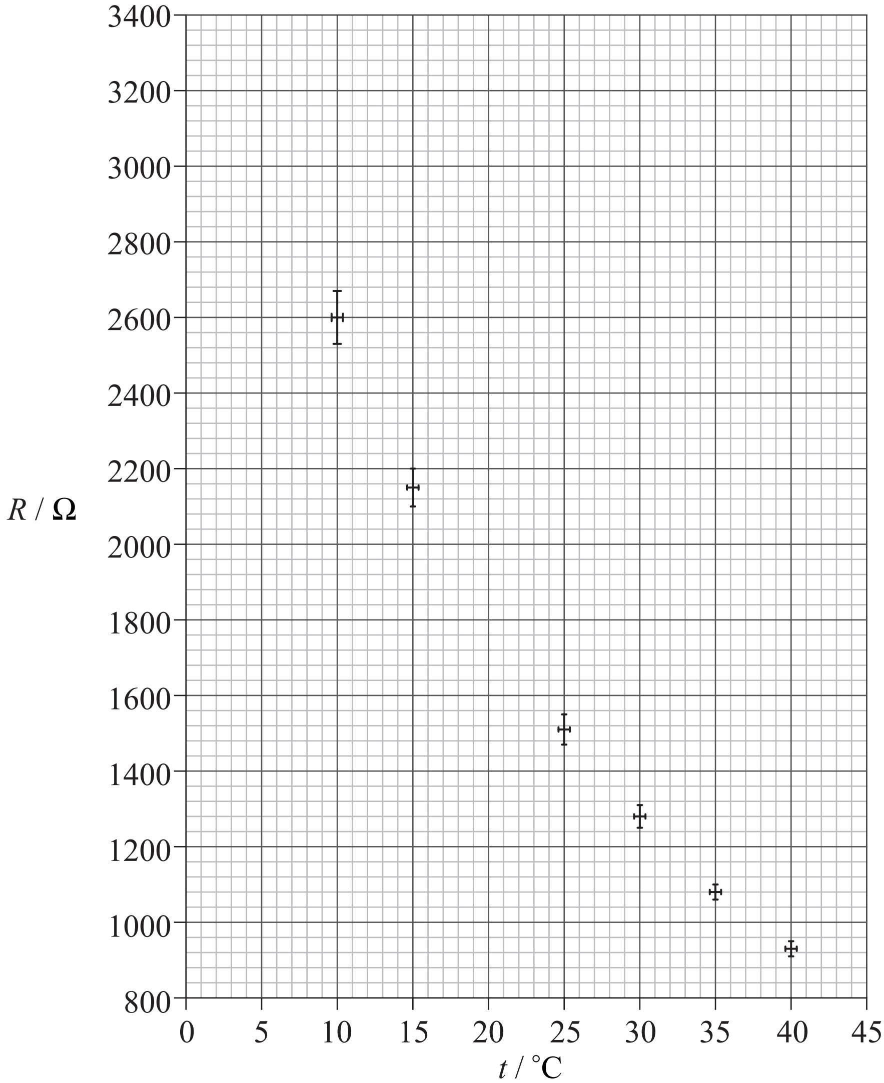
SECTION A

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

A1. Some data for the resistance *R* of an electrical component at different temperatures are shown below.

***t* / °C**	***R* / Ω**
10.0	2600
15.0	2150
25.0	1510
30.0	1280
35.0	1080
40.0	925

A graph of the variation with temperature *t* of the resistance *R* of the component is shown below. Error bars have been included.



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(Question A1 continued)

(a) Estimate the uncertainty range in the temperature measurements. *[1]*

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(b) Use the graph to determine the

(i) most probable resistance of the component at 20.0 ˚C and at 5.0 ˚C.

Resistance at 20.0 ˚C . . . . *[1]*

Resistance at 5.0 ˚C . . . . *[2]*

(ii) rate of change of resistance with temperature at 20.0 ˚C. *[3]*

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(c) The relationship between resistance and temperature is not linear. Describe, and explain, the evidence for a non-linear relationship that is provided by the graph. *[2]*

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(Question A1 continued)

(d) A student suggests that the relationship between the resistance R and temperature is of the form

$$R = \frac{c}{T}$$

where c is a constant and T is the thermodynamic (absolute) temperature.

