88106502

International Baccalaureate®
Baccalauréat International
Bachillerato Internacional

PHYSICS
HIGHER LEVEL
PAPER 2

Monday 8 November 2010 (afternoon)

2 hours 15 minutes

Candidate session number

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INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all of Section A in the spaces provided.
- Section B: answer two questions from Section B in the spaces provided.
- At the end of the examination, indicate the numbers of the questions answered in the candidate box on your cover sheet.

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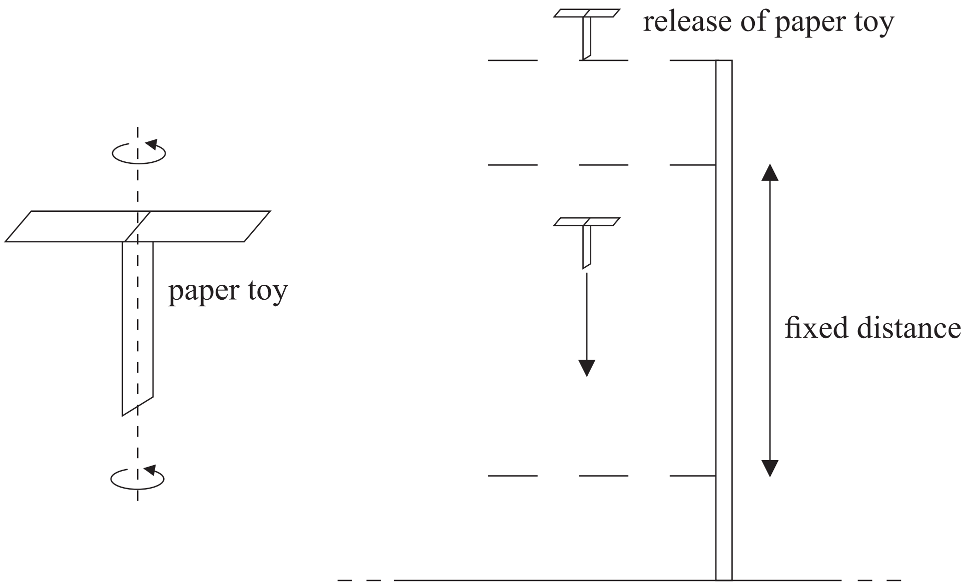
SECTION A

Answer ***all*** *the questions in the spaces provided.*

A1. Data analysis question.

A student performs an experiment with a paper toy that rotates as it falls slowly through the air. After release, the paper toy quickly attains a constant vertical speed as measured over a fixed vertical distance.

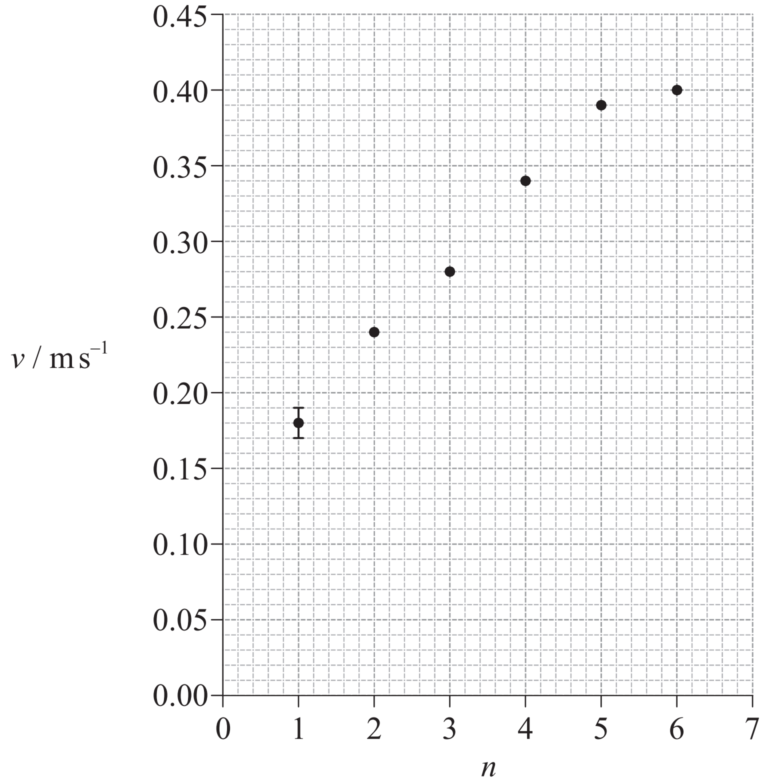


The aim of the experiment was to find how the terminal speed of the paper toy varies with its weight. The weight of the paper toy was changed by using different numbers of paper sheets in its construction.

