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

PHYSICS
HIGHER LEVEL
PAPER 2

Thursday 8 November 2007 (afternoon)

2 hours 15 minutes

Candidate session number

0 0

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.

SECTION A

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

A1. As part of a road-safety campaign, the braking distances of a car were measured.

A driver in a particular car was instructed to travel along a straight road at a constant speed v. A signal was given to the driver to stop and he applied the brakes to bring the car to rest in as short a distance as possible. The total distance D travelled by the car after the signal was given was measured for corresponding values of v. A sketch-graph of the results is shown below.
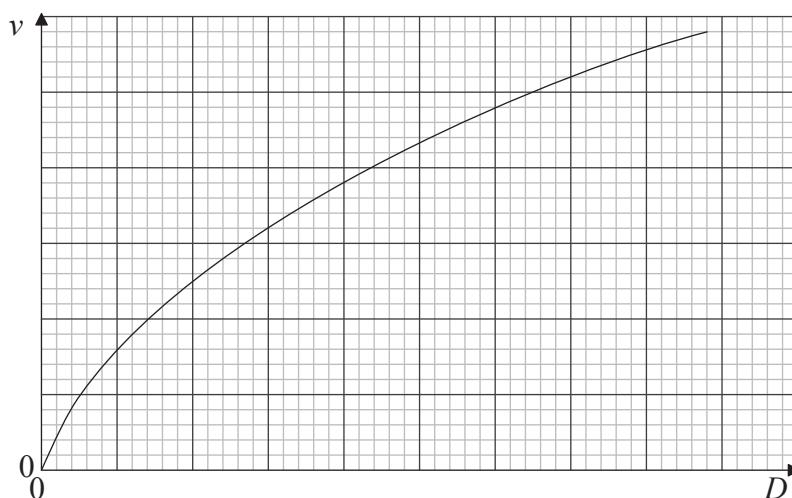
(a) State why the sketch graph suggests that D and v are **not** related by an expression of the form

$$D = mv + c,$$

where m and c are constants.   *[1]*

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(This question continues on the following page)

(Question A1 continued)

(b)   It is suggested that D and v may be related by an expression of the form

$$D = av + bv^2,$$

where a and b are constants.

In order to test this suggestion, the data shown below are used. The uncertainties in the measurements of D and v are not shown.

v / m s^{-1}	D / m	$\dfrac{D}{v}$ / . . . .
10.0	14.0	1.40
13.5	22.7	1.68
18.0	36.9	2.05
22.5	52.9	
27.0	74.0	2.74
31.5	97.7	3.10

(i)   In the table above, state the unit of $\dfrac{D}{v}$. *[1]*

(ii)   Calculate the magnitude of $\dfrac{D}{v}$, to an appropriate number of significant digits, for $v = 22.5\,\text{m s}^{-1}$. *[1]*

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(Question A1 continued)

(c)   Data from the table are used to plot a graph of $\dfrac{D}{v}$ (*y*-axis) against *v* (*x*-axis). Some of the data points are shown plotted below.
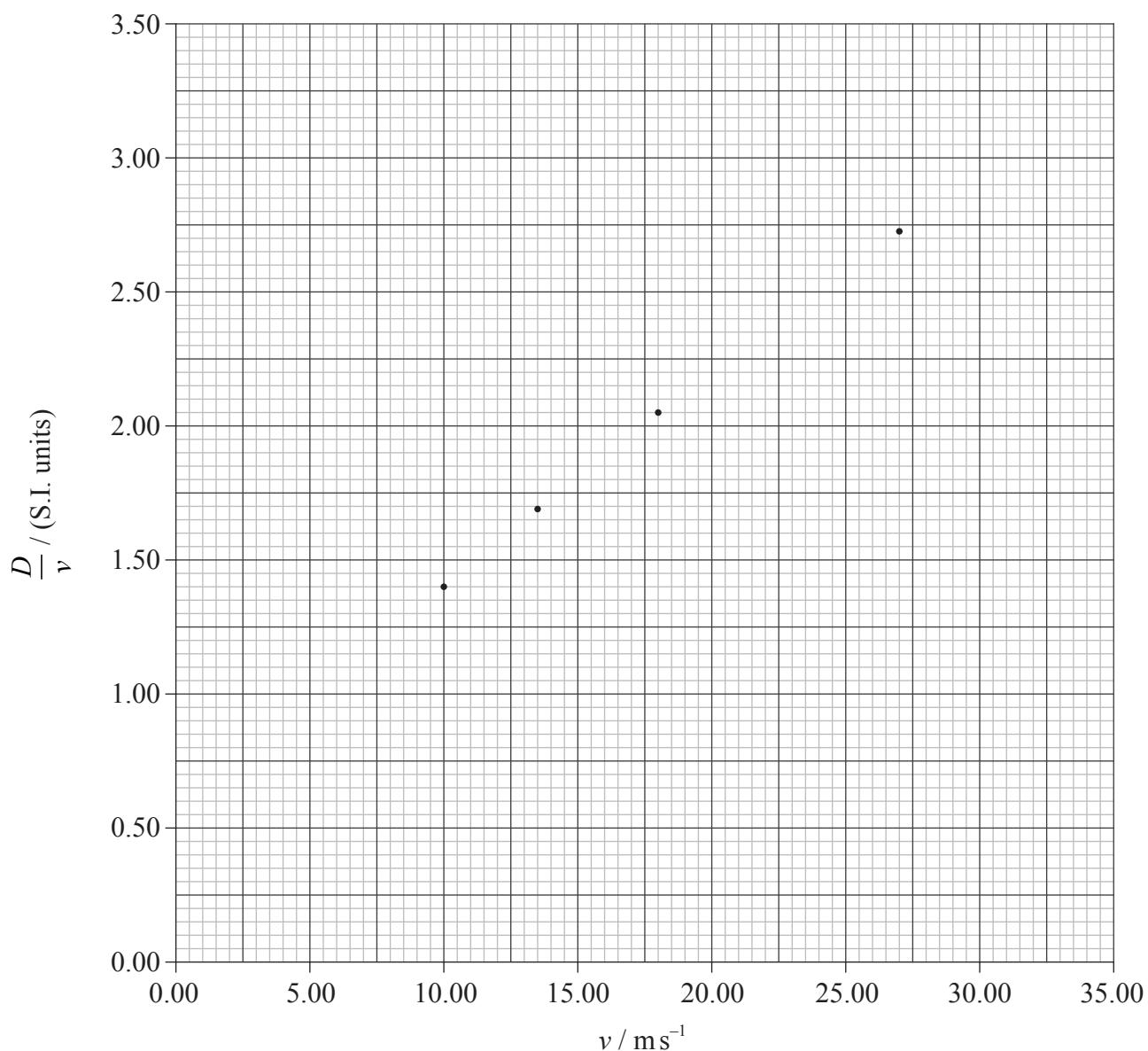
On the graph above,