Use data from the table to determine, without drawing a graph, whether this suggestion is correct. *[3]*

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A2. The resistive force F that acts on an object moving at speed v in a stationary fluid of constant density is given by the expression

$$F = kv^2$$

where k is a constant.

(a) State the derived units of

(i) force F. *[1]*

. . . .

(ii) speed v. *[1]*

. . . .

(b) Use your answers in (a) to determine the derived units of k. *[1]*

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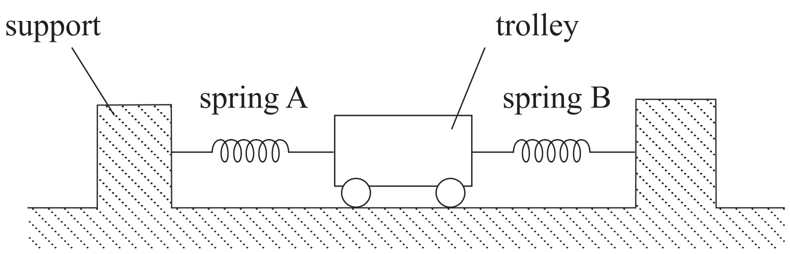
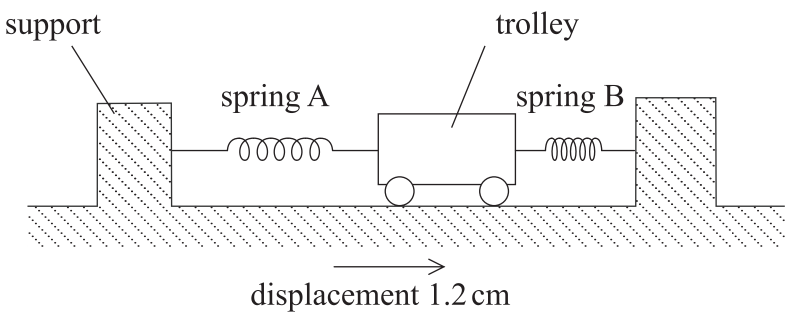
A3. Two identical springs A and B each have a force constant (force per unit extension) of $2.5\,\mathrm{N\,cm^{-1}}$. One end of each spring is attached to a trolley and the other ends are attached to rigid supports, as shown.



The springs are horizontal and, when the trolley is at rest, the extension of each spring is 3.0 cm. The trolley is displaced 1.2 cm to the right.



(a) Calculate the magnitude of the force on the trolley due to

(i) spring A alone. *[2]*

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. . . .

(ii) spring B alone. *[1]*

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(b) The trolley is released. Determine the initial acceleration of the trolley of mass 0.75 kg. *[2]*

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A4. An uncharged gold-leaf electroscope is shown in diagram 1.