(This question continues on the following page)

(Question A1 continued)

The graph shows a plot of the terminal speed v of the paper toy (calculated from the raw data) and the number of paper sheets n used to construct the toy. The uncertainty in v for $n=1$ is shown by the error bar.



(a) The fixed distance is 0.75 m and has an absolute uncertainty of 0.01 m. The percentage uncertainty in the time taken to fall through the fixed distance is 5 %.

(i) Calculate the absolute uncertainty in the terminal speed of the paper toy for $n=6$. *[3]*

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(ii) On the graph, draw an error bar on the point corresponding to $n=6$. *[1]*

(b) On the graph, draw a line of best-fit for the data points. *[1]*

(This question continues on the following page)

(Question A1 continued)

(c) The student hypothesizes that v is proportional to n. Use the data points for $n=2$ and $n=4$ from the graph opposite to show that this hypothesis is incorrect. *[3]*

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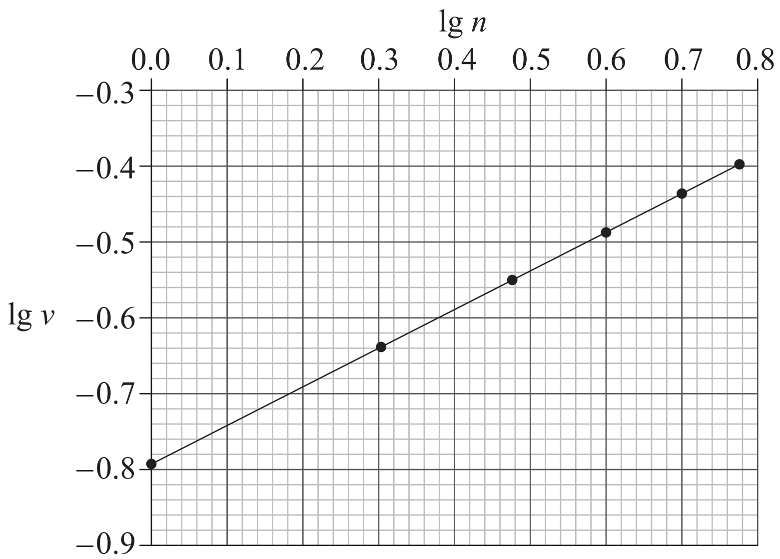
(d) Another student hypothesized that v might be proportional to $\sqrt{n}$. To verify this hypothesis he plotted a graph of lg v against lg n as shown below.



Show that the graph verifies the hypothesis that v is proportional to $\sqrt{n}$. *[4]*

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A2. This question is about fuel for heating.

(a) Define the *energy density* of a fuel. *[1]*

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(b) A room heater burns liquid fuel and the following data are available.

Density of liquid fuel	$= 8.0 \times 10^{2}\,\text{kg}\,\text{m}^{-3}$
Energy produced by $1\,\text{m}^3$ of liquid fuel	$= 2.7 \times 10^{10}\,\text{J}$
Rate at which fuel is consumed	$= 0.13\,\text{g}\,\text{s}^{-1}$
Temperature at which air enters heater	$= 12\,^{\circ}\text{C}$
Temperature at which air leaves heater	$= 32\,^{\circ}\text{C}$
Specific heat capacity of air	$= 990\,\text{J}\,\text{kg}^{-1}\,\text{K}^{-1}$

(i) Use the data to calculate the power output of the room heater, ignoring the power required to convert the liquid fuel into a gas. *[3]*

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(ii) All the energy output of the room heater raises the temperature of the air moving through it. Use the data to calculate the mass of air that moves through the room heater in **one** second. *[3]*

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A3. This question is about digital data storage.

(a) Describe, with reference to the structure of a DVD, how stored digital data are read. *[4]*

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(b) The Blu-ray storage system uses a laser diode that emits a wavelength of 405 nm, whereas the older DVD system uses radiation of wavelength 650 nm. Explain the advantages of using a smaller wavelength. *[4]*

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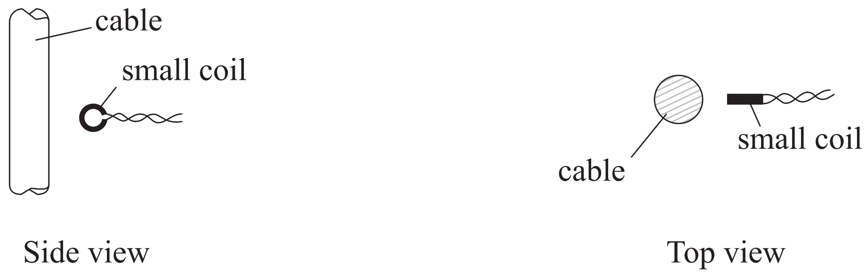
A4. This question is about electromagnetic induction.

