IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
PROGRAMA DEL DIPLOMA DEL BI

M05/4/PHYSI/SP2/ENG/TZ1/XX+

22056511

PHYSICS
STANDARD LEVEL
PAPER 2

Thursday 19 May 2005 (afternoon)

1 hour 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 one question 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.

SECTION A

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

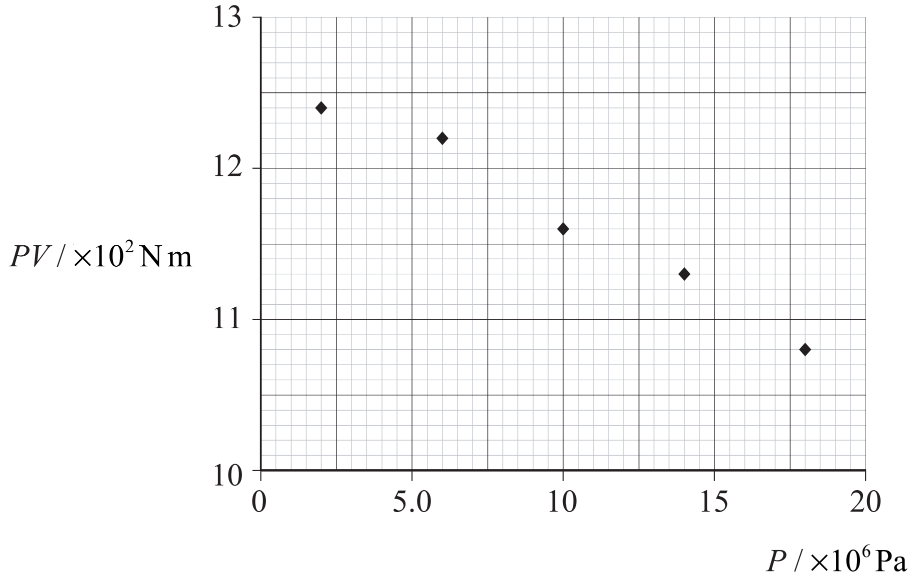
A1. Data analysis question

At high pressures, a real gas does not behave as an ideal gas. For a certain range of pressures, it is suggested that the relation between the pressure P and volume V of one mole of the gas at constant temperature is given by the equation

$$PV = A + BP$$

where A and B are constants.

In an experiment to measure the deviation of nitrogen gas from ideal gas behaviour, 1 mole of nitrogen gas was compressed at a constant temperature of 150 K. The volume V of the gas was measured for different values of the pressure P. A graph of the product PV of pressure and volume was plotted against the pressure P and is shown below. (Error bars showing the uncertainties in measurements are not shown).



(a) Draw a line of best fit for the data points. *[1]*

(This question continues on the following page)

(Question A1 continued)

(b) Use the graph to determine the values of the constants A and B in the equation

$$PV = A + BP.$$ *[5]*

Constant A . . . .

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Constant B . . . .

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(c) State the value of the constant B for an ideal gas. *[1]*

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(d) The equation $PV = A + BP$ is valid for pressures up to 6.0×10^{7} Pa.

(i) Determine the value of PV for nitrogen gas at a pressure of 6.0×10^{7} Pa. *[2]*

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(ii) Calculate the difference between the value of PV for an ideal gas and nitrogen gas when both are at a pressure of 6.0×10^{7} Pa. *[2]*

