



**PHYSICS
HIGHER LEVEL
PAPER 2**

SPECIMEN PAPER

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.

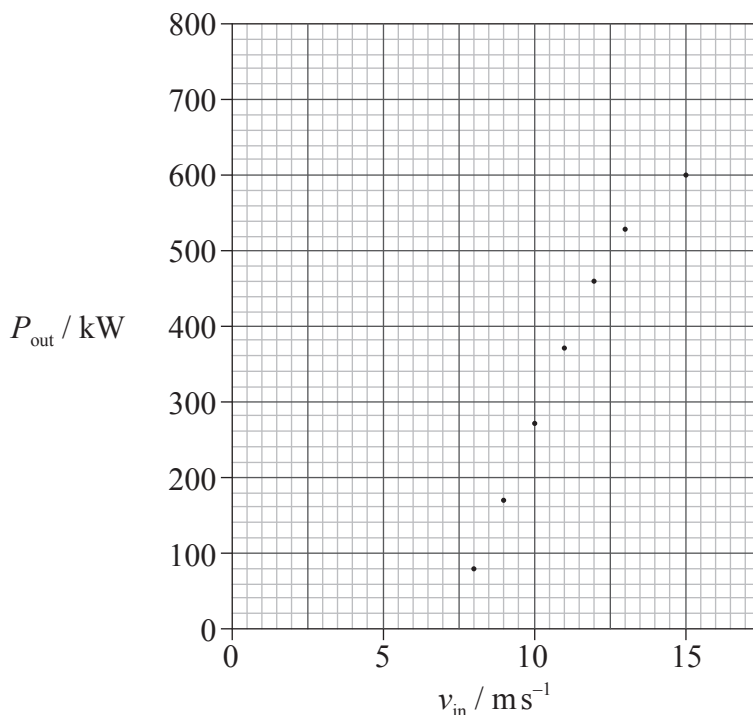
SECTION A

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

A1. This question is about the electrical power available from a wind turbine.

The maximum electrical power generated by a wind turbine, P_{out} , was measured over a range of incident wind speeds, v_{in} .

The graph below shows the variation with v_{in} of P_{out} . Uncertainties for the data are not shown.



(a) It is suggested that P_{out} is proportional to $\sqrt{v_{\text{in}}}$.

(i) Draw the line of best-fit for the data points. [1]

(ii) State **one** reason why the line you have drawn does not support this hypothesis. [1]

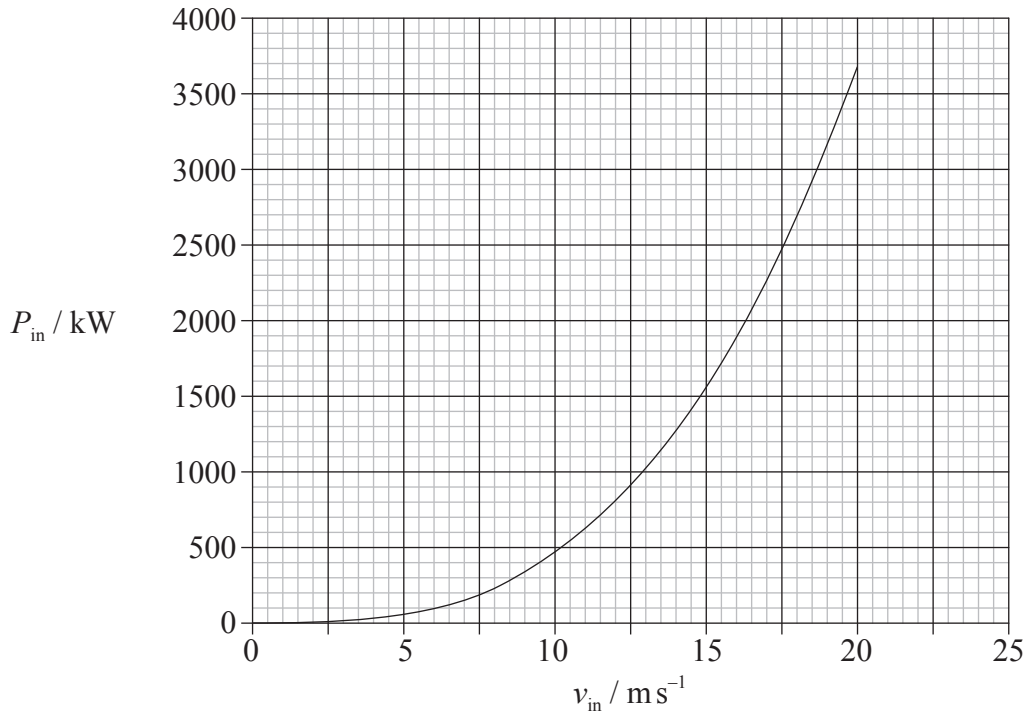
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(iii) The uncertainty in the power at 15 m s^{-1} is 5%. Draw an error bar on the graph to represent this uncertainty. [2]

