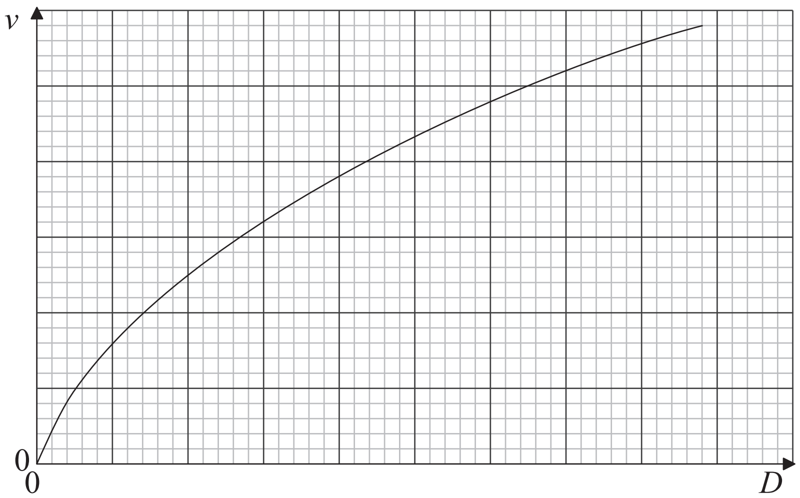
SECTION A

*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	$\frac{D}{v}$ / . . . .
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 $\frac{D}{v}$. *[1]*

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

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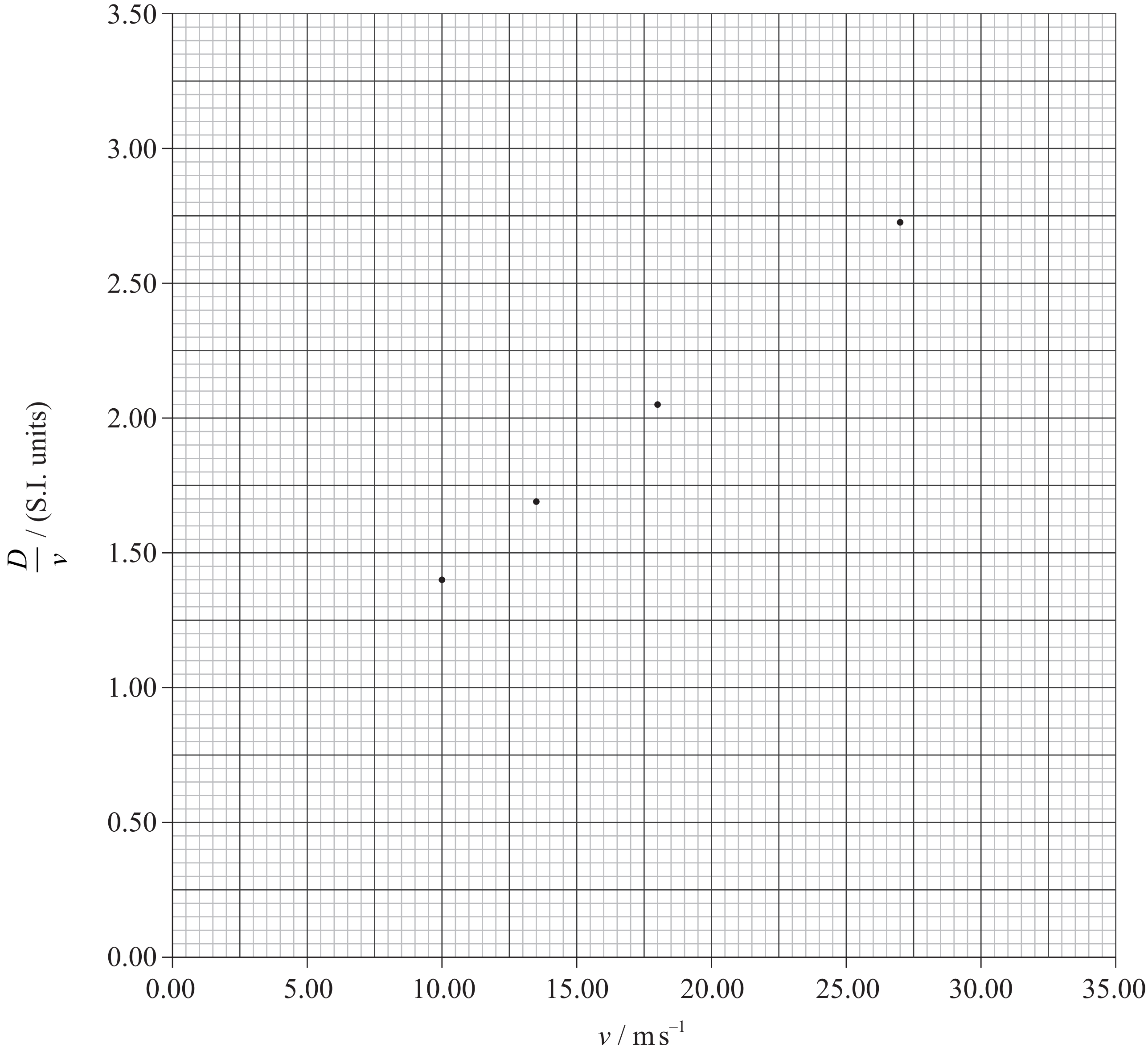
(Question A1 continued)