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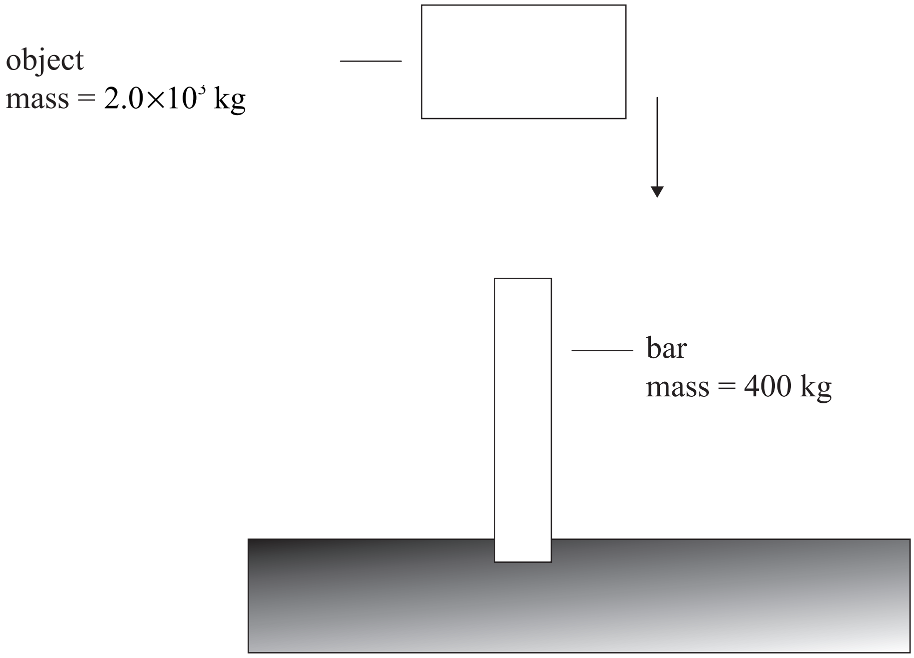
A2. This question is about driving a metal bar into the ground.

Large metal bars can be driven into the ground using a heavy falling object.



In the situation shown, the object has a mass 2.0×10^3 kg and the metal bar has a mass of 400 kg.

The object strikes the bar at a speed of $6.0\,\text{m}\,\text{s}^{-1}$. It comes to rest on the bar without bouncing. As a result of the collision, the bar is driven into the ground to a depth of 0.75 m.

(a) Determine the speed of the bar immediately after the object strikes it. *[4]*

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(b) Determine the average frictional force exerted by the ground on the bar. *[3]*

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A3. This question is about the force between current-carrying wires.

Diagram 1 below shows two long, parallel vertical wires each carrying equal currents in the same direction. The wires pass through a horizontal sheet of card. Diagram 2 shows a plan view of the wires looking down onto the card.

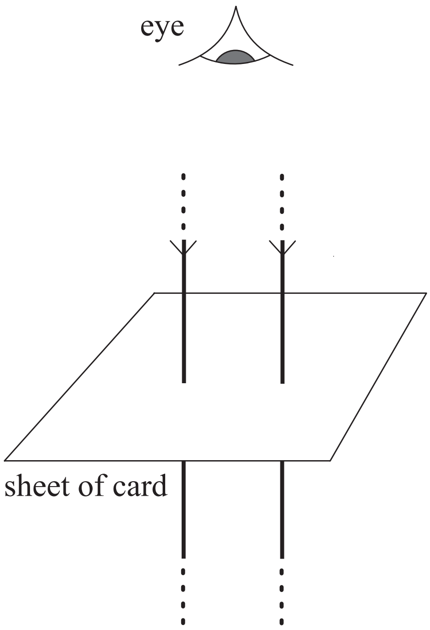

diagram 1

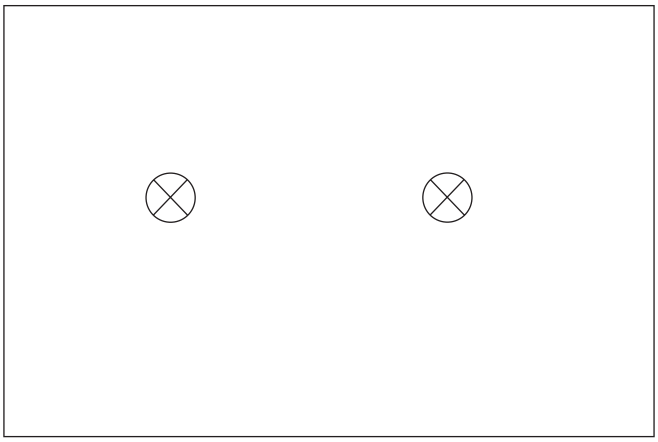

diagram 2

(a) (i) Draw on diagram 1 the direction of the force acting on each wire. *[1]*

(ii) Draw on diagram 2 the magnetic field pattern due to the currents in the wire. *[3]*