(i)   plot the data points for speeds corresponding to $22.5\,\mathrm{m\,s^{-1}}$ and to $31.5\,\mathrm{m\,s^{-1}}$.   *[2]*

(ii)   draw the best-fit line for all the data points.   *[1]*

(This question continues on the following page)

(Question A1 continued)

(d)   Use your graph in (c) to determine

    (i)   the total stopping distance D for a speed of $35\,\mathrm{m\,s^{-1}}$.   *[2]*

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    (ii)   the intercept on the $\dfrac{D}{v}$ axis.   *[1]*

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    (iii)   the gradient of the best-fit line.   *[2]*

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(e)   Using your answers to (d)(ii) and (d)(iii), deduce the equation for D in terms of v.   *[1]*

    $D=$ . . . .

(f)   The uncertainty in the measurement of the distance D is $\pm 0.3\,\mathrm{m}$ and the uncertainty in the measurement of the speed v is $\pm 0.5\,\mathrm{m\,s^{-1}}$.

    (i)   For the data point corresponding to $v=27.0\,\mathrm{m\,s^{-1}}$, calculate the absolute uncertainty in the value of $\dfrac{D}{v}$.   *[2]*

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    (ii)   Each of the data points in (b) was obtained by taking the average of several values of D for each value of v. Suggest what effect, if any, the taking of averages will have on the uncertainties in the data points.   *[2]*

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A2. This question is about circular motion.

A stone is attached to an inextensible string. The stone is made to rotate at constant speed v in a horizontal circle. Diagram 1 below shows the stone in two positions A and B.
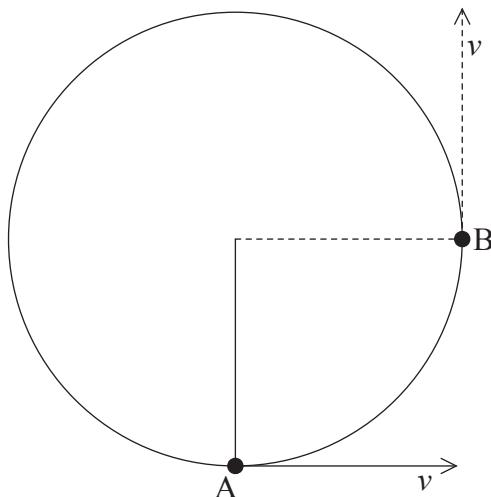
Diagram 1   **Diagram 2**

Diagram 2 above shows the velocity vector of the stone at point A.

(a) On **diagram 2**, draw vectors to show the change in velocity Δv of the stone from point A to point B. *[3]*

(b) Use your completed diagram 2 to explain why a force, directed towards the centre of the circle, is necessary to cause circular motion. *[2]*

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A3. This question is about electrical circuits.

