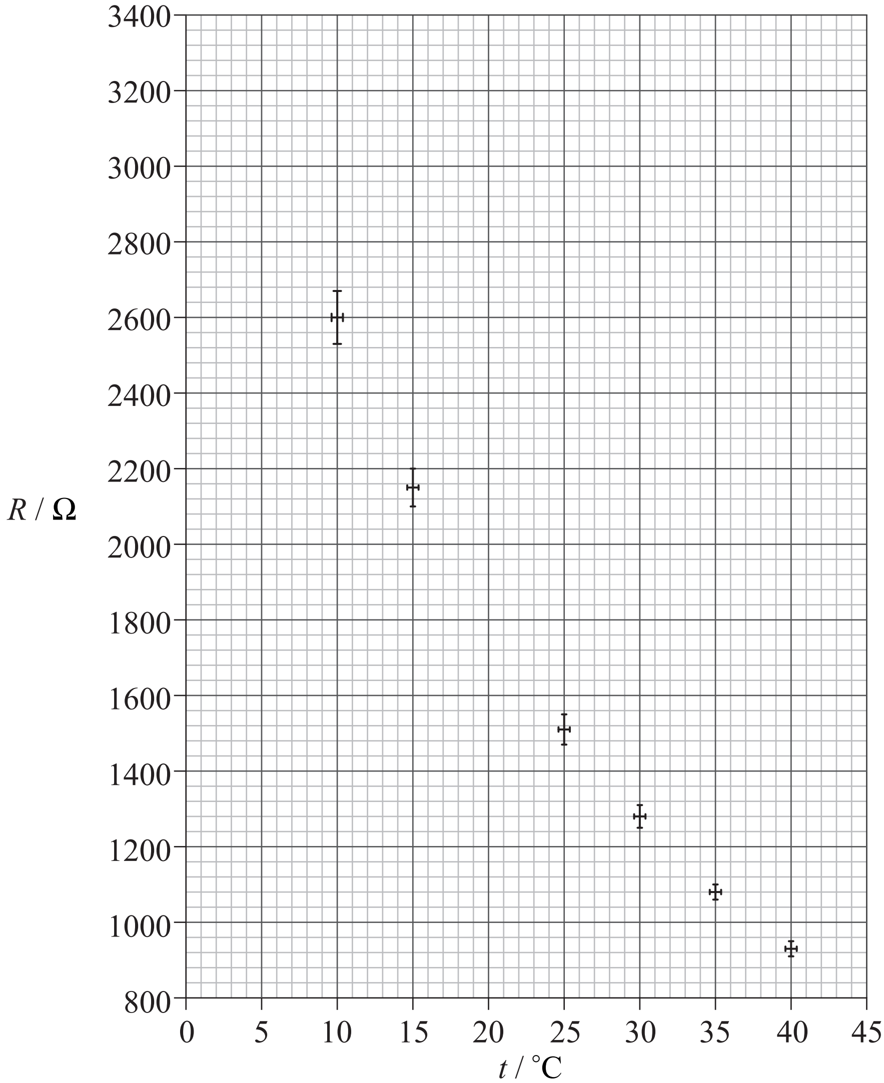
SECTION A

*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.



(This question continues on the following page)

(Question A1 continued)

(a) Estimate the

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

. . . .

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

. . . .

. . . .

. . . .

(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]*

. . . .

. . . .

. . . .

(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]*

. . . .

. . . .

. . . .

(This question continues on the following page)

(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]*

. . . .

. . . .

. . . .

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]*

. . . .

. . . .

. . . .

. . . .

(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]*

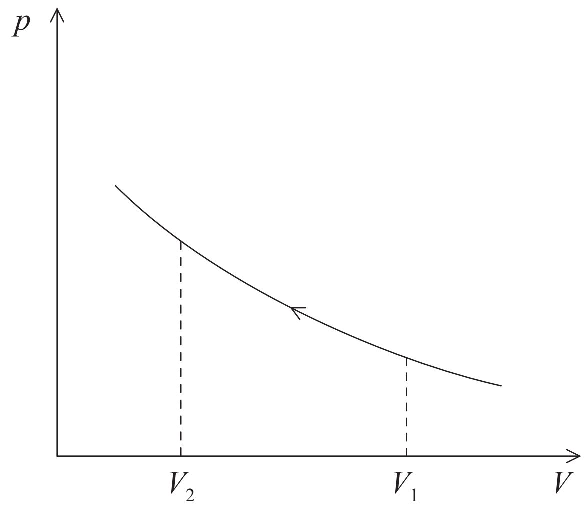
. . . .

. . . .

. . . .

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]*

the gas: . . . .

. . . .

the surroundings: . . . .

. . . .

A4. This question is about an ideal transformer.