(b) The card is removed and one of the two wires is free to move. Describe and explain, the changes in the velocity and in acceleration of the moveable wire. *[3]*

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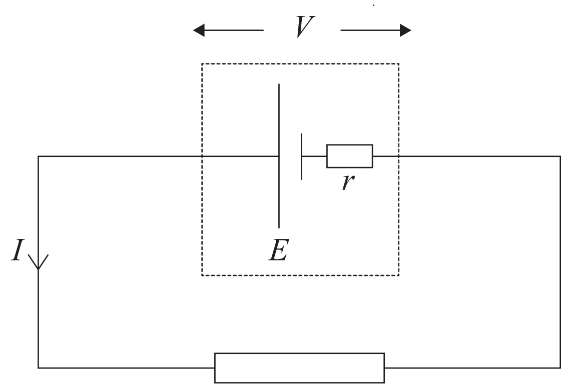
SECTION B

This section consists of three questions: B1, B2 and B3. Answer ***one*** *question.*

B1. This question is in **two** parts. **Part 1** is about e.m.f. and internal resistance. **Part 2** is about an experiment to measure the temperature of a flame.

Part 1 e.m.f. and internal resistance

A dry cell has an e.m.f. E and internal resistance r and is connected to an external circuit. There is a current I in the circuit when the potential difference across the terminals of the cell is V.



(a) State expressions, in terms of E, V, r and I where appropriate, for

(i) the total power supplied by the cell. *[1]*

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(ii) the power dissipated in the cell. *[1]*

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(iii) the power dissipated in the external circuit. *[1]*

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(b) Use your answers to (a) to derive a relationship between V, E, I and r. *[2]*

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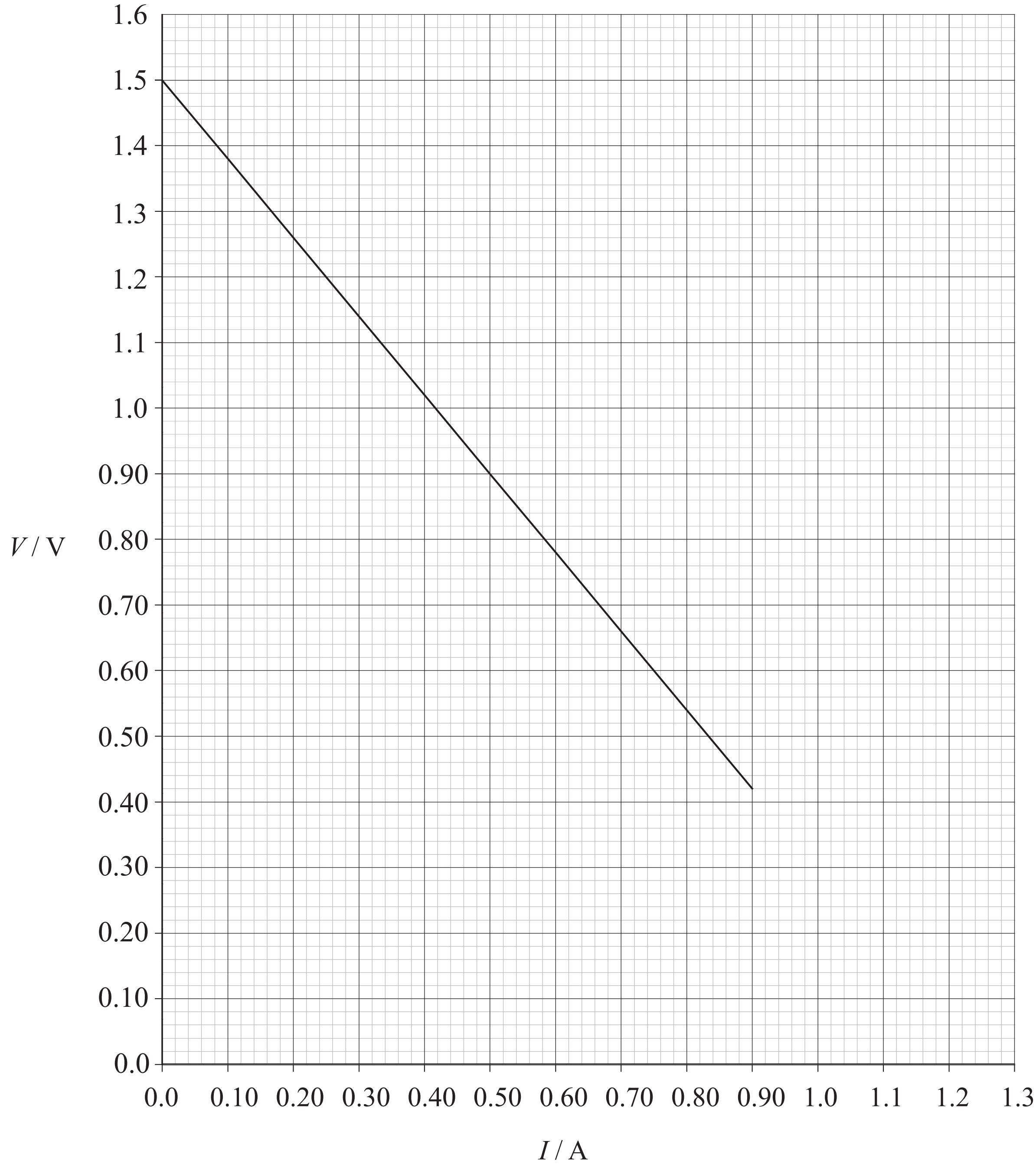
(Question B1, part 1 continued)