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(Question A1 continued)

- (b) The theoretical relationship between the available power in the wind, P_{in} , and incident wind speed is shown in the graph below.



Using both graphs,

- (i) determine the efficiency of the turbine for an incident wind speed of 14ms^{-1} . [3]

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- (ii) suggest, without calculation, how the efficiency of the turbine changes with increasing wind speed. [3]

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(Question A1 continued)

- (c) Outline **one** advantage and **one** disadvantage of using wind turbines to generate electrical energy. [2]

Advantage:

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Disadvantage:

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A2. This question is about radioactivity.

- (a) Outline a method for the measurement of the half-life of a radioactive isotope having a half-life of approximately 10^9 years. [3]

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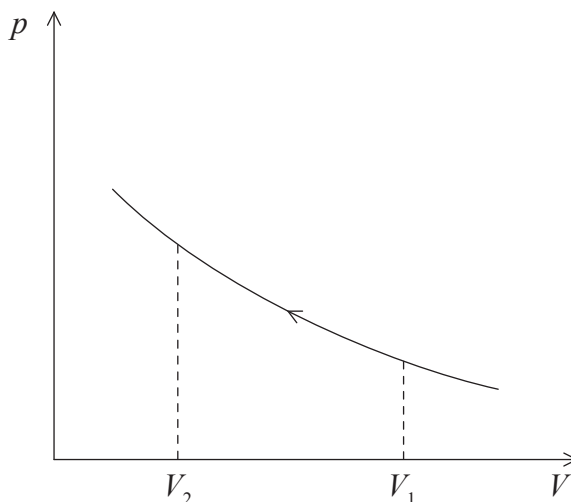
- (b) A radioactive isotope has a half-life $T_{\frac{1}{2}}$. Determine the fraction of this isotope that remains in a particular sample of the isotope after a time of $1.6 T_{\frac{1}{2}}$. [2]

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A3. This question is about an ideal gas and entropy.

- (a) A fixed mass of an ideal gas is compressed from volume V_1 to volume V_2 at constant temperature. The variation with volume V of the pressure p of the gas is shown below.



On the diagram above, draw a line to show the variation of pressure p as the volume of the gas is changed from V_1 to V_2 without allowing any thermal energy to enter or leave the gas. [2]

- (b) On the diagram in (a), identify

- (i) with the letter G, the line that represents the change that requires the greater amount of work done on the gas. [1]
- (ii) by shading an area of the diagram, the part of the diagram that represents the difference between the work done in the two changes. [1]

- (c) For the compression of the gas at constant temperature, deduce what change, if any, occurs in the entropy of the gas and of its surroundings. [3]

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the surroundings:

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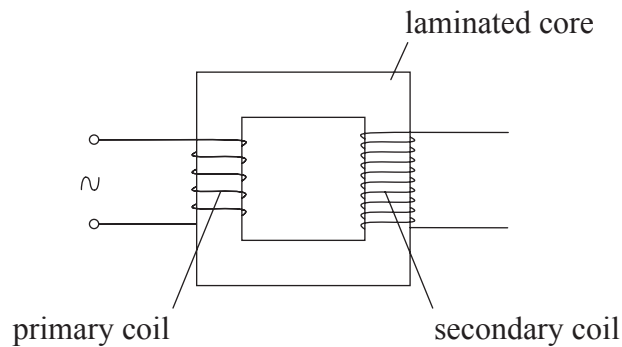


A4. This question is about an ideal transformer.

(a) State Faraday’s law of electromagnetic induction. [2]

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(b) The diagram below shows an ideal transformer.