The graph below shows the *I-V* (current-voltage) characteristic of an electrical component T.
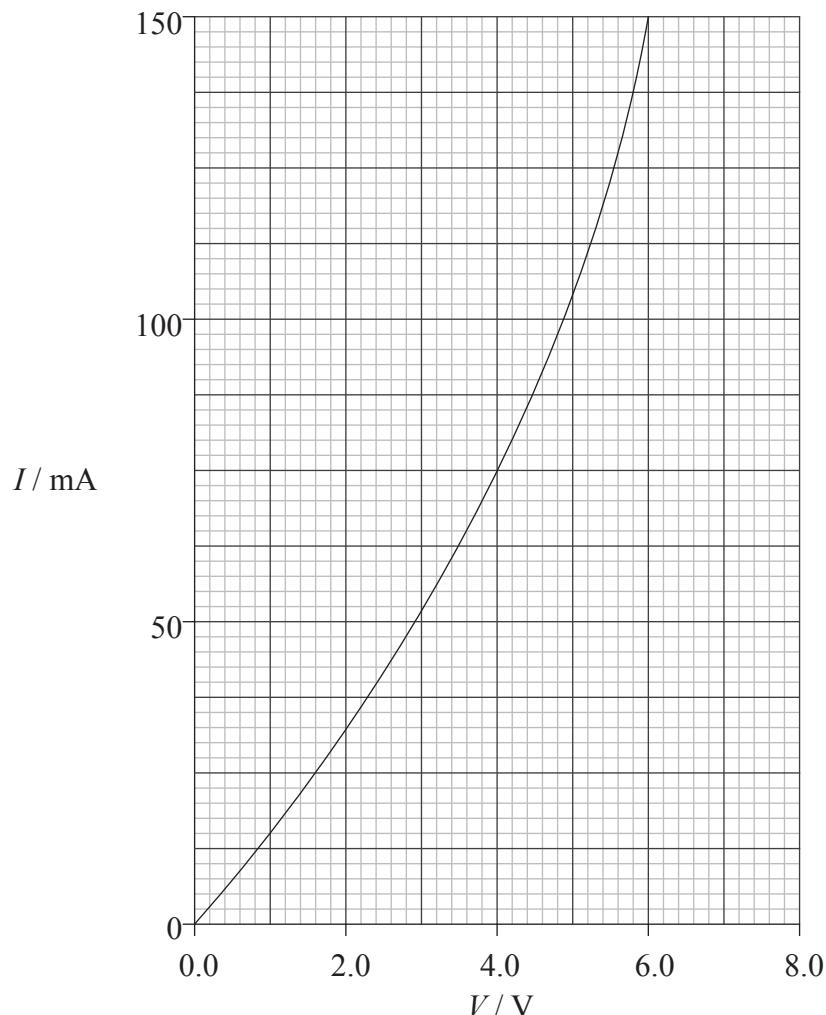
(a)   On the graph above, draw the *I-V* characteristic in the range $V=0$ to $V=6.0$V for a resistor R having a constant resistance of $40\,\Omega$.   *[1]*

(This question continues on the following page)

(Question A3 continued)

(b)   The component T and the resistor R are connected in parallel as shown below.
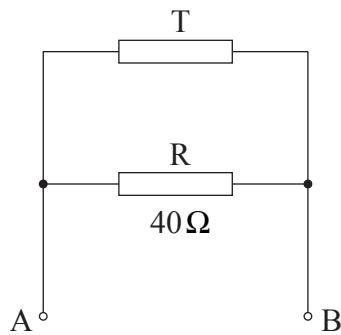
When a battery of constant e.m.f. *E* and negligible internal resistance is connected between the terminals A and B, the current in the resistor R is 100 mA.

(i)   Calculate the e.m.f. *E* of the battery.   *[1]*

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(ii)   Use the graph to determine the current in T.   *[1]*

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(iii) Calculate the power dissipation in T.   *[2]*

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(Question A3 continued)

(c)   In order to reduce the power dissipation in component T, a second resistor R of resistance $40\,\Omega$ is connected in series with T. The circuit is shown below.
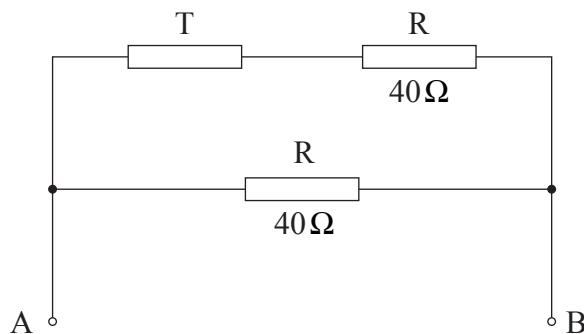
The battery connected between A and B is unchanged.

Use the graph to determine

(i)   the current in resistor T.   *[2]*

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(ii)   the power dissipation in T.   *[2]*

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A4. This question is about wave-particle duality.

A collimated beam of electrons, all having the same speed v, is incident on a carbon film contained in an evacuated glass container as shown below.
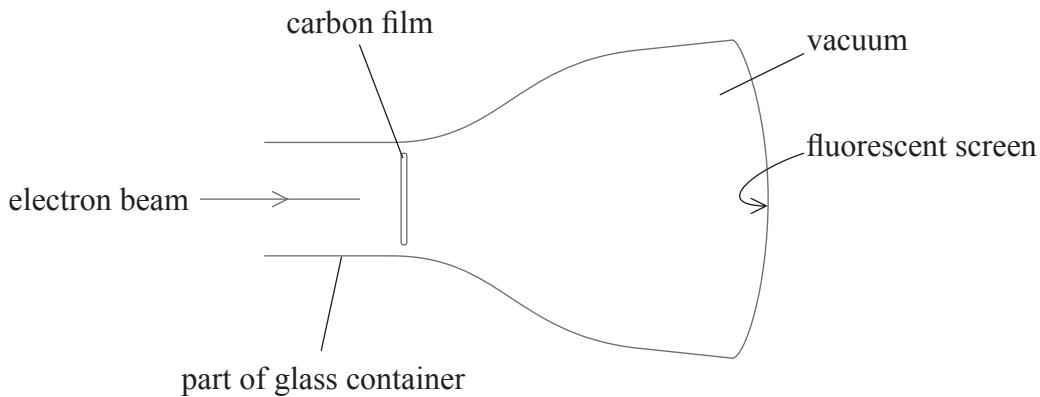
The electrons pass through the carbon film and are incident on a fluorescent screen.

(a)   Describe the appearance of the pattern produced on the fluorescent screen.   *[2]*

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(b)   The speed v of the incident electrons is increased. Suggest why there is a change in the pattern that is observed on the fluorescent screen.   *[3]*

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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 linear motion and **Part 2** is about nuclear reactions.