The graph below shows the variation of V with I for the dry cell.



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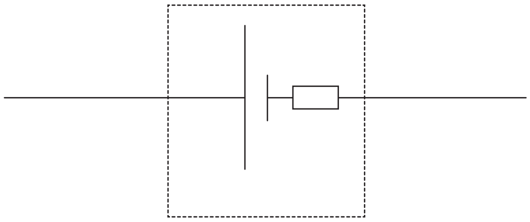
(Question B1, part 1 continued)

(c) Complete the diagram below to show the circuit that could be used to obtain the data from which the graph was plotted. *[3]*



(d) Use the graph, explaining your answers, to

(i) determine the e.m.f. E of the cell. *[2]*

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(ii) determine the current in the external circuit when the resistance R of the external circuit is very small. *[2]*

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(iii) deduce that the internal resistance r of the cell is about $1.2\,\Omega$. *[3]*

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(Question B1, part 1 continued)

(e) The maximum power dissipated in the external circuit occurs when the resistance of the external circuit has the same value as the internal resistance of the cell. Calculate the maximum power dissipation in the external circuit. *[3]*

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(Question B1 continued)

Part 2 The temperature of a flame

(a) Define *heat (thermal) capacity.* *[1]*

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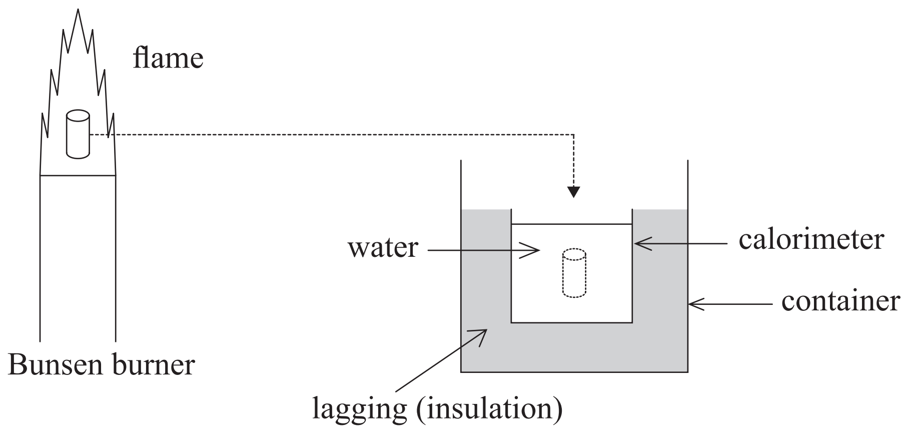
A piece of metal is held in the flame of a Bunsen burner for several minutes. The metal is then quickly transferred to a known mass of water contained in a calorimeter.