(c) Data from the table are used to plot a graph of $\frac{D}{v}$ (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 m s^{-1} and to 31.5 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 $35\,\text{m s}^{-1}$. *[2]*

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(ii) the intercept on the $\frac{D}{v}$ 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) (i) Use your answer to (e) to calculate the distance D for a speed v of $35.0\,\text{m s}^{-1}$. *[1]*

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(ii) Briefly discuss your answers to (d)(i) and (f)(i). *[1]*

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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

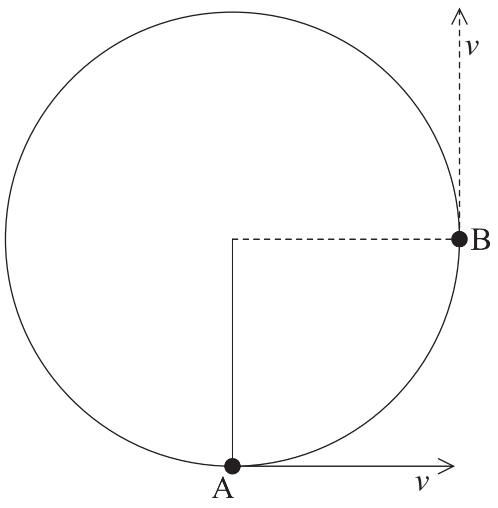

Diagram 2

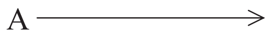

Diagram 2 above shows the velocity vector of the stone at point A.

(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 resistance.

(a) Define *electrical resistance*. *[1]*

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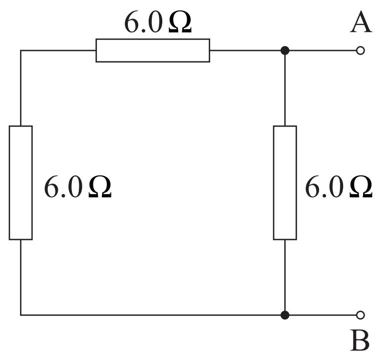
(b) (i) Three resistors, each of resistance 6.0 Ω, are connected as shown below.



Calculate the total resistance between point A and point B of this arrangement. *[1]*

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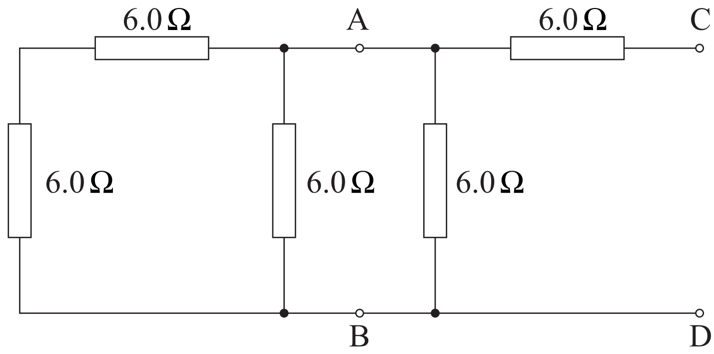
(Question A3 continued)

(ii) The arrangement in (b)(i) is now connected to two more resistors, as shown below. Each resistor is of resistance 6.0 Ω.