Part 1   Linear motion

At a sports event, a skier descends a slope AB. At B there is a dip BC of width 12 m. The slope and dip are shown in the diagram below. The vertical height of the slope is 41 m.
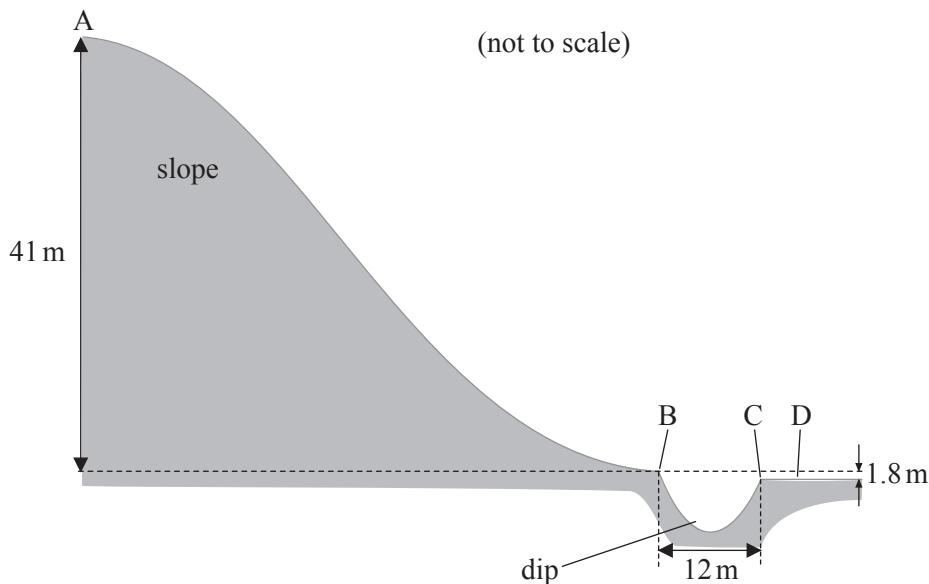
The graph below shows the variation with time t of the speed v down the slope of the skier.
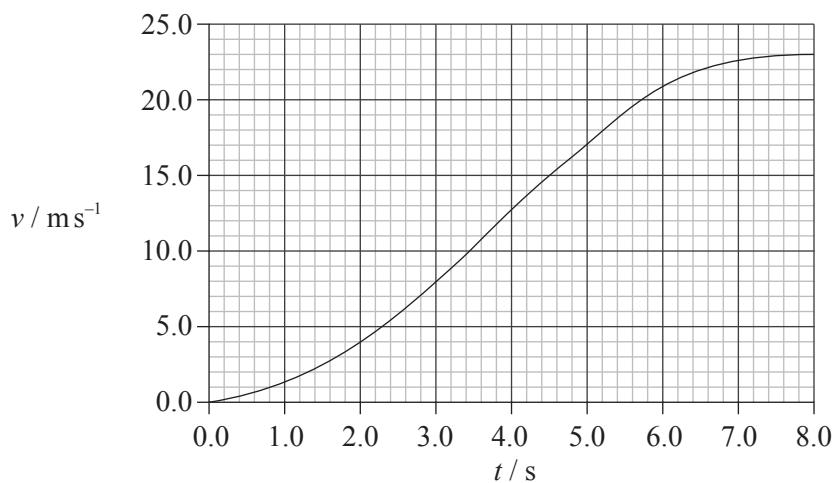
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(Question B1 part 1 continued)

The skier, of mass 72 kg, takes 8.0 s to ski, from rest, down the length AB of the slope.

(a)   Use the graph to

    (i)   calculate the kinetic energy E_K of the skier at point B.   *[2]*

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    (ii)   determine the length of the slope.   *[4]*

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(b)   (i)   Calculate the change ΔE_P in the gravitational potential energy of the skier between point A and point B.   *[2]*

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    (ii)   Use your answers to (a) and (b)(i) to determine the average retarding force on the skier between point A and point B.   *[3]*

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    (iii)   Suggest **two** causes of the retarding force calculated in (ii).   *[2]*

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      2.   ....

(This question continues on the following page)

(Question B1 part 1 continued)

(c)   At point B of the slope, the skier leaves the ground. He "flies" across the dip and lands on the lower side at point D. The lower side C of the dip is 1.8 m below the upper side B.

Determine the distance CD of the point D from the edge C of the dip. Air resistance may be assumed to be negligible.   *[4]*

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(d)   The lower side of the dip is altered so that it is inclined to the horizontal, as shown below.
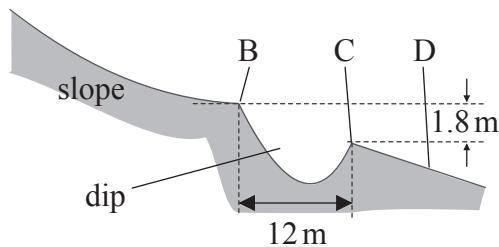
(i)   State the effect of this change on the landing position D.   *[1]*

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(ii)   Suggest the effect of this change on the impact felt by the skier on landing.   *[2]*

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(Question B1 continued)

Part 2   Nuclear reactions

(a)   (i)   State what is meant by radioactive decay.   *[2]*

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(ii)   Radioactive decay is said to be a random process. State what is meant by random decay.   *[2]*

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(b)   In 1919, Rutherford was investigating the bombardment of nitrogen by α-particles. He discovered that, in the interaction between an α-particle and a nitrogen nucleus, the nitrogen nucleus was transformed into an oxygen nucleus with the emission of a proton.