The water into which the metal has been placed is stirred until it reaches a steady temperature.

(b) Explain why

(i) the metal is transferred as quickly as possible from the flame to the water. *[1]*

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(ii) the water is stirred. *[1]*

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(Question B1, part 2 continued)

The following data are available:

heat capacity of metal	$= 82.7\,\mathrm{J\,K^{-1}}$
heat capacity of the water in the calorimeter	$= 5.46\times10^{2}\,\mathrm{J\,K^{-1}}$
heat capacity of the calorimeter	$= 54.6\,\mathrm{J\,K^{-1}}$
initial temperature of the water	$= 288\,\mathrm{K}$
final temperature of the water	$= 353\,\mathrm{K}$

(c) Assuming negligible energy losses in the processes involved, use the data to calculate the temperature T of the Bunsen flame. *[4]*

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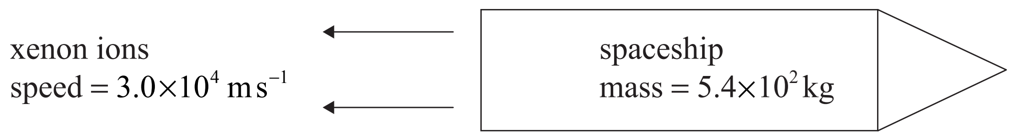
B2. This question is in **two** parts. **Part 1** is about momentum and the kinematics of a proposed journey to Jupiter. **Part 2** is about radioactive decay.

Part 1 Momentum and kinematics

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

A solar propulsion engine uses solar power to ionise atoms of xenon and to accelerate them. As a result of the acceleration process, the ions are ejected from the spaceship with a speed of 3.0×10^{4} m s^{-1}.



(b) The mass (nucleon) number of the xenon used is 131. Deduce that the mass of one ion of xenon is 2.2×10^{-25} kg. *[2]*

(c) The original mass of the fuel is 81 kg. Deduce that, if the engine ejects 7.7×10^{18} xenon ions every second, the fuel will last for 1.5 years. (1 year = 3.2×10^{7} s) *[2]*

(This question continues on the following page)

(Question B2, part 1 continued)

(d) The mass of the spaceship is 5.4×10^{2} kg. Deduce that the initial acceleration of the spaceship is $8.2\times10^{-5}\,\text{m}\,\text{s}^{-2}$. *[5]*

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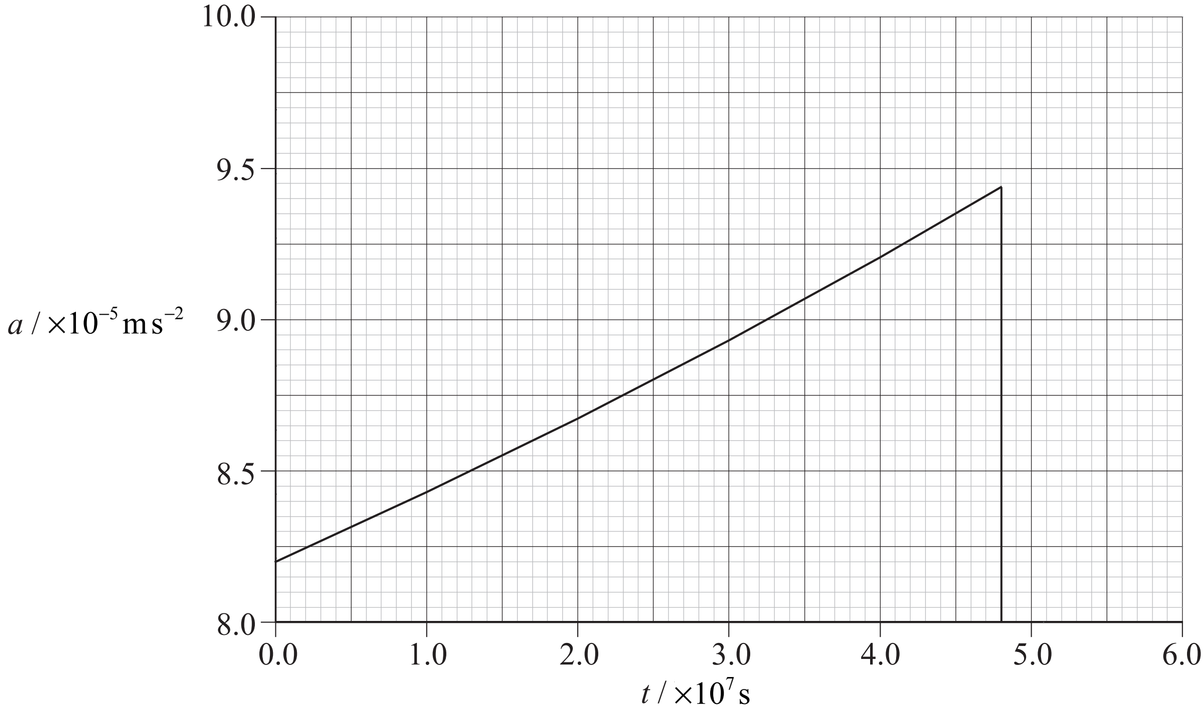
(Question B2, part 1 continued)