(a) In order to measure the rms value of an alternating current in a cable, a small coil of wire is placed close to the cable.



The plane of the small coil is parallel to the direction of the cable. The ends of the small coil are connected to a high resistance ac voltmeter.

Use Faraday's law to explain why an emf is induced in the small coil. *[3]*

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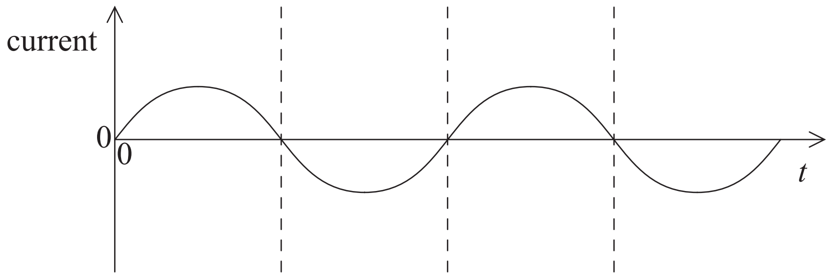
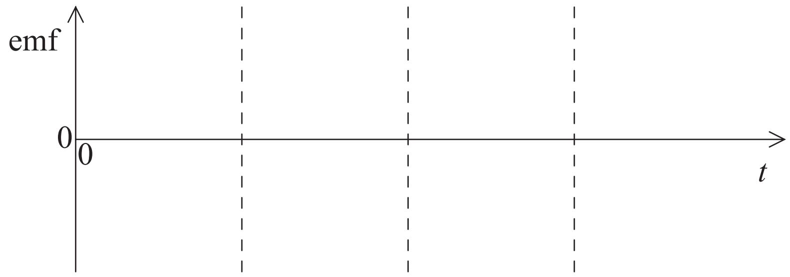
(Question A4 continued)

(b) The graph below shows the variation with time t of the current in the cable.



On the axes below, draw a sketch graph to show the variation with time of the emf induced in the small coil. *[2]*



(c) Explain how readings on the high resistance ac voltmeter can be used to compare the rms values of alternating currents in different cables. *[3]*

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A5. This question is about the Rutherford model of the atom.

(a) Most alpha particles used to bombard a thin gold foil pass through the foil without a significant change in direction. A few alpha particles are deviated from their original direction through angles greater than 90°. Use these observations to describe the Rutherford atomic model. *[5]*

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(Question A5 continued)

(b) The isotope gold-197 $\left({}^{197}_{79}\text{Au}\right)$ is stable but the isotope gold-199 $\left({}^{199}_{79}\text{Au}\right)$ is not.

(i) Outline, in terms of the forces acting between nucleons, why, for large stable nuclei such as gold-197, the number of neutrons exceeds the number of protons. *[3]*

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(ii) A nucleus of ${}^{199}_{79}\text{Au}$ decays to a nucleus of ${}^{199}_{80}\text{Hg}$. State the **two** particles, other than γ-photon, emitted in this decay. *[2]*

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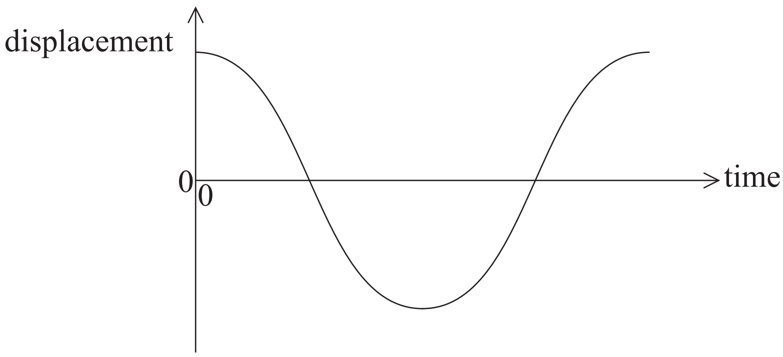
SECTION B

*This section consists of four questions: B1, B2, B3 and B4. Answer **two** questions.*

B1. This question is in **two** parts. **Part 1** is about the simple pendulum. **Part 2** is about the de Broglie hypothesis.