(i)   Complete the nuclear reaction equation for this transformation.   *[2]*

$$^{14}_{7}\text{N} + {}^{4}_{2}\text{He} \rightarrow {}^{\text{.......}}_{\text{.......}}\text{O} + {}^{\text{.......}}_{\text{.......}}\text{p}$$
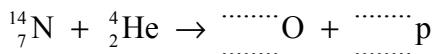
(ii)   The rest masses of the particles shown in the reaction equation are given in the table below.

particle	rest mass / u
He	4.00260
N	14.00307
O	16.99913
p	1.00783

Calculate the minimum energy, in MeV, of an α-particle required to cause this transformation. Explain your answer.   *[4]*

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B2. This question is in **two** parts. **Part 1** is about momentum and **Part 2** is about thermal physics.

Part 1 Momentum

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

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1633

(Question B2, part 1 continued)

(b)   A toy rocket of mass 0.12 kg contains 0.59 kg of water as shown in the diagram below.

high-pressure air

water
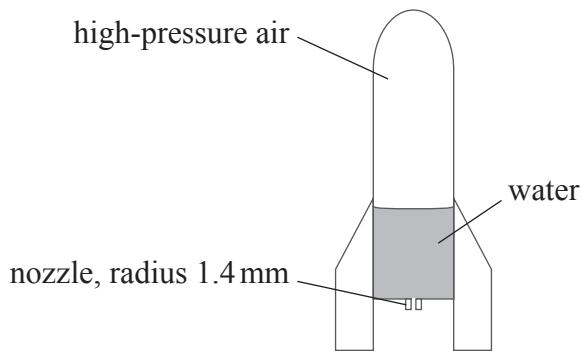
nozzle, radius 1.4 mm

The space above the water contains high-pressure air. The nozzle of the rocket has a circular cross-section of radius 1.4 mm. When the nozzle is opened, water emerges from the nozzle at a **constant speed** of 18 m s^{-1}. The density of water is 1000 kg m^{-3}.

(i)   Deduce that the volume of water ejected per second through the nozzle is 1.1×10^{-4} m^3.   *[2]*

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(ii)   Deduce that the upward force that the ejected water exerts on the rocket is approximately 2.0 N. Explain your working by reference to Newton's laws of motion.   *[4]*

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(iii)   State why the rocket does not lift off at the instant that the nozzle is opened.   *[1]*

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(Question B2, continued)

Part 2   Temperature, specific heat and latent heat

(a)   Outline how a temperature scale is constructed.   *[2]*

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(b)   Discuss why even an accurate thermometer may affect the reliability of a temperature
        reading.   *[2]*

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(Question B2, part 2 continued)

(c) (i) Define *specific heat capacity*. [2]

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(ii) The table below gives data for water and ice.

specific heat capacity of water	$4.2\,kJ\,kg^{-1}\,K^{-1}$
specific latent heat of fusion of ice	$330\,kJ\,kg^{-1}$

A beaker contains $450\,g$ of water at a temperature of $24\,°C$. The thermal (heat) capacity of the beaker is negligible and no heat is gained by, or lost to, the atmosphere. Calculate the mass of ice, initially at $0\,°C$, that must be mixed with the water so that the final temperature of the contents of the beaker is $8.0\,°C$. [4]

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Turn over

(Question B2, part 2 continued)

Ideal gases and heat engines

(d)   An ideal gas is contained in a cylinder by means of a piston as shown below.
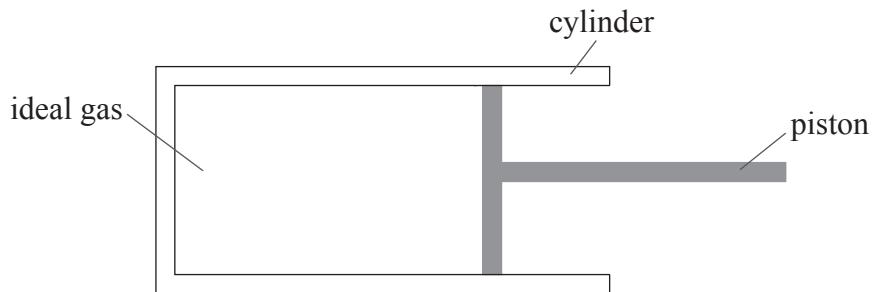
The piston is pushed quickly into the cylinder.

For the resulting change of state of the gas,

(i)   state, and explain, whether the change is isochoric, isobaric **or** adiabatic.   *[2]*

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(ii)   use the molecular model of an ideal gas to explain why the temperature of the
gas changes.   *[3]*

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2033

(Question B2, part 2 continued)

(e)   A heat engine operates between a high-temperature source and a sink at a lower temperature as shown below.
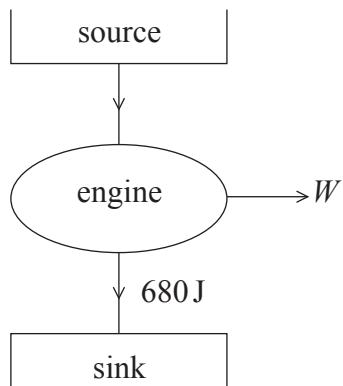
The overall efficiency of the engine is 15 %. The engine transfers 680 J of energy to the sink.

(i)   Determine the work W done by the engine. *[2]*

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(ii) There is a gain in entropy as a result of the engine doing work W. Identify **two** further entropy changes and, by reference to the second law of thermodynamics, state how the **three** changes are related. *[4]*

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Turn over

B3. This question is in **two** parts. **Part 1** is about magnetic and electrical force fields. **Part 2** is about gravitational force fields.