The graph below shows the variation with time t of the acceleration a of the spaceship. The solar propulsion engine is switched on at time $t = 0$ when the speed of the spaceship is $1.2\times10^{3}\,\text{m s}^{-1}$.



(e) Explain why the acceleration of the spaceship is increasing with time. *[2]*

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(f) Using data from the graph, calculate the speed of the spaceship at the time when the xenon fuel has all been used. *[4]*

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(Question B2, part 1 continued)

(g) The distance of the spaceship from Earth when the solar propulsion engine is switched on is very small compared to the distance from Earth to Jupiter. The fuel runs out when the spaceship is a distance of 4.7×10^{11} m from Jupiter. Estimate the total time that it would take the spaceship to travel from Earth to Jupiter. *[2]*

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(Question B2 continued)

Part 2 Radioactive decay

A nucleus of the isotope xenon, Xe – 131, is produced when a nucleus of the radioactive isotope iodine I - 131 decays.

(a) Explain the term *isotopes*. *[2]*

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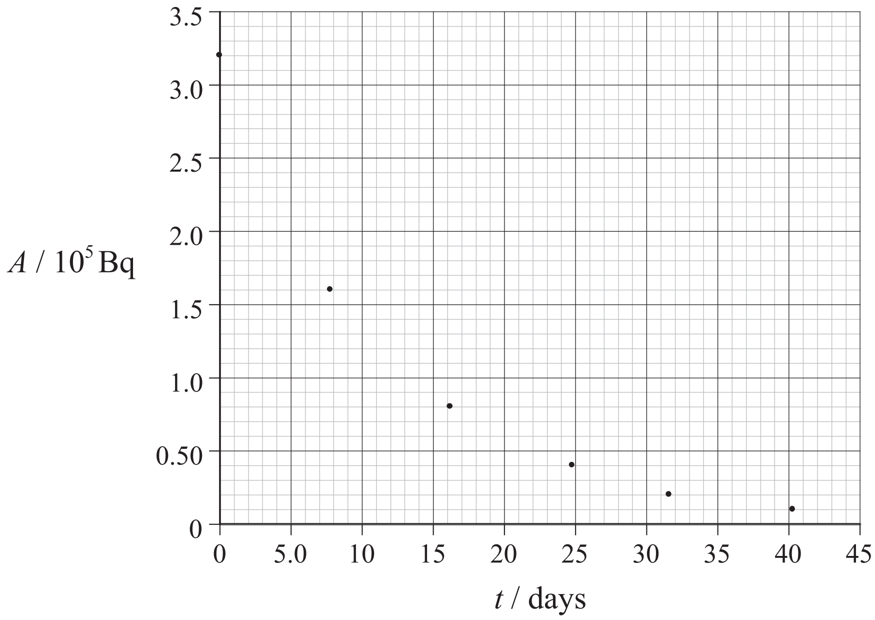
(b) Fill in the boxes below in order to complete the nuclear reaction equation for this decay. *[2]*

$$^{131}_{\square}\mathrm{I} \rightarrow {}^{131}_{54}\mathrm{Xe} + \beta^{-} + \square$$

(c) The activity A of a freshly prepared sample of the iodine isotope is 3.2×10^{5} Bq. The variation of the activity A with time t is shown below.