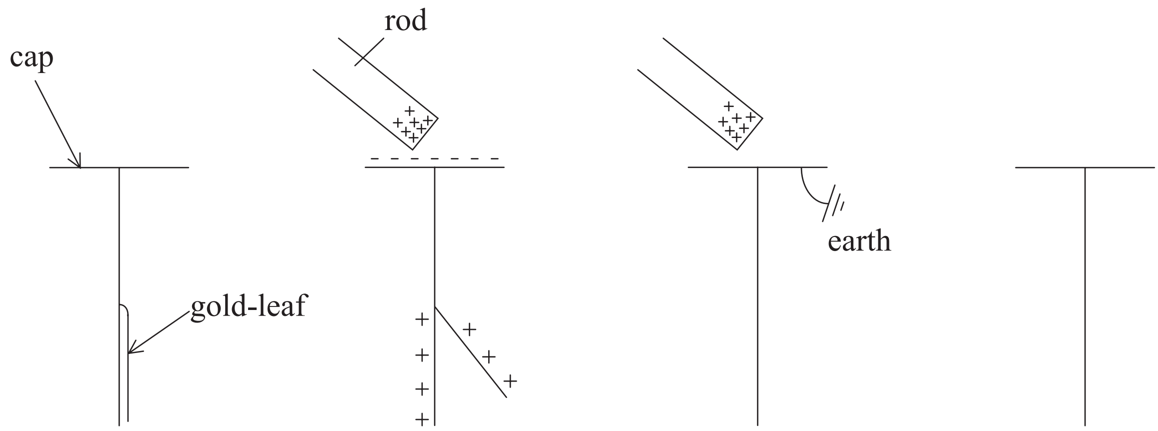

diagram 1		diagram 2		diagram 3		diagram 4

A positively charged rod is brought near to the cap of the electroscope. The gold-leaf diverges and the distribution of charge on the electroscope is shown in diagram 2.

(a) The cap of the electroscope is now earthed. On **diagram 3**, draw the position of the gold-leaf and the distribution of charge on the electroscope. *[2]*

(b) The earth in (a) as well as the rod are now removed. On **diagram 4**, draw the position of the gold-leaf and the final distribution of charge on the electroscope. *[2]*

(c) Suggest, by reference to your diagrams, whether the divergence of the gold-leaf gives a measure of the charge on the electroscope. *[1]*

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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 momentum and **Part 2** is about force fields.

Part 1 Momentum

(a) Define

(i) *linear momentum.* *[1]*

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(ii) *impulse.* *[1]*

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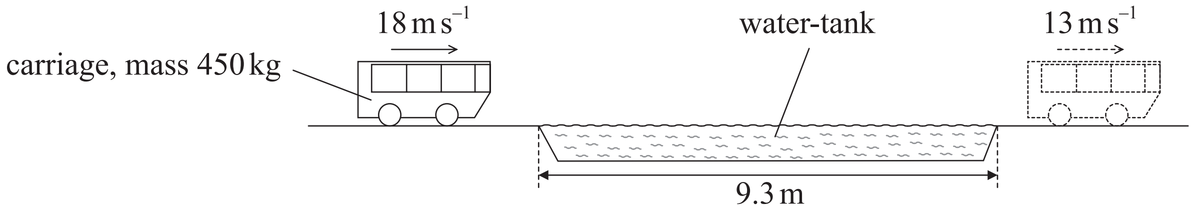
(This question continues on the following page)

(Question B1, part 1 continued)

(b) In a ride in a pleasure park, a carriage of mass 450 kg is travelling horizontally at a speed of 18 m s^{-1}. It passes through a shallow tank containing stationary water. The tank is of length 9.3 m. The carriage leaves the tank at a speed of 13 m s^{-1}.



As the carriage passes through the tank, the carriage loses momentum and causes some water to be pushed forwards with a speed of 19 m s^{-1} in the direction of motion of the carriage.

(i) For the carriage passing through the water-tank, deduce that the magnitude of its total change in momentum is 2250 N s. *[1]*

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(ii) Use the answer in (b)(i) to deduce that the mass of water moved in the direction of motion of the carriage is approximately 120 kg. *[2]*

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(iii) Calculate the mean value of the magnitude of the acceleration of the carriage in the water. *[3]*

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(This question continues on the following page)

(Question B1, part 1 continued)

(c) For the carriage in (b) passing through the water-tank, determine

(i) its total loss in kinetic energy. *[3]*

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(ii) the gain in kinetic energy of the water that is moved in the direction of motion of the carriage. *[1]*

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(d) By reference to the principles of conservation of momentum and of energy, explain your answers in (c). *[3]*

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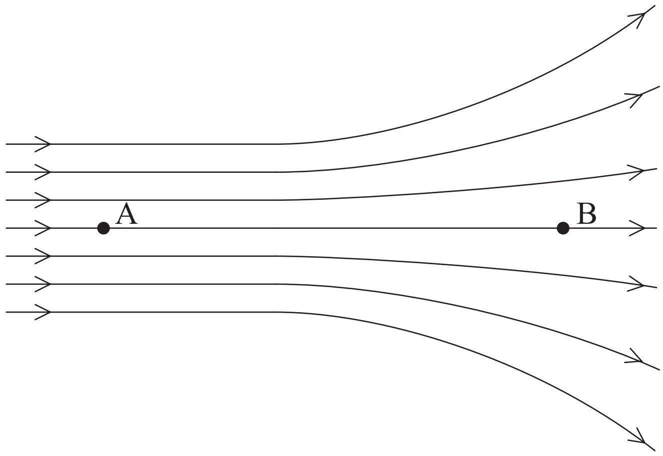
(Question B1 continued)

Part 2 Force fields

(a) Electric fields and magnetic fields may be represented by lines of force. The diagram below shows some lines of force.