Part 1 Magnetic and electrical force fields

A proton is accelerated from rest in a vacuum through a potential difference of 420 V. The proton then enters a region ABCD of uniform magnetic field as shown.
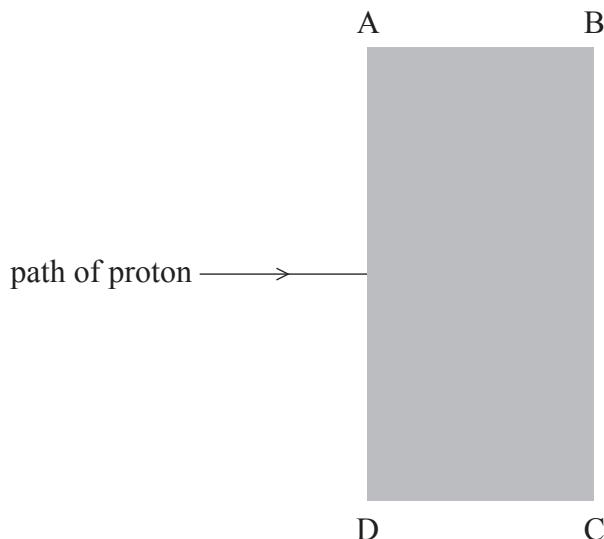
The magnetic field is directed into the plane of the paper. The field strength is 15 mT.

(a) (i) Calculate the speed of the proton as it enters the region of the magnetic field. *[2]*

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(ii) The path of the proton as drawn on the diagram is in the plane of the paper. The proton enters the region ABCD of the magnetic field and leaves through the side BC. On the diagram above, draw the path of the proton within and beyond the region ABCD of the magnetic field. Label the path P. *[2]*

(iii) Determine the magnitude of the force due to the magnetic field that acts on the proton while the proton is in the region ABCD. *[2]*

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(Question B3, part 1 continued)

(b) A uniform electric field is applied in the region ABCD. A second proton enters the region ABCD with the same velocity as the proton in (a). The electric field is adjusted so that, as the proton enters this region, the force on the proton due to the electric field is equal but opposite in direction to the force due to the magnetic field.

   (i)   On the diagram provided on page 22, draw an arrow to show the direction of the electric field. Label this arrow E. *[1]*

   (ii)   Determine the magnitude of the electric field strength. *[2]*

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(c) (i)   State Lenz's law. *[2]*

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   (ii)   Explain how Lenz's law is consistent with the law of conservation of energy. *[2]*

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(Question B3, part 1 continued)

(d)   A rectangular window PQRS has a metal frame.   The window is hinged on the vertical side RS as shown below.
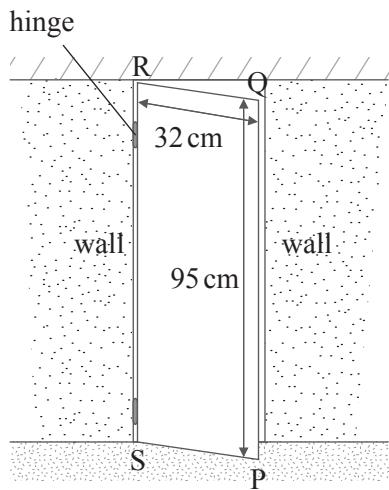
The window has width RQ of 32 cm and height PQ of 95 cm. When closed, the window is normal to the horizontal component of the Earth's magnetic field of field strength 18 µT. The window is opened through an angle of 90° in a time of 0.34 s.

(i)   Assuming that the flux linkage changes at a constant rate, calculate the e.m.f. induced in the frame of the window as it is being opened.   *[3]*

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(ii)   State across which parts of the frame the e.m.f. is induced. Explain your reasoning.   *[2]*

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(iii) Outline whether a vertical magnetic field, parallel to PQ and RS, would result in an induced e.m.f. as the window is opened.   *[2]*

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(Question B3, continued)

Part 2 Gravitational force fields

A satellite of mass m is orbiting a planet. The radius of the circular orbit is r. The planet may be assumed to be isolated in space and to have its mass M concentrated at its centre.

(a) Deduce that the kinetic energy E_K of the orbiting satellite is given by the expression

$$E_K = \frac{GMm}{2r}$$

where G is the gravitational constant. *[2]*

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(Question B3, part 2 continued)

(b)   Data for the planet are given below.

$$GM = 4.00 \times 10^{14}\,\mathrm{N\,m^2\,kg^{-1}}$$

distance from centre of planet / m	gravitational potential / J kg^{-1}
7.18×10^6	-5.571×10^7
7.26×10^6	-5.510×10^7

Rockets on the satellite are fired so that the satellite changes its orbit. The radius of the orbit decreases from 7.26×10^6 m to 7.18×10^6 m. The satellite may be assumed to have a constant mass m of 850 kg.

Calculate, for this satellite, the magnitude of the change in

(i)   its kinetic energy.   *[2]*

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(ii)   its gravitational potential energy.   *[2]*

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(iii)   its total energy.   *[1]*

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(c)   Using your answers in (b), state and explain whether the rocket on the satellite is fired so as to produce a force in the direction of, or in the opposite direction to, the direction of motion of the satellite.   *[3]*

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2733

Turn over

B4. This question is in **two** parts. **Part 1** is about the phenomena associated with the interference of waves. **Part 2** is about X-ray spectra.

**Part 1**   Interference of waves

Travelling waves

(a)   The graph below shows the variation with time t of the displacement x_A of wave A as it passes through a point P.

