $y = af(x)$, $y = f(x) + a$, $y = f(x + a)$, $y = f(ax)$, with the value of a positive or negative. Compositions of these transformations.

B8.3 Understand how altering the values of m and c affects the graph of $y = mx + c$.

B8.4 Understand how altering the values of a, b and c in $y = a(x + b)^2 + c$ affects the corresponding graph.

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B8.5 Use differentiation to help determine the shape of the graph of a given function; this might include finding stationary points (excluding inflexions) as well as finding when graphs are increasing or decreasing.

B8.6 Use algebraic techniques to determine where the graph of a function intersects the coordinate axes; appreciate the possible number of real roots a general polynomial can possess.

B8.7 Geometrical interpretation of algebraic solutions of equations; relationship between the intersections of two graphs and the solutions of the corresponding simultaneous equations.

B9. Forces and equilibrium

B9.1 Understand the vector nature of force.

B9.2 Find and use components and resultants.

B9.3 Calculate the moment of a force about some point (2-dimensional situation only).

B9.4 Understand the use of normal and frictional components of contact forces between two surfaces.

B9.5 Understand and use the condition for a particle to be in equilibrium in simple situations – these might include a block resting on an inclined plane. Equilibrium here will be treated as objects being stationary.

B9.6 Understand the terms ‘smooth’ and ‘rough’ and use the notion of limiting equilibrium.

B9.7 Use the coefficient of friction in questions, including the relationships $F = \mu R$ and $F \leq \mu R$.

B9.8 Understand the weight of a body acts through its centre of gravity; identify the position of the centre of gravity of simple planar bodies using symmetry.

B9.9 Solve problems involving equilibrium of rigid bodies under coplanar forces.

B10. Kinematics

B10.1 Understand graphical methods involving distance, displacement, speed, velocity, and acceleration.

B10.2 Use graphical representation of 1-dimensional motion to make various deductions (for example, find the displacement from a velocity-time graph).

B10.3 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. $v^2 = u^2 + 2as$

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B11. Newton's laws

B11.1 Apply Newton's laws to linear motion of point masses moving under the action of constant forces, including friction.

B11.2 Model a body moving vertically, or on an inclined plane moving with constant acceleration (questions involving two perpendicular motions – e.g. parabolic flight – will not be examined).

B11.3 Solve simple problems involving two bodies connected by a light inextensible string or rod (e.g. two bodies connected by a string over a light smooth pulley, or a car towing a caravan).

B12. Momentum

B12.1 Understand and use the definition of linear momentum.

B12.2 Understand and use the principle of conservation of momentum in 1-dimensional situations, including coalescence.

B13. Energy

B13.1 Understand and use the concepts of gravitational potential energy and kinetic energy.

B13.2 Understand and apply the principle of conservation of energy to simple situations.

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Appendix 2:

Additional knowledge assumed in Section 2

The questions in Section 2 assume knowledge of the content listed in this appendix, as well as knowledge of the content listed in Appendix 1.

1. Vectors and scalars

1.1 the distinction between vector and scalar quantities

1.2 resolution of vectors into two components at right angles

1.3 addition rule for two vectors

1.4 calculations for two perpendicular vectors

2. Mechanics

2.1 kinematics:

- **a.** use of kinematic equations in 1-dimension with constant velocity or acceleration
- **b.** graphical representation of accelerated motion
- **c.** interpretation of velocity-time and displacement-time graphs

2.2 dynamics:

- **a.** use of $F = ma$ when mass is constant
- **b.** 1- and 2-dimensional motion under constant force
- **c.** independent effect of perpendicular components with uniform acceleration, projectile motion

2.3 energy:

- **a.** calculation of work done for constant forces, including force not along the line of motion
- **b.** calculation of exchanges between gravitational potential energy and kinetic energy
- **c.** principle of conservation of energy

2.4 momentum:

- **a.** definition
- **b.** principle of conservation of momentum
- **c.** calculations for one-dimensional problems

3. Mechanical properties of matter

3.1 stress, strain, Young's modulus

3.2 force-extension graphs, energy stored

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4. Electric circuits

4.1 current:

- **a.** electric current as rate of flow of charge, $I = \Delta q/\Delta t$

4.2 emf and potential difference:

- **a.** definition of emf and concept of internal resistance
- **b.** potential difference in terms of energy transfer

4.3 resistance:

- **a.** definition
- **b.** resistivity
- **c.** Ohm's law

4.4 DC circuits:

- **a.** conservation of charge and energy in circuits
- **b.** relationships between currents, voltages and resistances in series and parallel circuits
- **c.** power dissipated
- **d.** potential divider circuits

5. Waves

5.1 qualitative treatment of polarisation and diffraction

5.2 path difference, phase and coherence, interference

5.3 graphical treatment of superposition and stationary waves

6. Quantum and nuclear physics

6.1 photons and particles

6.2 photon model to explain observable phenomena

6.3 evidence supporting the photon model

6.4 wave-particle duality, particle diffraction

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Appendix 3: Example questions

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

Section 1

Part A: Mathematics and Physics

1 A ball is thrown vertically upwards and leaves the thrower's hand with a speed of 12 m/s. 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. Take the value of the gravitational field strength *g* to be 10 N/kg.