(i) Use Faraday’s law to explain why, for normal operation of the transformer, the current in the primary coil must vary continuously. [2]

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(ii) Outline why the core is laminated. [2]

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(iii) The primary coil of an ideal transformer is connected to an alternating supply rated at 230V. The transformer is designed to provide power for a lamp rated as 12V, 42W and has 450 turns of wire on its secondary coil. Determine the number of turns of wire on the primary coil and the current from the supply for the lamp to operate at normal brightness. [3]

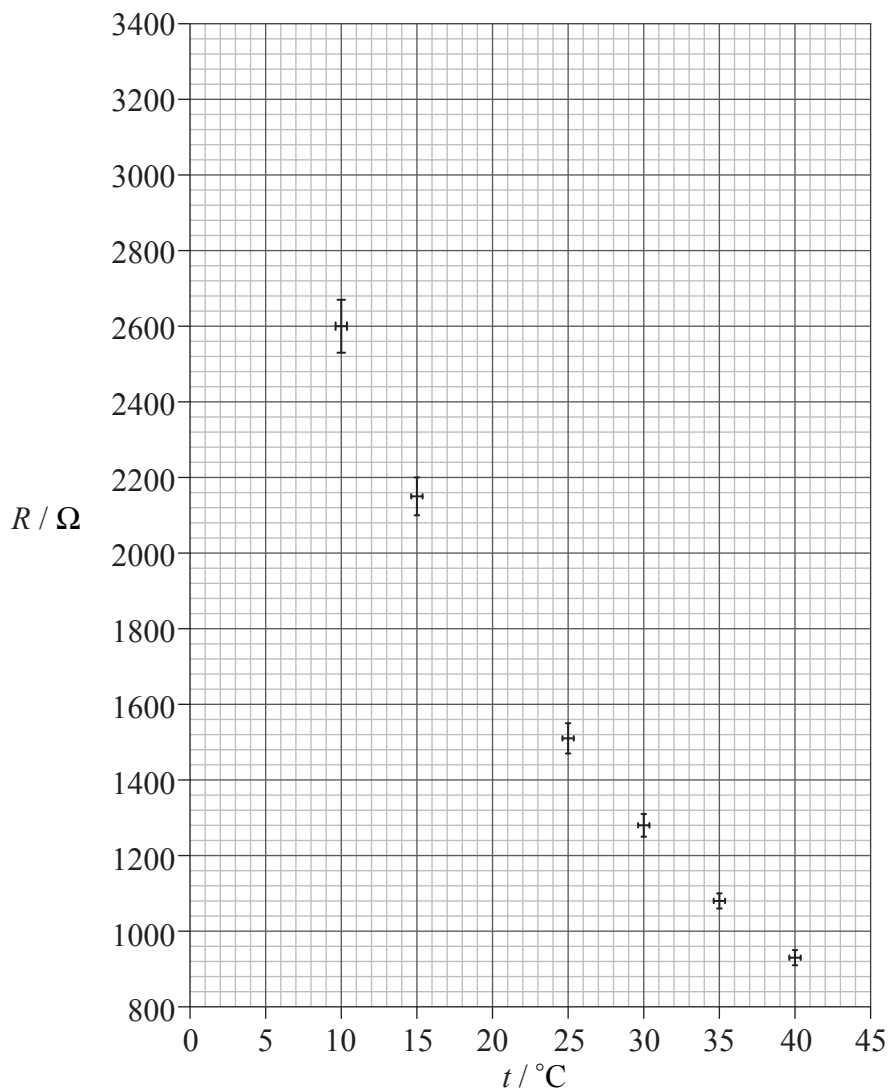
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A5. Some data for the resistance R of an electrical component at different temperatures are shown below.

$t / ^\circ\text{C}$	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.



(This question continues on the following page)



(Question A5 continued)

(a) Estimate the

(i) uncertainty range in the temperature measurements. [1]

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(ii) percentage uncertainty in the resistance at 10.0°C. [2]

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(b) - has been omitted from this problem

(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 A5 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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SECTION B

This section consists of three questions: B1, B2, B3. Answer two questions.

B1. This question is in two parts. Part 1 is about units and momentum
Part 2 is about simple harmonic motion and its connection with the greenhouse effect.

Part 1 Units and momentum

(a) Distinguish between fundamental units and derived units. [1]

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(b) The rate of change of momentum R of an object moving at speed v in a stationary fluid of constant density is given by the expression

$$R = kv^2$$

where k is a constant.