(i) State whether the field strength at A and at B is constant, increasing **or** decreasing when measured in the direction from A towards B. *[2]*

at A: . . . .

at B: . . . .

(ii) Explain why field lines can never touch or cross. *[2]*

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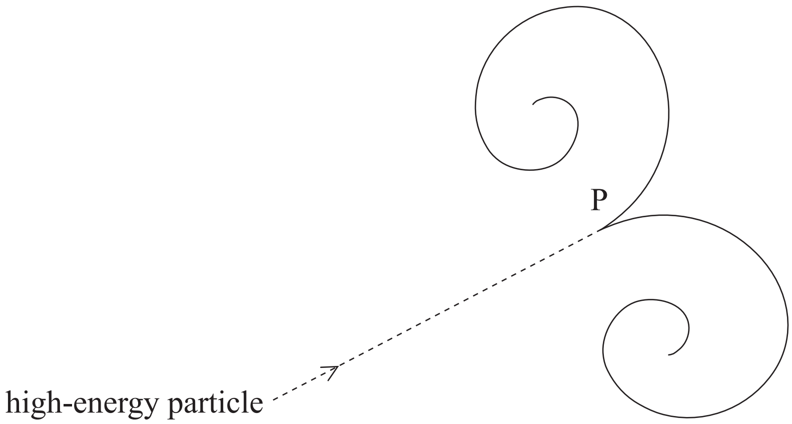
(This question continues on the following page)

(Question B1, part 2 continued)

(b) A bubble chamber is an apparatus that is used to show the paths of particles. A high-energy particle enters the chamber and, at a point P, there is a reaction that gives rise to two charged particles. The tracks of the particles are shown below.



There is a uniform field of force acting normally to the plane of the paper.

(i) State, and explain, whether the field of force is electric **or** magnetic. *[2]*

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(ii) The path of each of the two particles produced in the reaction is a spiral. One particle is spiralling clockwise, the other anti-clockwise. Suggest why they spiral in opposite directions. *[1]*

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(iii) Outline why each path is a spiral, rather than a circle. *[3]*

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B2. This question is in **two** parts. **Part 1** is about latent heat and specific heat and **Part 2** is about linear motion.

Part 1 Latent heat and specific heat

(a) (i) Define *specific latent heat of vaporization*. *[2]*

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(ii) Energy is supplied to a boiling liquid at a constant rate. Describe, in terms of molecular behaviour, why the temperature of the liquid remains constant. *[3]*

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(This question continues on the following page)

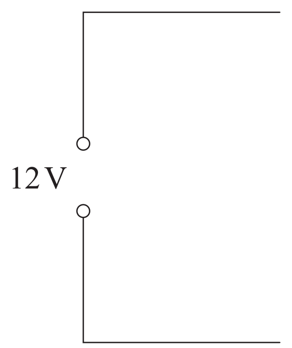
(Question B2, part 1 continued)

(b) A student determines the latent heat of vaporization of water by an electrical method. An electrical heater is used to boil water. When the water is boiling at a steady rate, the mass of water evaporated per minute is determined. The mass is determined for two different powers of the heater and the results are shown in the table below.

power of heater / *W*	**mass of water evaporated per minute / *g***
80.0	1.89
35.0	0.70

The power of the heater is determined using an ammeter and a voltmeter.

(i) The heater is labelled 9.0 V, 80.0 W. In the space below, draw an electrical circuit to show how the heater may be used correctly with a constant 12 V supply to provide different powers to the heater. Include the ammeter and voltmeter in your circuit. *[2]*



(ii) Calculate the current in the heater for a power output of 80.0 W. *[2]*

(iii) Use the data in the table above to determine a value for the specific latent heat of vaporization of water. *[4]*

(This question continues on the following page)

(Question B2, part 1 continued)

(c) In one particular make of electric kettle, the heater must always be immersed in water when the kettle is in use. The minimum volume of water that can be heated is $650\,cm^3$.