Part 1 Simple pendulum

(a) A pendulum consists of a bob suspended by a light inextensible string from a rigid support. The pendulum bob is moved to one side and then released. The sketch graph shows how the displacement of the pendulum bob undergoing simple harmonic motion varies with time over one time period.



On the sketch graph above,

(i) label with the letter A a point at which the acceleration of the pendulum bob is a maximum. *[1]*

(ii) label with the letter V a point at which the speed of the pendulum bob is a maximum. *[1]*

(b) Explain why the magnitude of the tension in the string at the midpoint of the oscillation is greater than the weight of the pendulum bob. *[3]*

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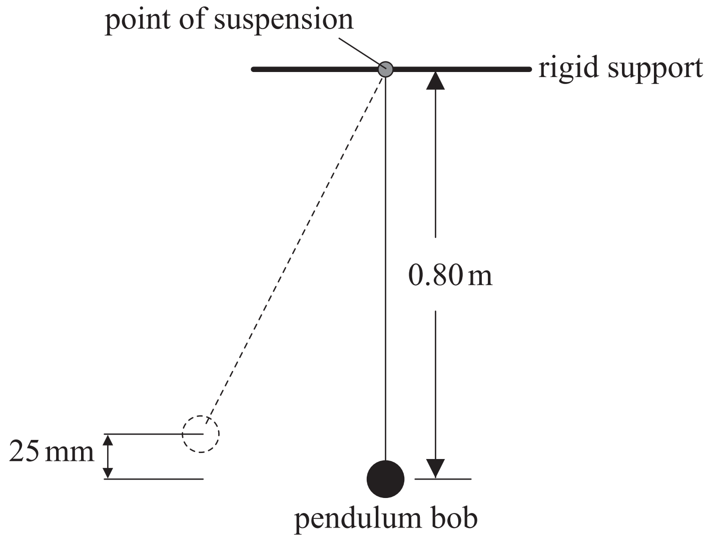
(Question B1, part 1 continued)

(c) The pendulum bob is moved to one side until its centre is 25 mm above its rest position and then released.



(i) Show that the speed of the pendulum bob at the midpoint of the oscillation is $0.70\,\text{m s}^{-1}$. *[2]*

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(ii) The mass of the pendulum bob is 0.057 kg. The centre of the pendulum bob is 0.80 m below the support. Calculate the magnitude of the tension in the string when the pendulum bob is vertically below the point of suspension. *[3]*

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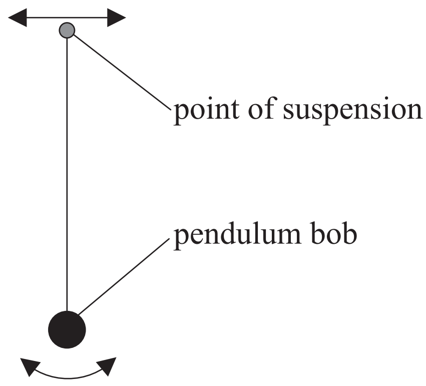
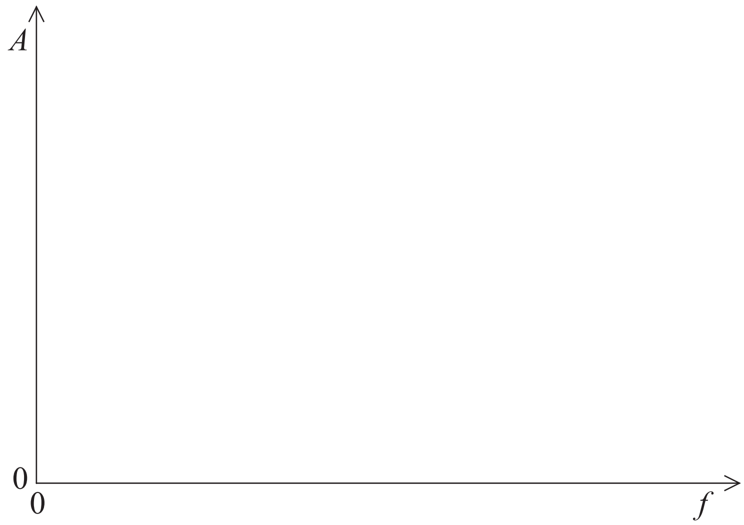
(Question B1, part 1 continued)

(d) The point of suspension of the pendulum bob is moved from side to side with a small amplitude and at a variable driving frequency *f*.