(i) State the derived units of speed v . [1]

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(ii) Determine the derived units of R . [2]

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(iii) Use the expression and your answers in (b)(i) and (b)(ii) to determine the derived units of k . [1]

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(Question B1, part 1 continued)

(c) Define

(i) *linear momentum.* [1]

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(ii) *impulse.* [1]

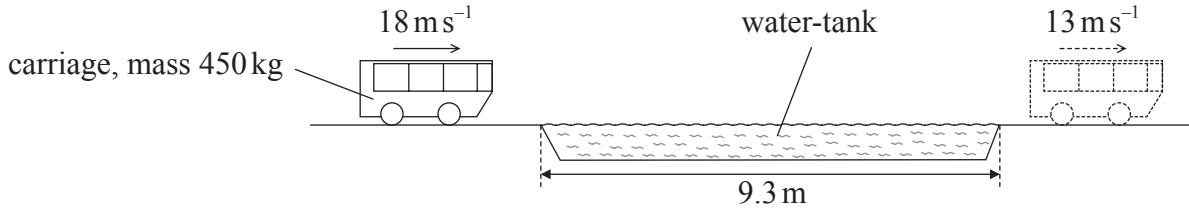
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(Question B1, part 1 continued)

- (d) 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 (d)(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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(Question B1, part 1 continued)

(e) For the carriage in (d) 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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(f) By reference to the principles of conservation of momentum and of energy, explain your answers in (e). [3]

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B1.

Part 2 Simple harmonic motion and the greenhouse effect

(a) A body is displaced from equilibrium. State the **two** conditions necessary for the body to execute simple harmonic motion. [2]

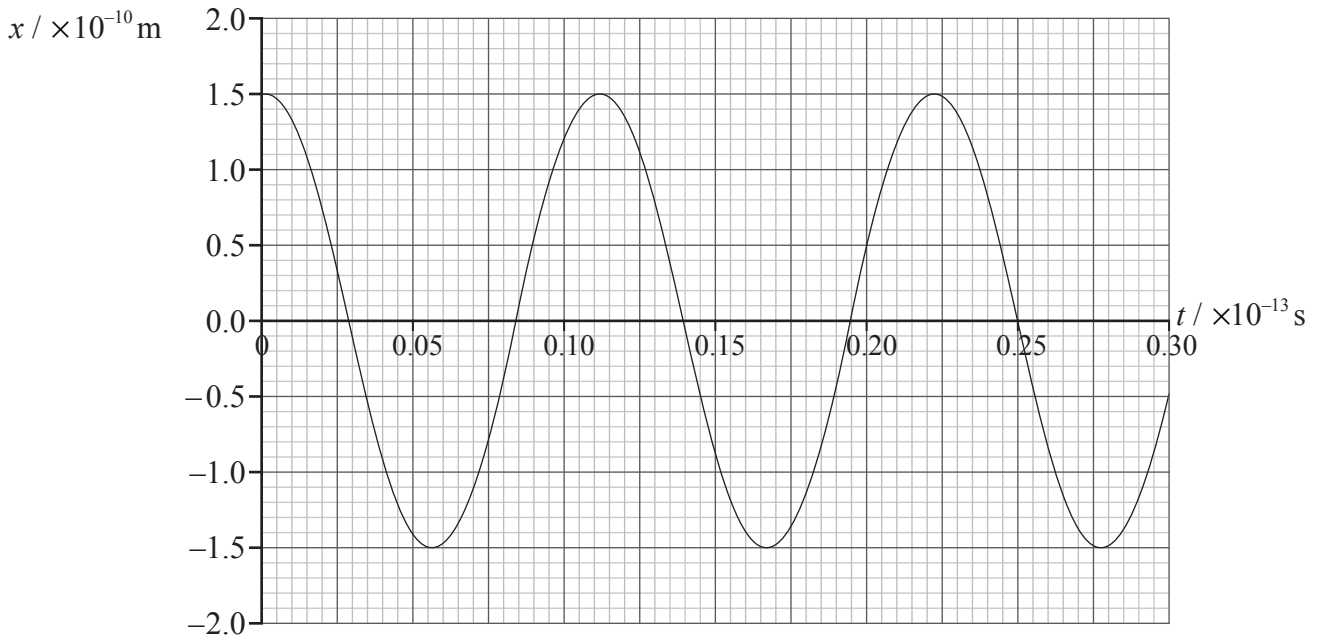
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(Question B1, part 2 continued)

- (b) In a simple model of a methane molecule, a hydrogen atom and the carbon atom can be regarded as two masses attached by a spring. A hydrogen atom is much less massive than the carbon atom such that any displacement of the carbon atom may be ignored.