The kettle is used six times each day to boil water for a single cup of tea. The cup has a volume of $350\,cm^3$. The mass of $1.0\,cm^3$ of water is 1.0 g.

(i) Calculate the mass of water that is heated, but not used, during one day. *[1]*

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(ii) The initial temperature of the water in the kettle before heating is 18°C. The specific heat capacity of water is $4.2 \times 10^3\,J\,kg^{-1}\,K^{-1}$. Deduce that the electrical energy wasted each day is $6.2 \times 10^5\,J$. *[1]*

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(iii) The cost of 1.0 MJ of electrical energy is 3.5 cents. Estimate the cost of the energy that is used each year to heat water that is not used to make tea. *[2]*

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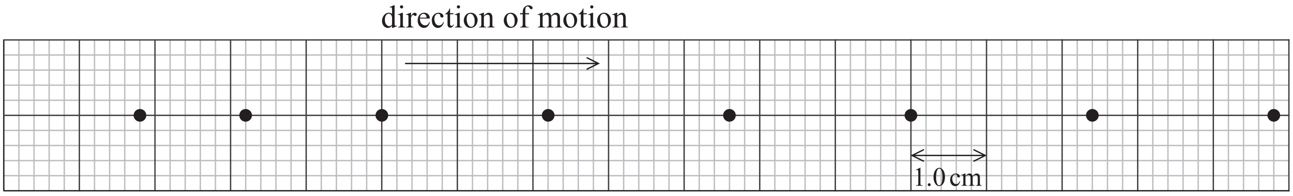
(This question continues on the following page)

(Question B2 continued)

Part 2 Linear motion

A car moves along a straight road. At time $t=0$ the car starts to move from rest and oil begins to drip from the engine of the car. One drop of oil is produced every 0.80 s. Oil drops are left on the road. The position of the oil drops are drawn to scale on the grid below such that 1.0 cm represents 4.0 m. The grid starts at time $t=0$.



(a) (i) State the feature of the diagram above which indicates that, initially, the car is accelerating. *[1]*

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(ii) On the grid above, draw further dots to show where oil would have dripped if the drops had been produced from the time when the car had started to move. *[2]*

(iii) Determine the distance moved by the car during the first 5.6 s of its motion. *[1]*

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(b) Using information from the grid above, determine for the car,

(i) the final constant speed. *[2]*

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(ii) the initial acceleration. *[2]*

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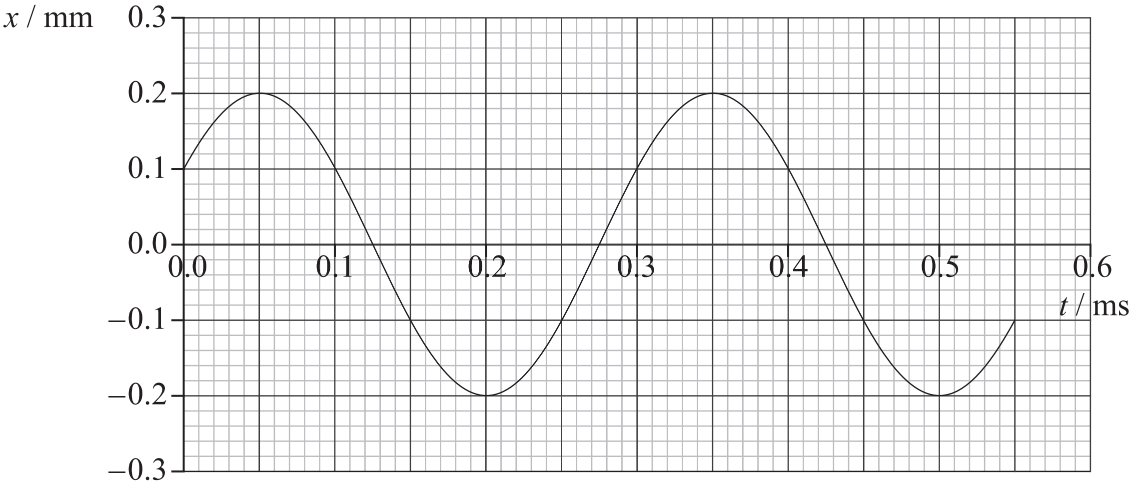
B3. This question is in **two** parts. **Part 1** is about waves and **Part 2** is about nuclear decay.