Wave A
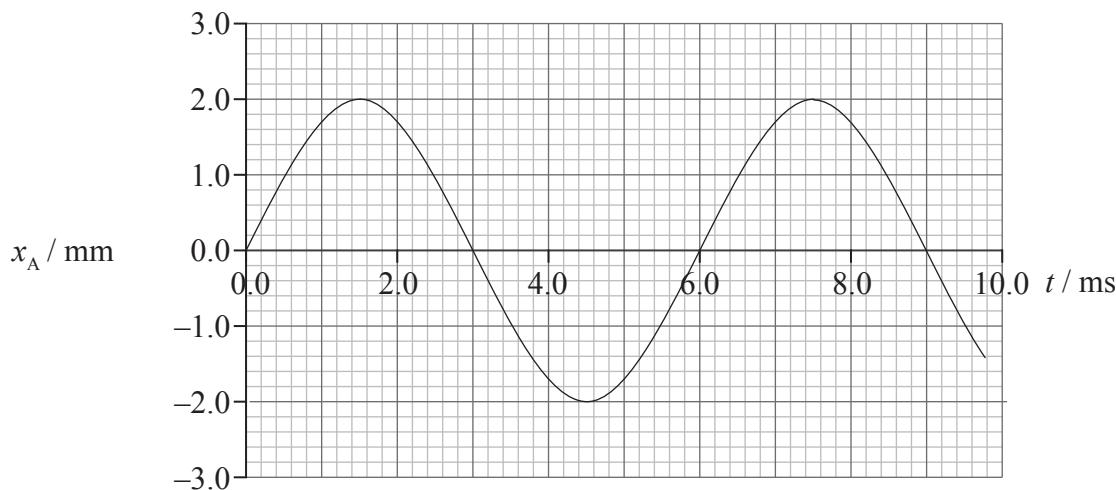
The graph below shows the variation with time t of the displacement x_B of wave B as it passes through point P.

Wave B
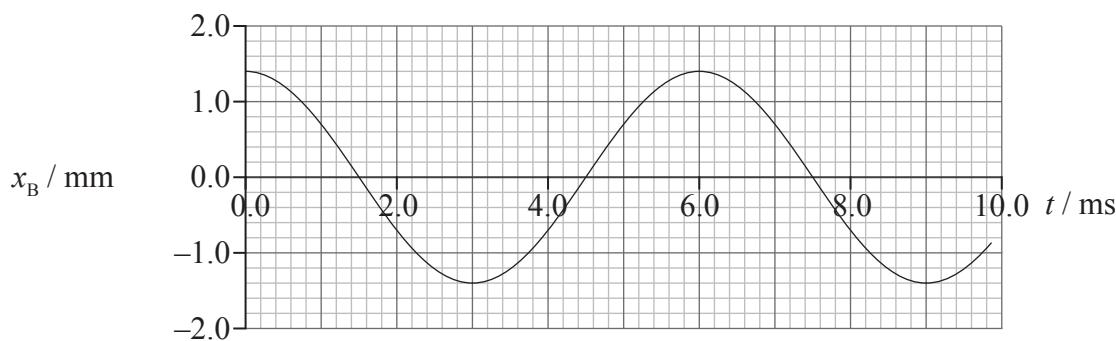
(i)   Calculate the frequency of the waves.   *[1]*

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2833

(Question B4, part 1 continued)

(ii) The waves pass simultaneously through point P. Use the graphs to determine the resultant displacement at point P of the two waves at time $t = 1.0$ ms and at time $t = 8.0$ ms.   *[3]*

At $t = 1.0$ ms: . . . .

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At $t = 8.0$ ms: . . . .

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(b) Monochromatic light passes through a double-slit arrangement. The diagram below shows the variation with distance of the intensity of the fringes of the interference pattern as observed on a screen.
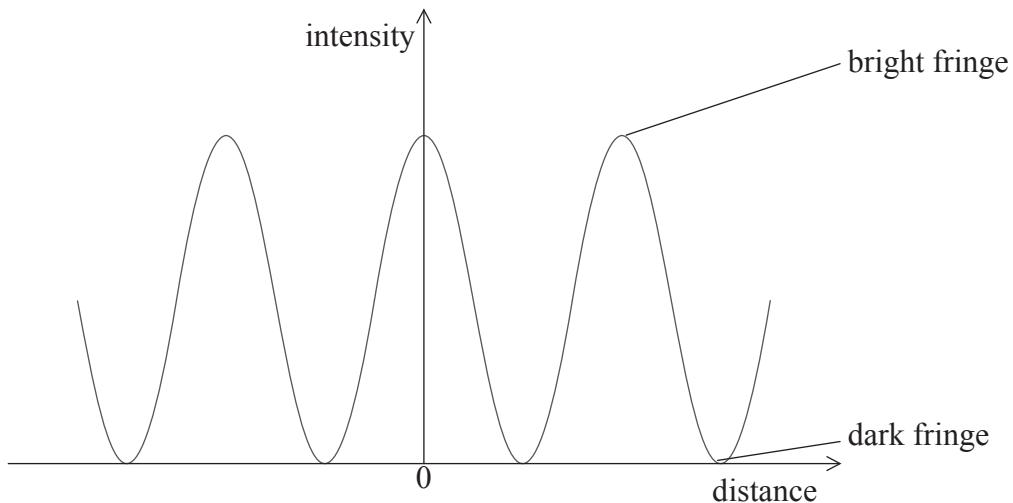
The intensity of the monochromatic light passing through one of the slits of the double-slit arrangement is reduced. State, and explain, the effect of this change on the appearance of the bright fringes and of the dark fringes.   *[2]*

bright fringes: . . . .

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dark fringes: . . . .