Using your answer in (b)(i), deduce that the total resistance between point C and point D is 8.4 Ω. *[2]*

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(iii) One of the resistors in the arrangement shown in (b)(ii) becomes faulty. The resistance between point C and point D is found to be 6.0 Ω. On the diagram in (b)(ii) above, identify the faulty resistor by drawing a circle around it. Deduce the nature of the fault. *[2]*

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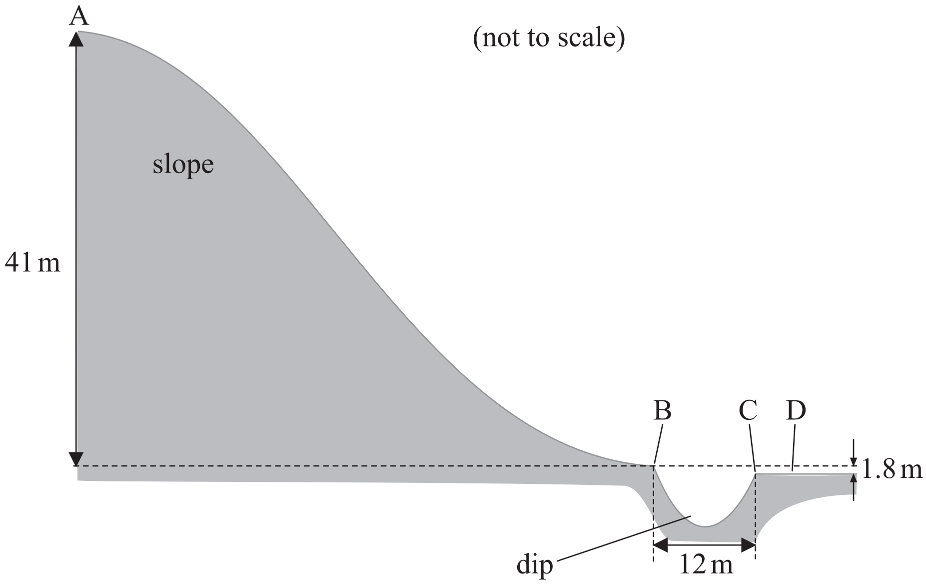
SECTION B

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

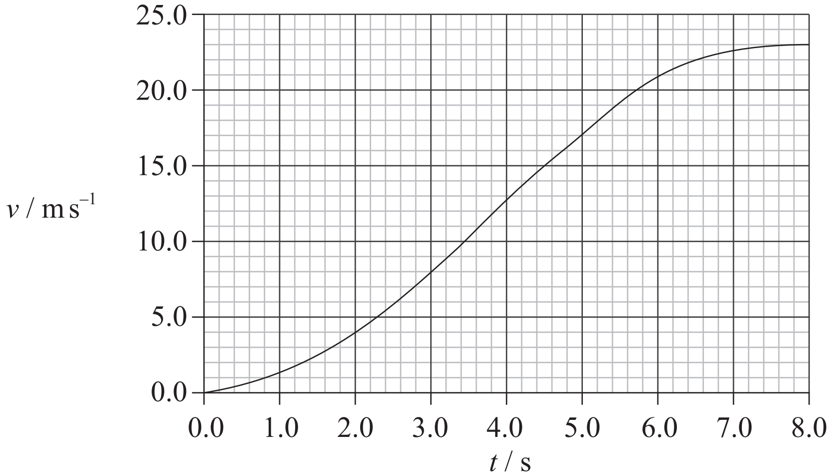
B1. This question is in **two** parts. **Part 1** is about linear motion and **Part 2** is about nuclear reactions.

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 magnitude of 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)(i) and (b)(i) to determine the ratio

$$\frac{(\Delta E_P - E_K)}{\Delta E_P}.$$ *[2]*

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(iii) Suggest what this ratio represents. *[1]*

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(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.

(i) Calculate the time taken for an object to fall, from rest, through a vertical distance of 1.8 m. Assume negligible air resistance. *[2]*

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(ii) The time calculated in (c)(i) is the time of flight of the skier across the dip. Determine the horizontal distance travelled by the skier during this time, assuming that the skier has the constant speed at which he leaves the slope at B. *[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]*

$$^{14}_{7}\text{N} + {}^{4}_{2}\text{He} \rightarrow {}^{\cdots\cdots}_{\cdots\cdots}\text{O} + {}^{\cdots\cdots}_{\cdots\cdots}\text{p}$$

(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 to occur. 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 temperature and thermal energy.