Part 1 Waves

(a) The graph below shows the variation with time *t* of the displacement *x* of one particle in a sound wave.



The speed of the wave is $380\,m\,s^{-1}$.

(i) Suggest, by marking the letter C on the *t*-axis of the graph above, one time at which the particle could be at the centre of a compression. *[1]*

(ii) State the amplitude of this sound wave. *[1]*

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(iii) Deduce the wavelength of the wave. *[3]*

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(Question B3, part 1 continued)

(b) (i) Outline the conditions necessary for the formation of a standing (stationary) wave. *[2]*

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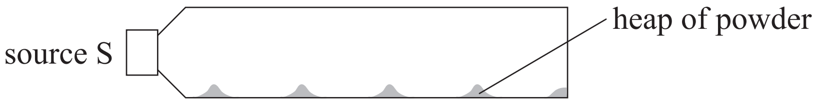
(ii) A horizontal tube, closed at one end, has some fine powder sprinkled along its length. A source S of sound is placed at the open end of the tube, as shown below.



The frequency of the source S is varied. Explain why, at a particular frequency, the powder is seen to form small equally-spaced heaps in the tube. *[2]*

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(iii) The mean separation of the heaps of powder in (b)(ii) is 9.3 cm when the frequency of the source S is 1800 Hz. Calculate the speed of sound in the tube. *[2]*

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(c) The experiment in (b)(ii) is repeated on a day when the temperature of the air in the tube is higher. The mean separation of the heaps is observed to have increased for the same frequency of the source S. Deduce qualitatively the effect, if any, of temperature rise on the speed of the sound in the tube. *[2]*

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(This question continues on the following page)

(Question B3 continued)

Part 2 Nuclear decay

(a) (i) Describe the phenomenon of natural radioactive decay. *[3]*

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(ii) Ionizing radiation is emitted during radioactive decay. Explain what is meant by the term ionizing. *[2]*

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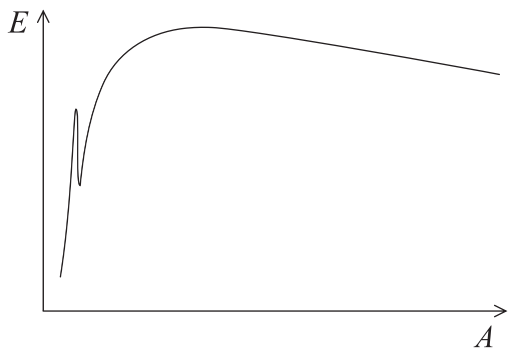
(b) The sketch graph below shows the variation with mass number (nucleon number) A of the binding energy per nucleon E of nuclei.



One possible nuclear reaction that occurs when uranium-235 is bombarded by a neutron to form xenon-142 and strontium-90 is represented as

$$^{235}_{92}\text{U} + ^{1}_{0}\text{n} \rightarrow ^{142}_{54}\text{Xe} + ^{90}_{38}\text{Sr} + 4^{1}_{0}\text{n}.$$

(i) Identify the type of nuclear reaction represented above. *[1]*

. . . .

(ii) On the sketch graph above, identify with their symbols the approximate positions of the uranium (U), the xenon (Xe) and the strontium (Sr) nuclei. *[2]*

(This question continues on the following page)

(Question B3, part 2 continued)

(iii) Data for the binding energies of xenon-142 and strontium-90 are given below.

isotope	**binding energy / MeV**
xenon-142	1189
strontium-90	784.8

The total energy released during the reaction is 187.9 MeV. Determine the binding energy per nucleon of uranium-235. *[3]*

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(iv) State why binding energy of the neutrons formed in the reaction is not quoted. *[1]*

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