For each value of the driving frequency a steady constant amplitude *A* is reached. The oscillations of the pendulum bob are lightly damped.

(i) On the axes below, sketch a graph to show the variation of *A* with *f*. *[2]*



(ii) Explain, with reference to the graph in (d)(i), what is meant by resonance. *[2]*

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(Question B1, part 1 continued)

(e) The pendulum bob is now immersed in water and the variable frequency driving force in (d) is again applied. Suggest the effect this immersion of the pendulum bob will have on the shape of your graph in (d)(i). *[2]*

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(Question B1 continued)

Part 2 de Broglie hypothesis

(a) Describe the de Broglie hypothesis. *[2]*

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(b) A beam of electrons is accelerated from rest through a potential difference of 85 V.

Show that the de Broglie wavelength associated with the electrons in the beam is 0.13 nm. *[3]*

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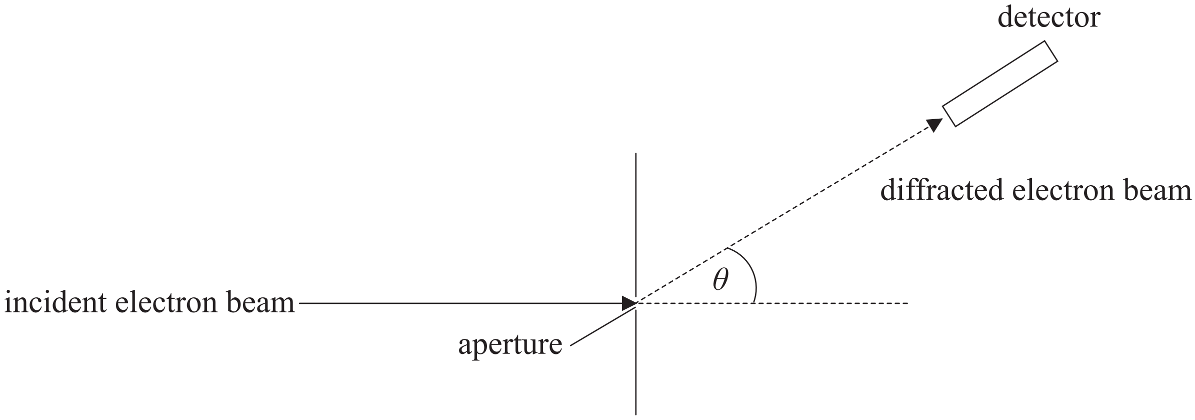
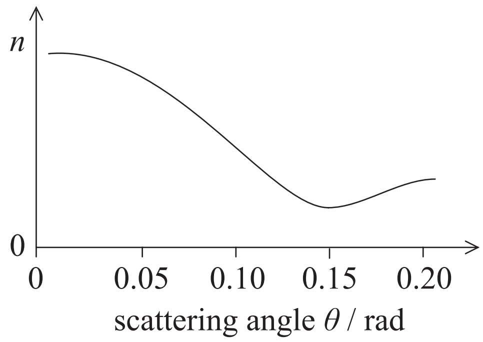
(Question B1, part 2 continued)

(c) Electrons with the same kinetic energy as those in (b) are incident on a circular aperture of diameter 1.1 nm.



The electrons are detected beyond the aperture.

The graph shows the variation with angle θ of the number n of electrons detected per second after diffraction by the aperture.



Use your answer to (b) opposite to explain how data from the graph support the de Broglie hypothesis. *[4]*

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B2. This question is in **two** parts. **Part 1** is about a lightning discharge. **Part 2** is about microwave radiation.

Part 1 Lightning discharge

(a) Define *electric field strength*. *[2]*

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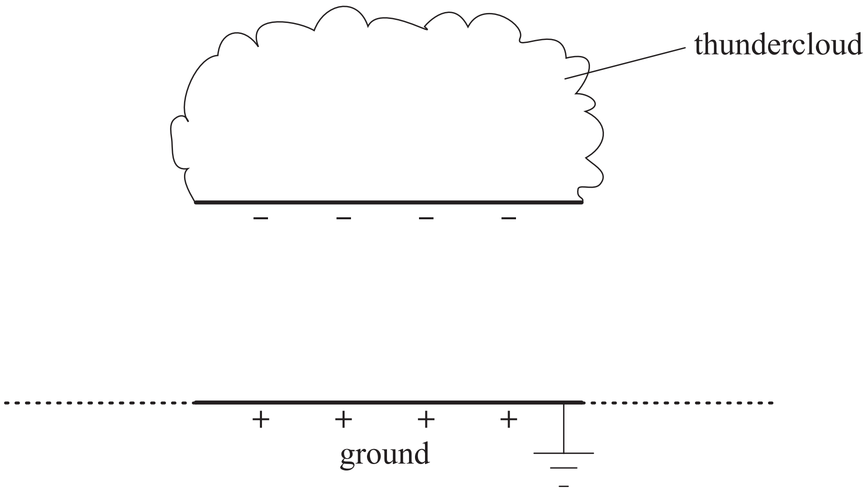
(b) A thundercloud can be modelled as a negatively charged plate that is parallel to the ground.