Draw a best-fit line for the data points. *[1]*

(d) Use the graph to estimate the half-life of I-131. *[1]*

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B3. This question is in **two** parts. **Part 1** is about waves and wave motion. **Part 2** is about atomic models.

Part 1 Waves and wave motion

(a) Describe, by reference to the propagation of energy, what is meant by a transverse wave. *[2]*

Transverse wave

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(b) State **one** example, other than a wave on a string, of a transverse wave. *[1]*

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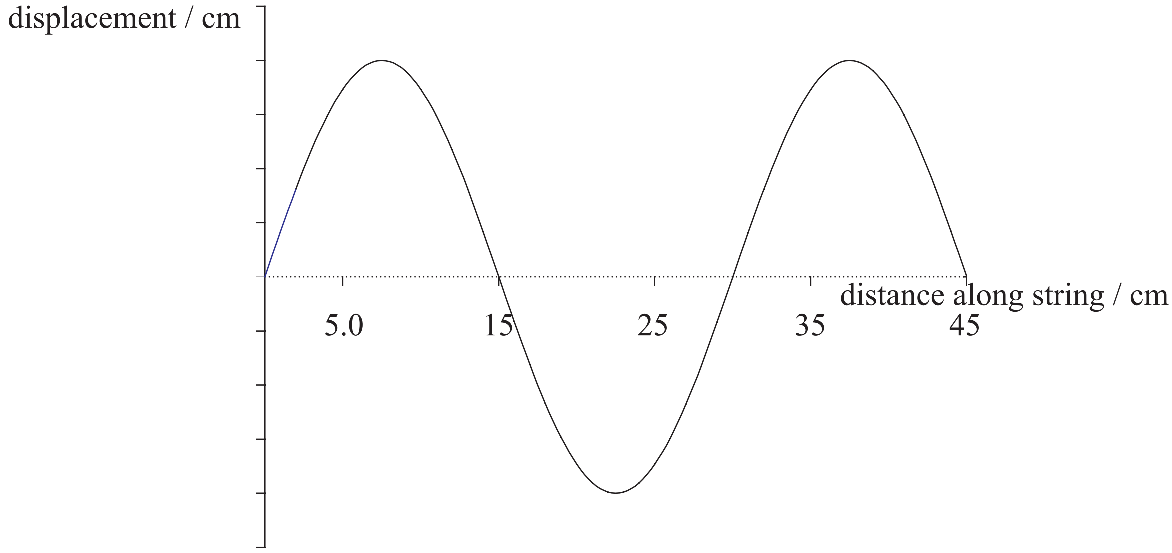
Question B3, part 1 continued)

A transverse wave is travelling along a string that is under tension. The diagram below shows the displacement of part of the string at time $t = 0$. The dotted line shows the position of the string when there is no wave travelling along it.



(c) On the diagram above, draw lines to identify for this wave

(i) the amplitude (label this A). *[1]*

(ii) the wavelength (label this λ). *[1]*

(d) The period of the wave is 1.2×10^{-3} s. Deduce that the speed of the wave is $250\,\mathrm{m\,s^{-1}}$. *[2]*