The graph below shows the variation with time t of the displacement x from its equilibrium position of a hydrogen atom in a molecule of methane.



The mass of hydrogen atom is $1.7 \times 10^{-27} \text{ kg}$. Use data from the graph above

- (i) to determine its amplitude of oscillation. [1]

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- (ii) to show that the frequency of its oscillation is $9.1 \times 10^{13} \text{ Hz}$. [2]

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- (iii) to show that the maximum kinetic energy of the hydrogen atom is $6.2 \times 10^{-18} \text{ J}$. [2]

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(Question B1, part 2 continued)

- (c) Assuming that the motion of the hydrogen atom is simple harmonic, its frequency of oscillation f is given by the expression

$$f = \frac{1}{2\pi} \sqrt{\frac{k}{m_p}},$$

where k is the force per unit displacement between a hydrogen atom and the carbon atom and m_p is the mass of a proton.

- (i) Show that the value of k is approximately 560 N m^{-1} . [1]

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- (ii) Estimate, using your answer to (c)(i), the maximum acceleration of the hydrogen atom. [2]

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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 force fields.

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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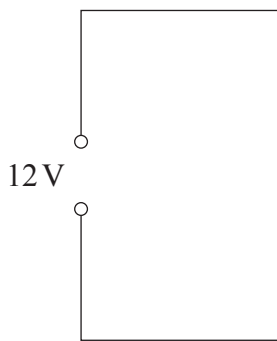
(Question B2, part 1 continued)

- (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]

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

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(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 $4.2 \times 10^3 \text{ J kg}^{-1} \text{ K}^{-1}$. Deduce that the electrical energy wasted each day is $6.2 \times 10^5 \text{ J}$. [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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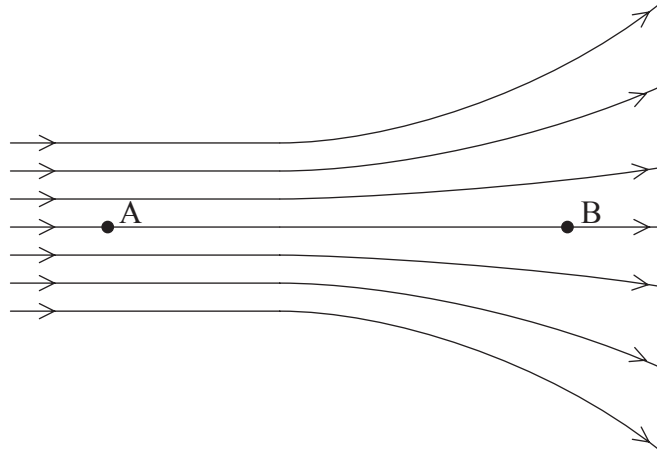
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(Question B2 continued)

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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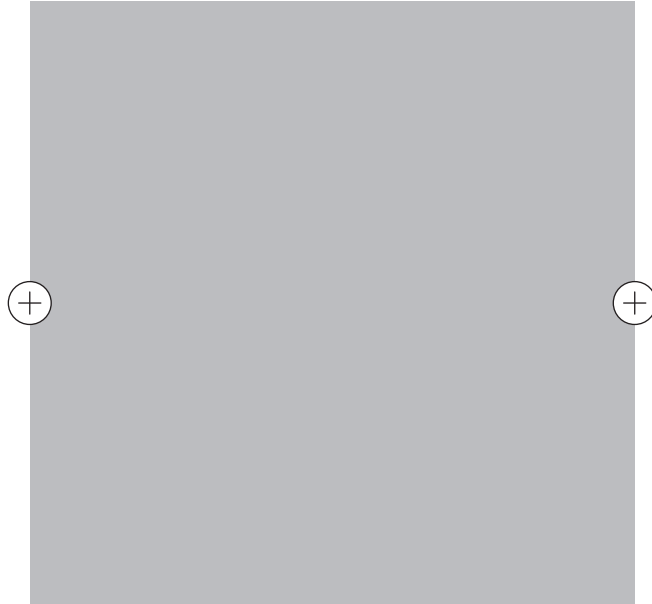
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(Question B2, part 2 continued)

- (iii) The diagram below shows two insulated metal spheres. Each sphere has the same magnitude of positive charge.