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(Question B4, part 1 continued)

Standing (stationary) waves

(c)   A tube is filled with water and a tuning fork is sounded above the tube, as shown in diagram 1.
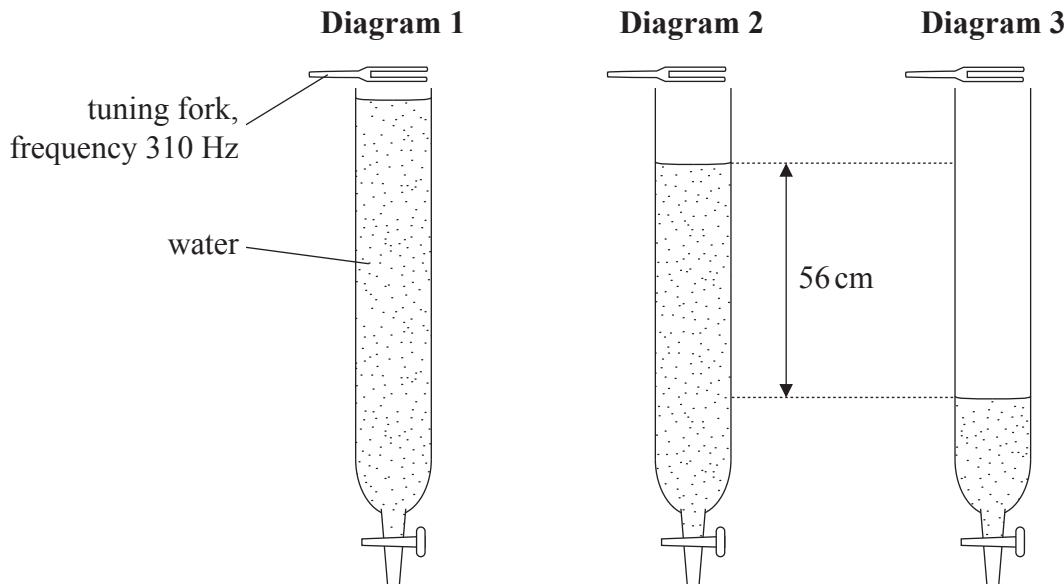
Water is allowed to run out of the tube and, at the position shown in diagram 2, a loud sound is heard for the first time. Water continues to run out of the tube and a loud sound is next heard at the position shown in diagram 3.

(i)   A loud sound indicates that a standing (stationary) wave has been produced in the tube. Outline how the standing wave is formed.   *[2]*

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(ii)   On **diagram 3**, draw lines to represent the standing wave produced in the tube. Also, identify, with the letter N, the positions of the nodes of the standing wave.   *[2]*

(iii)   The change in height of the water surface between the positions shown in diagram 2 and diagram 3 is 56 cm. The frequency of the tuning fork is 310 Hz. Calculate the speed of sound in the tube.   *[3]*

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(Question B4, part 1 continued)

Doppler effect

(d)   (i)   State what is meant by the Doppler effect.   *[2]*

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(ii)   A source of sound has frequency f and is moving with constant speed v directly towards a stationary observer. The speed of sound in still air is c. Derive an expression for the frequency f_o of the sound heard by the observer. Explain your working.   *[3]*

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(iii)   A moving police car produces sound from its engine and from its siren. The car passes a stationary person. The person notices a Doppler shift as the car passes. When the police car, travelling at the same speed, next passes the person, its siren is not sounding. The Doppler shift is not as noticeable. Suggest **one** reason for this observation.   *[2]*

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(Question B4, continued)

Part 2   X-ray spectra

The graph shows the variation with wavelength λ of the relative intensity of an X-ray spectrum produced when electrons strike a metal target.
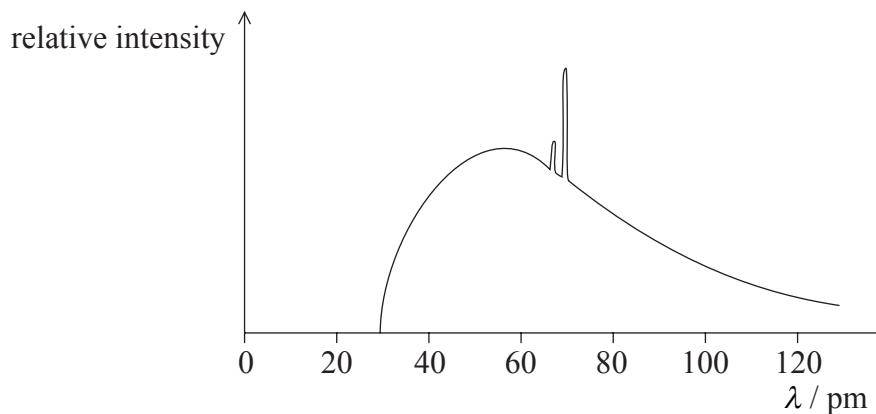
The spectrum consists of a continuous spectrum and a line spectrum (the "spikes").

(a)   (i)   State why there is a sharp cut-off at the short-wavelength end of the spectrum.   *[1]*

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      (ii)   Explain why the wavelengths of the line spectrum are characteristic of the target element.   *[3]*

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(This question continues on the following page)

(Question B4, part 2 continued)

(b) In 1913, Moseley discovered that the frequency *f* of a line in the spectrum is related to the proton number (atomic number) *Z* of the target atoms by the expression

$$f = a(Z - b)^2,$$

where *a* and *b* are constants.

One line in the spectrum produced by a certain metal target has a wavelength of 0.154 nm. For this line, $a = 2.50 \times 10^{15}$ Hz and $b = 1.00$.

Calculate the proton number of the target metal. *[3]*

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(c) Determine the minimum potential difference through which electrons in the X-ray tube must be accelerated so that the line of wavelength 0.154 nm may be observed in the spectrum. *[3]*

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