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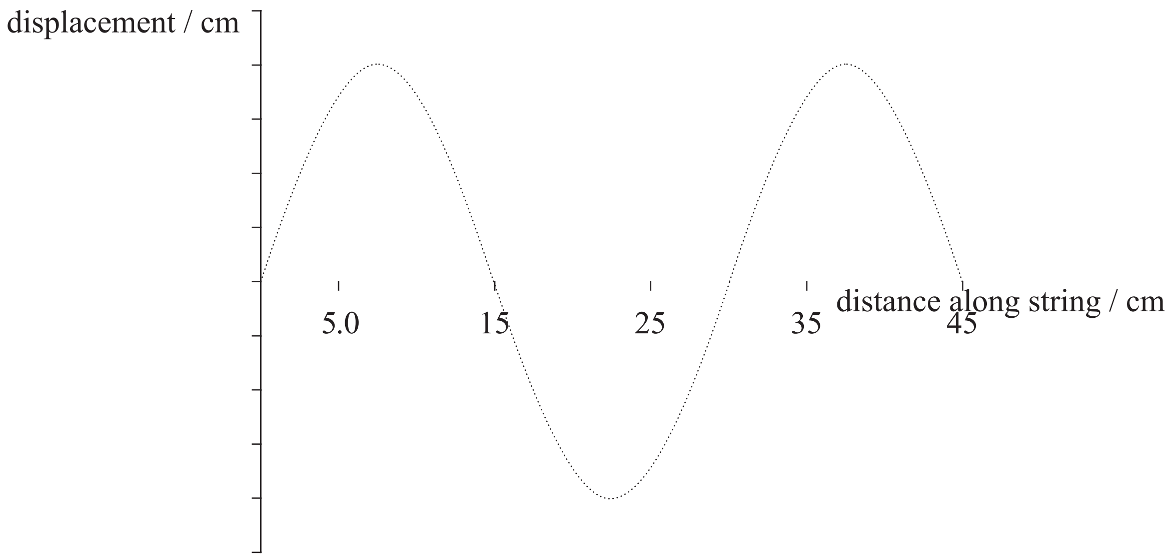
(Question B3, part 1 continued)

(e) Using the axes below, draw the displacement of the string when $t = 3.0\times10^{-4}$ s. (The displacement of the string at $t = 0$ is shown as a dotted line.) *[3]*



The string is maintained at the same tension and is adjusted in length to 45 cm. It is made to resonate at its first harmonic (fundamental) frequency.

(f) Explain what is meant by resonance. *[2]*

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(g) Describe how the string can be made to resonate at its first harmonic frequency only. *[2]*

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(h) Determine the frequency of the first harmonic of the string. *[2]*

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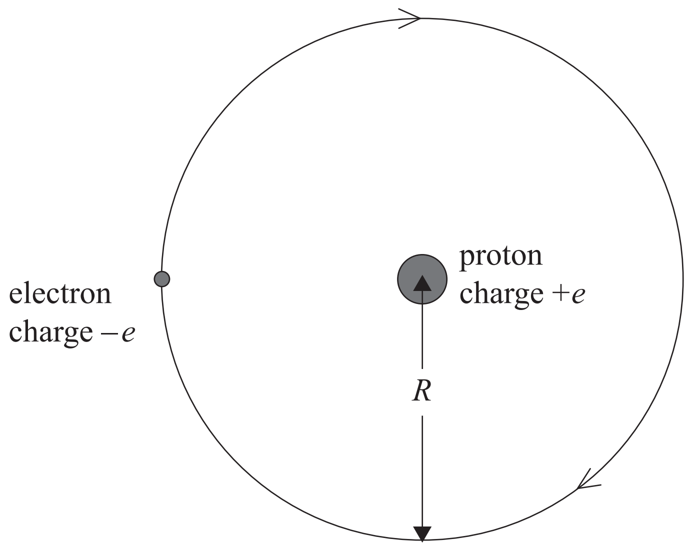
(Question B3 continued)

Part 2 Atomic models

The diagram below (not to scale) shows a simple model of the hydrogen atom in which the electron orbits the proton in a circular path of radius R.



(a) On the diagram, draw an arrow to show the direction of

(i) the acceleration of the electron (label this A). *[1]*

(ii) the velocity of the electron (label this V). *[1]*

(b) State an expression for the magnitude of the electrostatic force F acting on the electron. *[1]*

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(c) The orbital speed of the electron is $2.2\times10^{6}\ \mathrm{m\,s^{-1}}$.

Deduce that the radius R of the orbit is 5.2×10^{-11} m.

[3]

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(Question B3, part 2 continued)

(d) A more complex model of the atom suggests that the orbital radius can only take certain discrete values. This leads to the idea of discrete energy levels within the atom. Outline the evidence that supports the existence of discrete energy levels. *[3]*

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