The magnitude of the charge on the plate increases due to processes in the atmosphere. Eventually a current discharges from the thundercloud to the ground.

On the diagram, draw the electric field pattern between the thundercloud base and the ground. *[3]*

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(Question B2, part 1 continued)

(c) The current discharges when the magnitude of the electric field between the ground and the thundercloud base is $0.33\,\text{MN}\,\text{C}^{-1}$. The thundercloud base is 750 m above the ground.

(i) Calculate, just before discharge, the potential difference between the thundercloud base and the ground. *[3]*

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(ii) The potential difference V, between the thundercloud base and the ground, is given by

$$V = \frac{Qd}{A\varepsilon_0}$$

where Q is the charge on the thundercloud base, A is the area of the base, and d is the distance between the base and the ground. The area of the base is $1.2\times10^{7}\,\text{m}^{2}$.

Calculate, just before discharge, the charge on the base of the thundercloud. *[2]*

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(iii) Determine the energy released in the discharge. *[4]*

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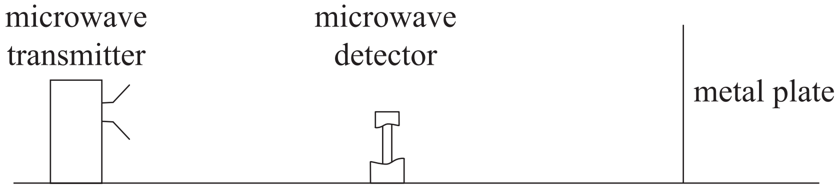
(Question B2 continued)

Part 2 Microwave radiation

A microwave transmitter emits radiation of a single wavelength towards a metal plate along a line normal to the plate. The radiation is reflected back towards the transmitter.



A microwave detector is moved along a line normal to the microwave transmitter and the metal plate. The detector records a sequence of equally spaced maxima and minima of intensity.

(a) Explain how these maxima and minima are formed. *[4]*

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(b) The microwave detector is moved through 130 mm from one point of minimum intensity to another point of minimum intensity. On the way it passes through nine points of maximum intensity. Calculate the

(i) wavelength of the microwaves. *[2]*

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(ii) frequency of the microwaves. *[2]*

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(Question B2, part 2 continued)

(c) Describe and explain how it could be demonstrated that the microwaves are polarized. *[3]*

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B3. This question is about nuclear fission.

(a) A possible fission reaction is

$$^{235}_{92}\text{U} + ^{1}_{0}\text{n} \rightarrow ^{92}_{36}\text{Kr} + ^{141}_{56}\text{Ba} + x\,^{1}_{0}\text{n}.$$

(i) State the value of x. *[1]*

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(ii) Show that the energy released when one uranium nucleus undergoes fission in the reaction in (a) is about 2.8×10^{-11} J. *[4]*

Mass of neutron	= 1.00867 u
Mass of U-235 nucleus	= 234.99333 u
Mass of Kr-92 nucleus	= 91.90645 u
Mass of Ba-141 nucleus	= 140.88354 u

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(iii) State how the energy of the neutrons produced in the reaction in (a) is likely to compare with the energy of the neutron that initiated the reaction. *[1]*

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(b) Outline the role of the moderator. *[2]*

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(This question continues on the following page)

(Question B3 continued)

(c) (i) A nuclear power plant that uses U-235 as fuel has a useful power output of 16 MW and an efficiency of 40 %. Assuming that each fission of U-235 gives rise to 2.8×10^{-11} J of energy, determine the mass of U-235 fuel used per day. *[4]*

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(ii) Describe how some reactors are used to produce plutonium-239. *[2]*

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(iii) State the importance of plutonium-239. *[1]*

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(Question B3 continued)

(d) Some nuclear reactors have a heat exchanger that uses a gas that is kept at constant volume. The first law of thermodynamics can be represented as $Q = \Delta U + W$.