In the shaded area between the spheres, draw the electric field pattern due to the two spheres.

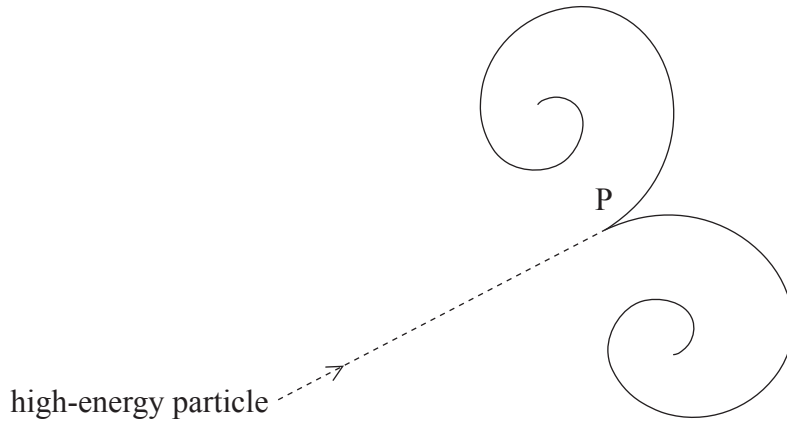
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(Question B2, part 2 continued)

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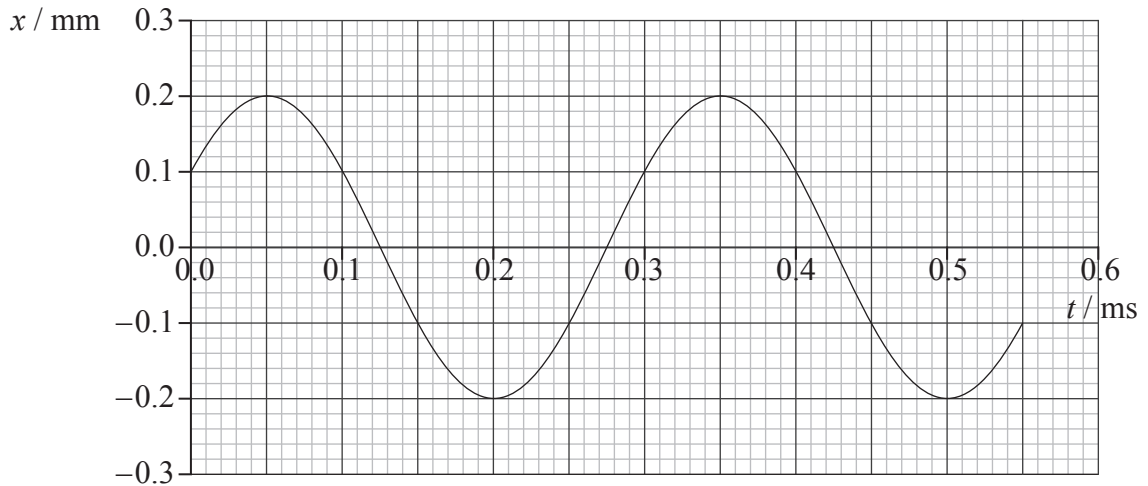
- (iii) Outline why each path is a spiral, rather than a circle. [3]

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

Part 1 Wave phenomena

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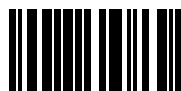
- (c) The experiment in (b)(ii) is repeated on a day when the temperature of the air in the tube is higher. The mean separation of the heaps is observed to have increased for the same frequency of the source S. Deduce qualitatively the effect, if any, of temperature rise on the speed of the sound in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