To what height does the ball rise?

A 7.2 m

B 14.4 m

C 24 m

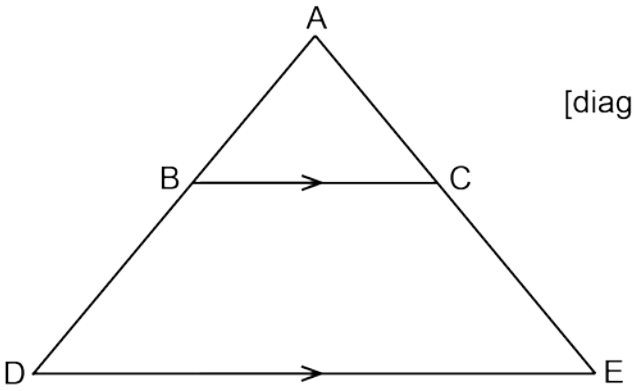
D 60 m

E 120 m

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

BC is parallel to DE.

AB = 4 cm BC = x cm DE = $x + 3$ cm DB = $x - 4$ cm



[diagram not to scale]

Calculate the length of DE.

A 5 cm

B 7 cm

C 9 cm

D $4 + 2\sqrt{7}$ cm

E $7 + 2\sqrt{7}$ cm

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Part B: Advanced Mathematics and Advanced Physics

1 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

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

A $\frac{1}{12}$

B $\frac{1}{3}$

C $\frac{1}{2}$

D $\frac{7}{12}$

E 2

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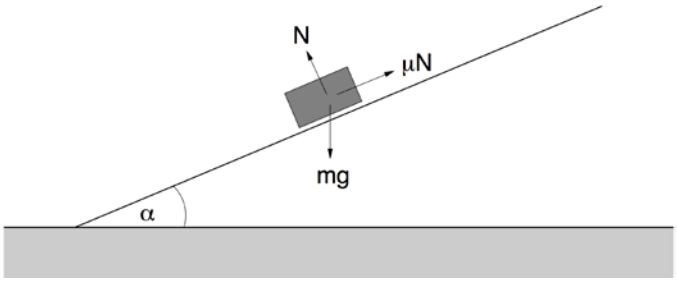
Section 2

1 Consider a block of mass m moving with velocity v down a slope of angle α to the horizontal. The coefficient of friction between the block and the slope is μ. You may assume that α is sufficiently large to ensure that the block accelerates down the slope and does not topple. Take the gravitational field strength to be g.

The diagram represents the forces acting on the block.



Assuming $v = 0$ at time $t = 0$, what is the equation for the velocity v of the block as a function of time?

A $v = g(\sin\alpha + \mu\cos\alpha)t$

B $v = g(\cos\alpha + \mu\sin\alpha)$

C $v = g(\cos\alpha - \mu\sin\alpha)t$

D $v = g(\sin\alpha - \mu\cos\alpha)t$

E $v = g(\sin\alpha - \mu\cos\alpha - \cos\alpha)t$

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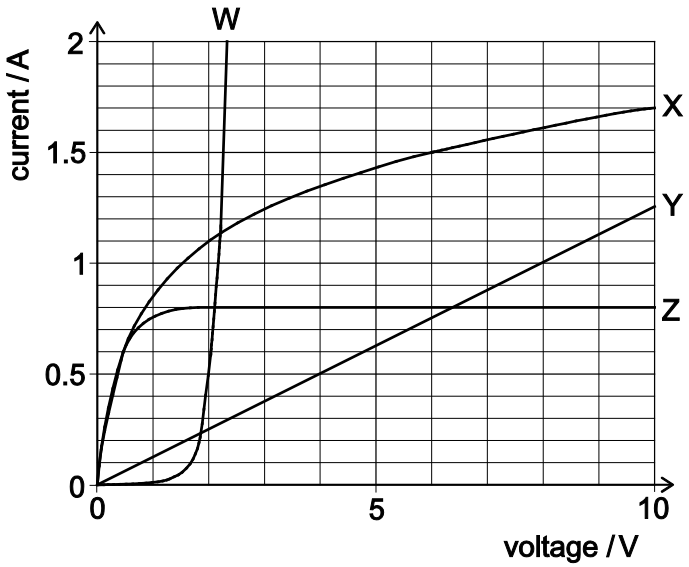
2 The graph shows the current against voltage characteristics of four different electronic devices W, X, Y and Z. One of the devices is an 8 Ω resistor and one is a filament lamp rated 9 W at 6 V. You may assume that the filament lamp does not 'blow' in the context of this question.



The filament lamp and the resistor are connected in parallel to a 6.0 V power supply with negligible internal resistance.

Approximately what current is drawn from the supply?

A 0.75 A

B 1.5 A

C 1.83 A

D 2.25 A

E 2.42 A

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