(i) State the meanings of Q and W. *[2]*

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W: . . . .

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(ii) Describe how the first law of thermodynamics applies in the operation of the heat exchanger. *[4]*

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(iii) Discuss the entropy changes that take place in the gas and in the surroundings. *[4]*

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B4. This question is in **two** parts. **Part 1** is about collisions. **Part 2** is about the gravitational field of Mars.

Part 1 Collisions

(a) State the principle of conservation of momentum. *[2]*

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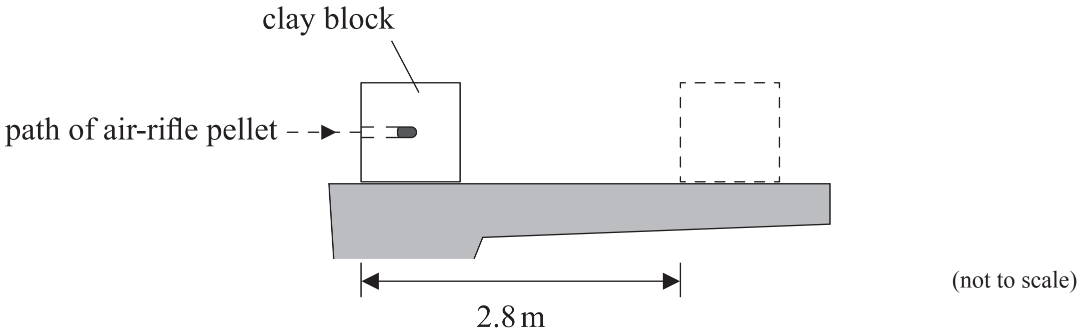
(Question B4, part 1 continued)

(b) In an experiment, an air-rifle pellet is fired into a block of modelling clay that rests on a table.



The air-rifle pellet remains inside the clay block after the impact.

As a result of the collision, the clay block slides along the table in a straight line and comes to rest. Further data relating to the experiment are given below.

Mass of air-rifle pellet	= 2.0 g
Mass of clay block	= 56 g
Velocity of impact of air-rifle pellet	= 140 m s^{-1}
Stopping distance of clay block	= 2.8 m

(i) Show that the initial speed of the clay block after the air-rifle pellet strikes it is 4.8 m s^{-1}. *[2]*

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(ii) Calculate the average frictional force that the surface of the table exerts on the clay block whilst the clay block is moving. *[4]*

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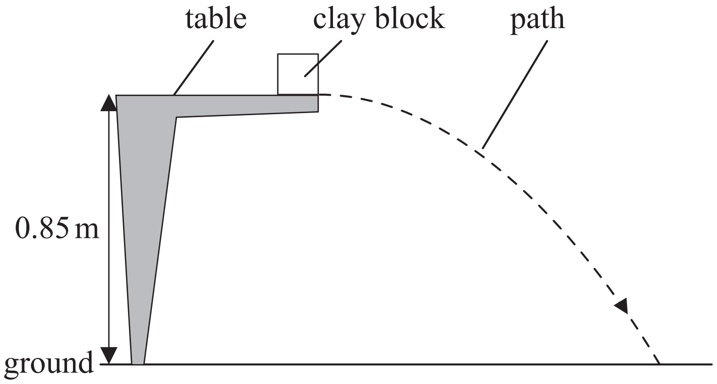
(Question B4, part 1 continued)

(c) The experiment is repeated with the clay block placed at the edge of the table so that it is fired away from the table. The initial speed of the clay block is 4.3 m s^{-1} horizontally. The table surface is 0.85 m above the ground.



(i) Ignoring air resistance, calculate the horizontal distance travelled by the clay block before it strikes the ground. *[4]*

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(ii) The diagram in (c) shows the path of the clay block neglecting air resistance. On the diagram, draw the approximate shape of the path that the clay block will take assuming that air resistance acts on the clay block. *[3]*

(This question continues on the following page)

(Question B4 continued)