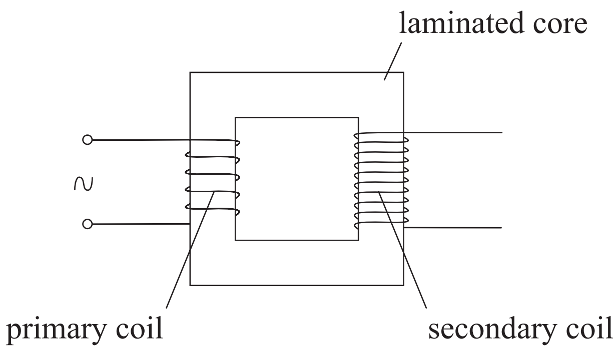
(a) State Faraday's law of electromagnetic induction. *[2]*

. . . .

. . . .

. . . .

(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]*

. . . .

. . . .

. . . .

. . . .

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

. . . .

. . . .

. . . .

(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]*

. . . .

. . . .

. . . .

. . . .

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 units and momentum and **Part 2** is about X-rays.

Part 1 Units and momentum

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

. . . .

. . . .

(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]*

. . . .

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

. . . .

. . . .

. . . .

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

. . . .

. . . .

(This question continues on the following page)

(Question B1, part 1 continued)

(c) Define

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

. . . .

. . . .

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

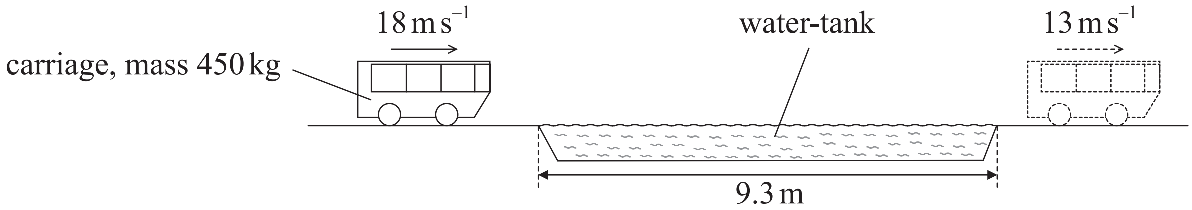
. . . .

. . . .

(This question continues on the following page)

(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]*

. . . .

. . . .

(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]*

. . . .

. . . .

. . . .

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

. . . .

. . . .

. . . .

. . . .

(This question continues on the following page)

(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]*

. . . .

. . . .

. . . .

. . . .

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

. . . .

. . . .

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

. . . .

. . . .

. . . .

. . . .

(This question continues on the following page)

(Question B1 continued)

Part 2 X-rays

(a) Draw a labelled diagram of an experimental arrangement for the production of X-rays. *[4]*

(b) Suggest how each of the following may be controlled.

(i) Intensity of the X-ray beam *[2]*

. . . .

. . . .

. . . .

(ii) Minimum wavelength of X-ray photons *[2]*

. . . .

. . . .

. . . .

(This question continues on the following page)

(Question B1, part 2 continued)

(c) State, and explain, the origin of the continuous part of an X-ray spectrum. *[2]*

. . . .

. . . .

. . . .

Blank page

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]*

. . . .

. . . .

. . . .

(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]*

. . . .

. . . .

. . . .

. . . .

(This question continues on the following page)

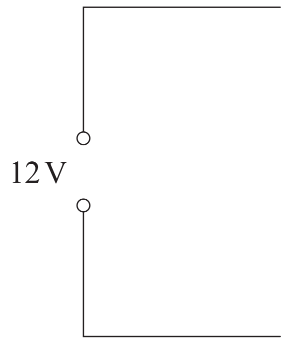
(Question B2, part 1 continued)

(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]*

. . . .

. . . .

(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]*

. . . .

. . . .

. . . .

(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]*

. . . .

. . . .

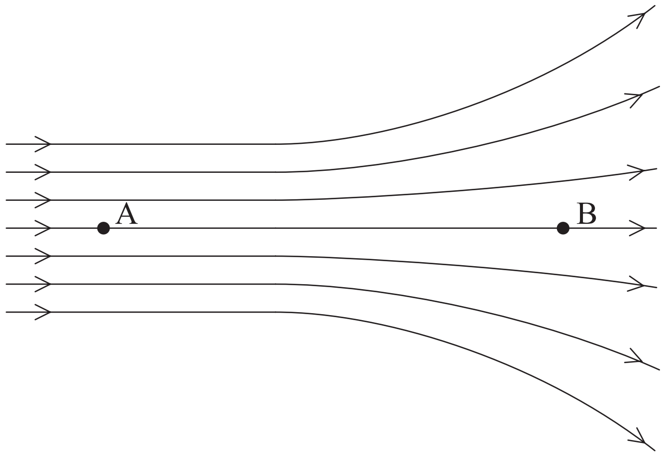
. . . .

(This question continues on the following page)

(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]*

. . . .

. . . .