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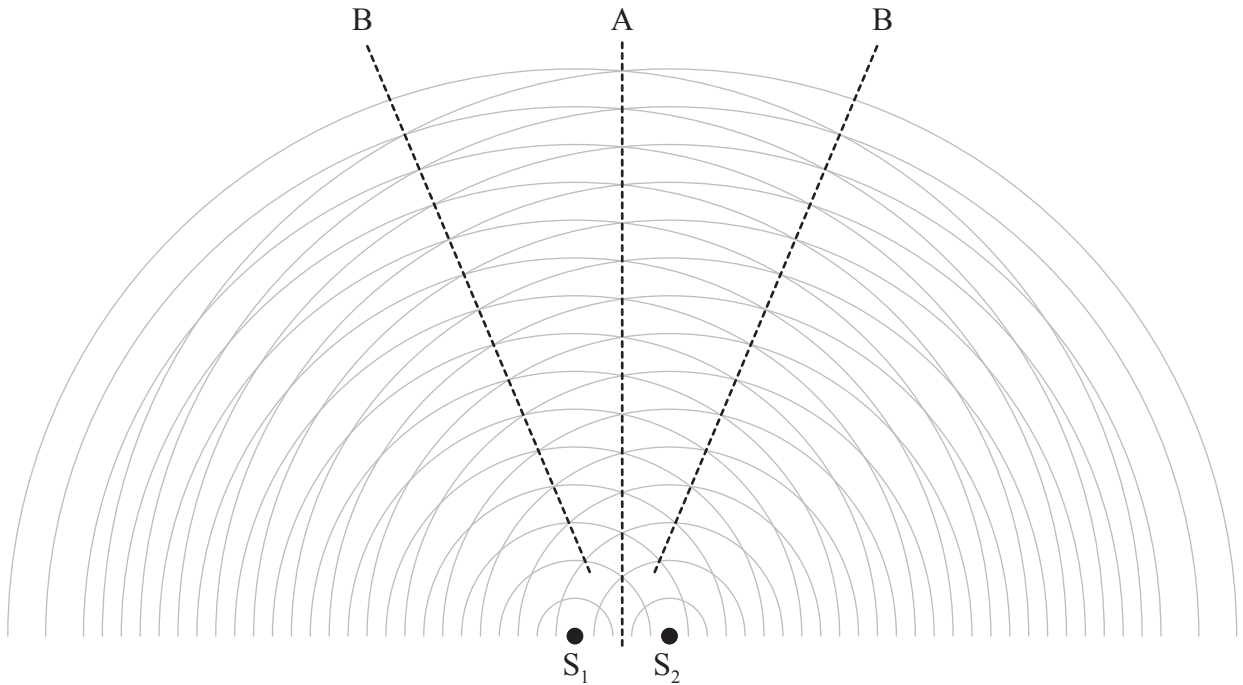
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(Question B3, part 1 continued)

- (d) The diagram below shows wavefronts produced by two sources S_1 and S_2 of sound that are vibrating in phase.



The waves interfere constructively along the lines labelled A and B.

- (i) State what is meant by constructive interference. [3]

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- (ii) On the diagram above, draw another line, labelled C, along which the waves interfere constructively. [1]

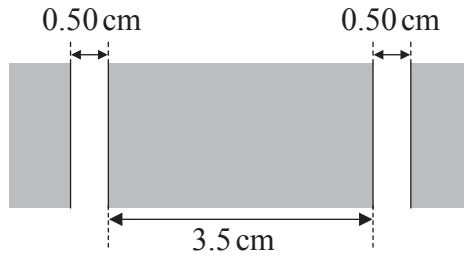
- (iii) On the diagram above, draw another line, labelled D, along which the waves interfere destructively. [1]

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(Question B3, part 1 continued)

- (e) A double slit consists of two slits, each of width 0.50 cm that are 3.5 cm apart, as shown below.



A beam of sound, incident normally to the plane of the double slit, passes through the slits. A detector is moved along a line parallel to the plane of the double slit at a distance of 1.5 m from the slits. The distance between points of maximum sound intensity is 1.2 m. Determine the wavelength of the sound wave. [3]

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(Question B3 continued)

Part 2 Nuclear decay

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

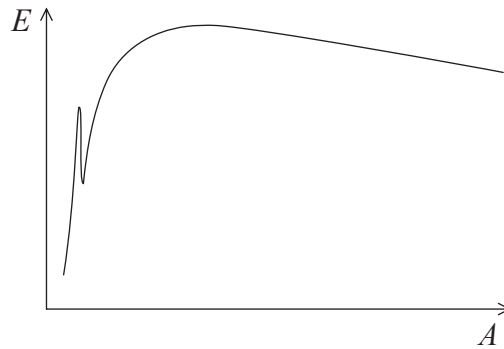
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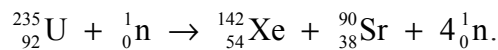
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- (b) The sketch graph below shows the variation with mass number (nucleon number) A of the binding energy per nucleon E of nuclei.



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



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

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- (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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