Part 2 Gravitational field of Mars

(a) Define *gravitational potential energy* of a mass at a point. *[1]*

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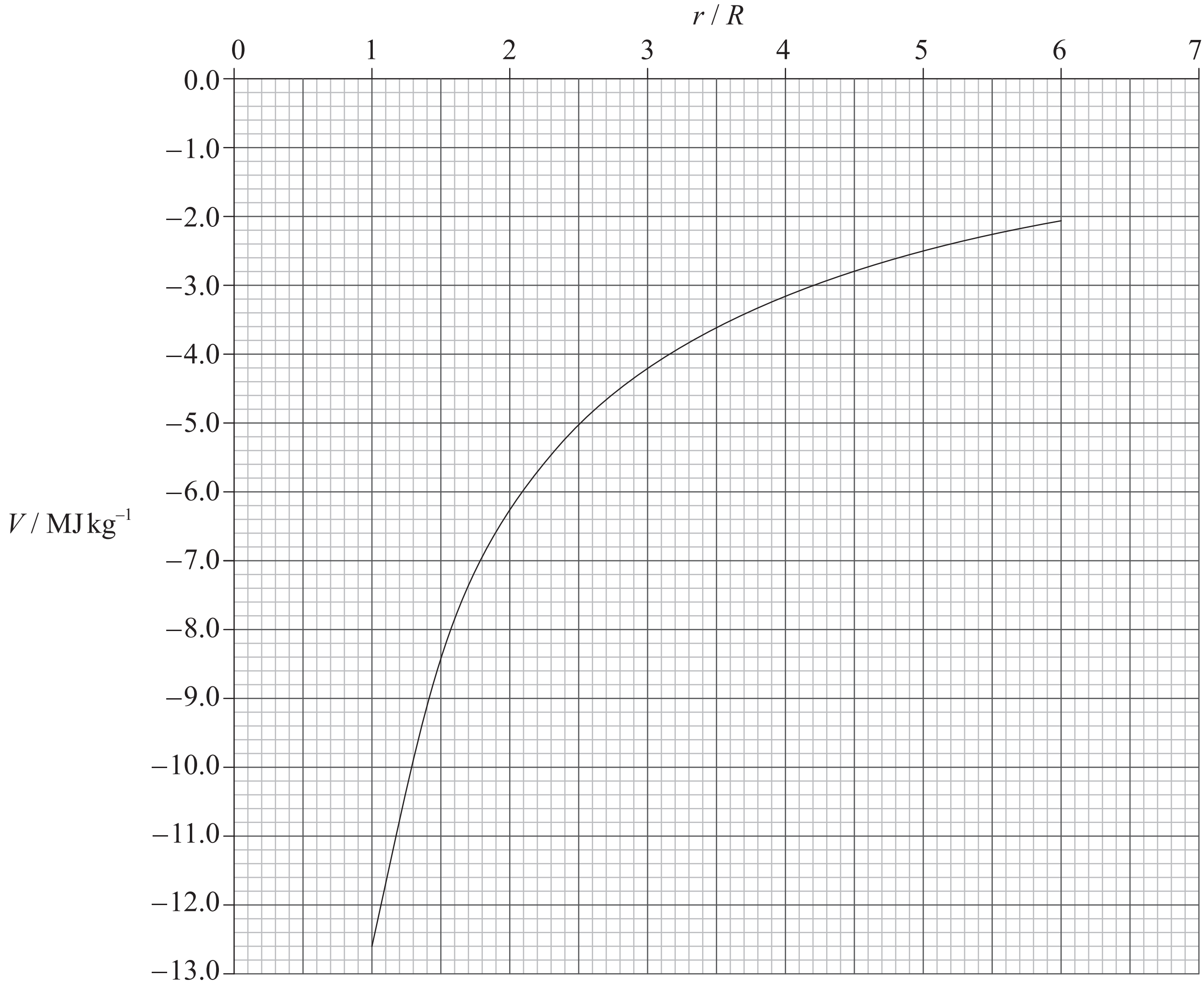
(b) The graph shows the variation with distance r from the centre of Mars of the gravitational potential V. R is the radius of Mars which is 3.3 Mm. (Values of V for $r<R$ are not shown.)



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(Question B4, part 2 continued)

A rocket of mass 1.2×10^{4} kg lifts off from the surface of Mars. Use the graph to

(i) calculate the change in gravitational potential energy of the rocket at a distance $4R$ from the centre of Mars. *[3]*

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(ii) show that the magnitude of the gravitational field strength at a distance $4R$ from the centre of Mars is $0.23\,\text{N kg}^{-1}$. *[2]*

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(c) Use the answer to (b)(ii) to show that the magnitude of the gravitational field strength at the surface of Mars is $3.7\,\text{N kg}^{-1}$. *[2]*

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(d) The gravitational potential at the surface of Earth is $-63\,\text{MJ kg}^{-1}$. Without any further calculation, compare the escape speed required to leave the surface of Earth with that of the escape speed required to leave the surface of Mars. *[2]*

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