Part 1 Momentum

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

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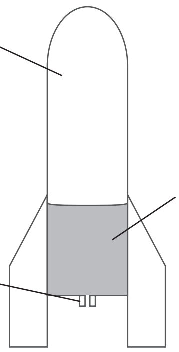
(Question B2, part 1 continued)

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



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 $18\,\text{m}\,\text{s}^{-1}$. The density of water is $1000\,\text{kg}\,\text{m}^{-3}$.

(i) Deduce that the volume of water ejected per second through the nozzle is $1.1\times10^{-4}\,\text{m}^3$. *[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) Calculate the time delay between opening the nozzle and the rocket achieving lift-off. *[2]*

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(Question B2, continued)

Part 2 Temperature and thermal energy

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

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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(d) (i) Distinguish between evaporation and boiling. *[2]*

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(ii) Explain, in terms of molecular behaviour, why boiling involves a transfer of thermal energy with no change in temperature. *[3]*

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B3. This question is in **two** parts. **Part 1** is about wave properties. **Part 2** is about magnetic and electric fields.

Part 1 Wave properties

(a) By reference to the energy of a travelling wave, state what is meant by

(i) a ray. *[1]*

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(ii) wave speed. *[1]*

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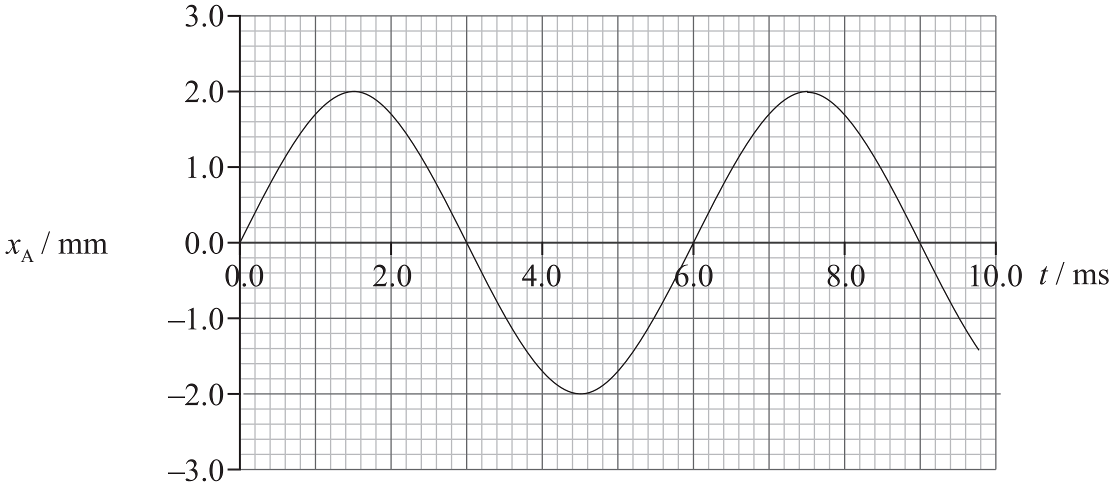
(Question B3, part 1 continued)

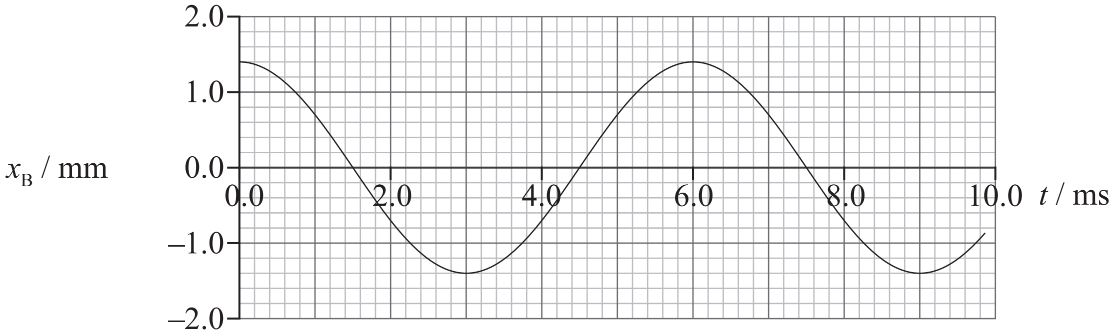
(b) The graph below shows the variation with time t of the displacement x_A of wave A as it passes through a point P.

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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(Question B3, 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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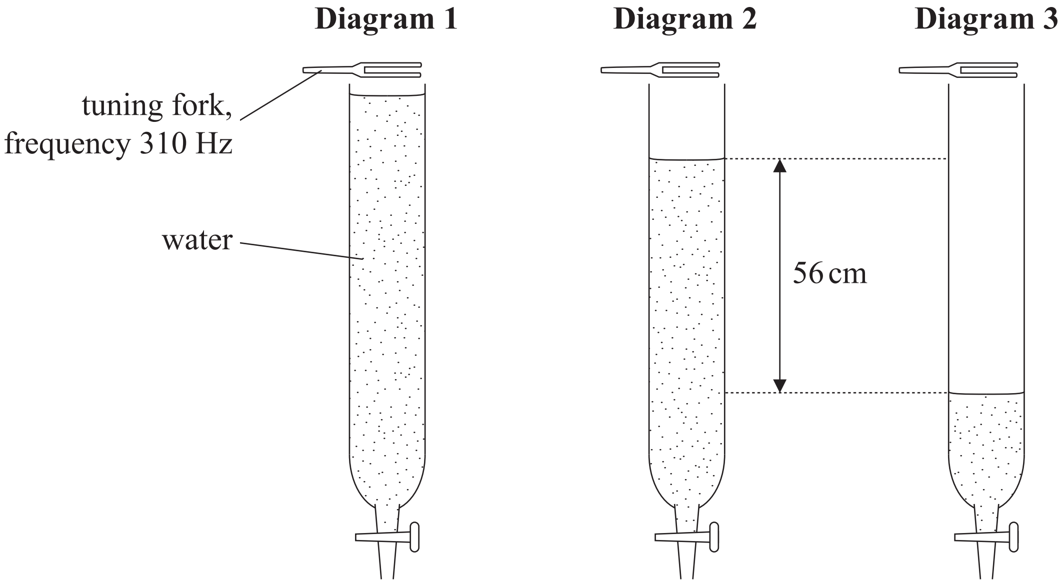
(Question B3, part 1 continued)

(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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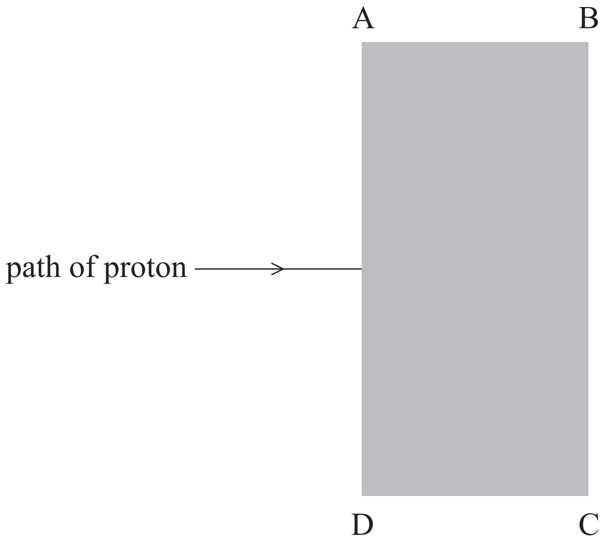
(Question B3, continued)

Part 2 Magnetic and electric 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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(This question continues on the following page)

(Question B3, part 2 continued)

(b) (i) Define *electric field strength* at a point. *[2]*

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(ii) Determine the magnitude of the electric field strength that would produce a force on a proton that is equal to the force calculated in (a)(iii). *[2]*

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(iii) The electric field calculated in (b)(ii) is applied in the region ABCD. The electric field is arranged such that, when a proton enters the region, the force due to the electric field is opposite in direction to the force due to the magnetic field. Suggest, with a reason, the path that the proton will follow in the region ABCD. *[2]*

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