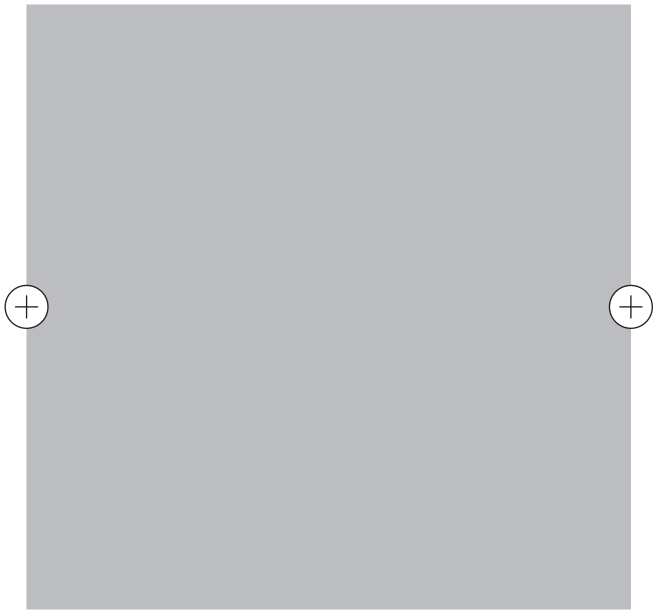
. . . .

. . . .

(This question continues on the following page)

(Question B2, part 2 continued)

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

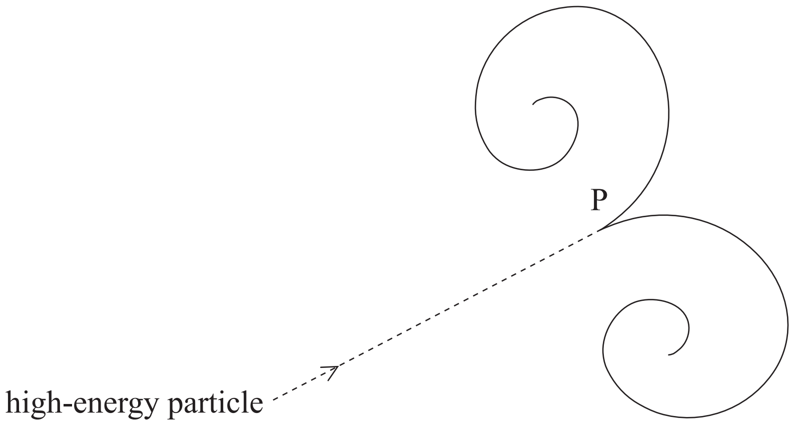


In the shaded area between the spheres, draw the electric field pattern due to the two spheres. *[3]*

(This question continues on the following page)

(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]*

. . . .

. . . .

. . . .

(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]*

. . . .

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

. . . .

. . . .

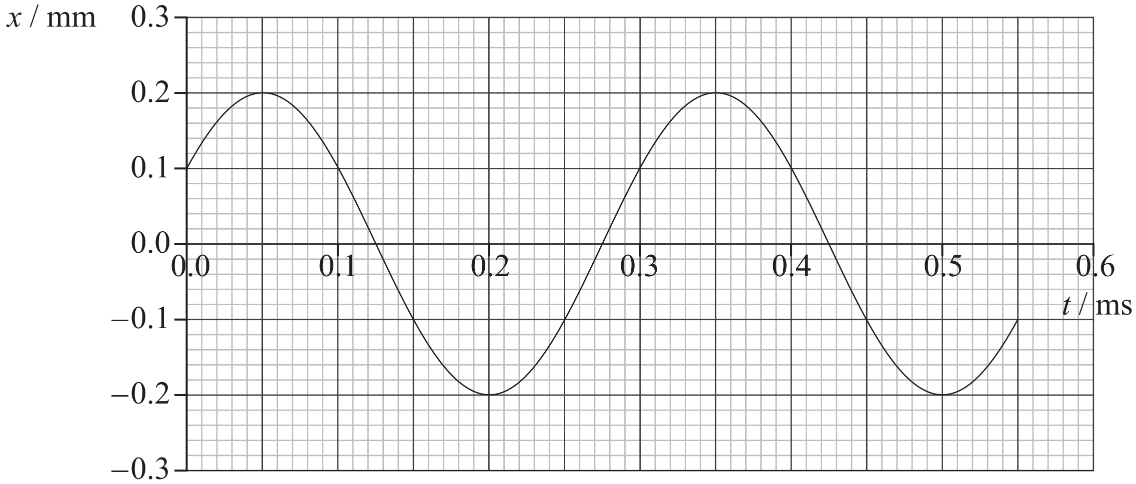
. . . .

Blank page

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 $380\,\text{m}\,\text{s}^{-1}$.

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

. . . .

. . . .

. . . .

. . . .

(This question continues on the following page)

(Question B3, part 1 continued)

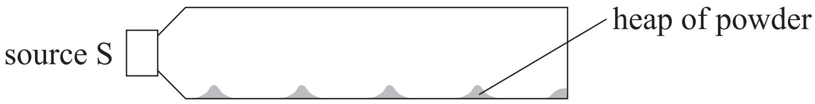
(b) (i) Outline the conditions necessary for the formation of a standing (stationary) wave. *[2]*

. . . .

. . . .

. . . .

(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]*

. . . .

. . . .

. . . .

(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]*

. . . .

. . . .

. . . .

(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]*

. . . .

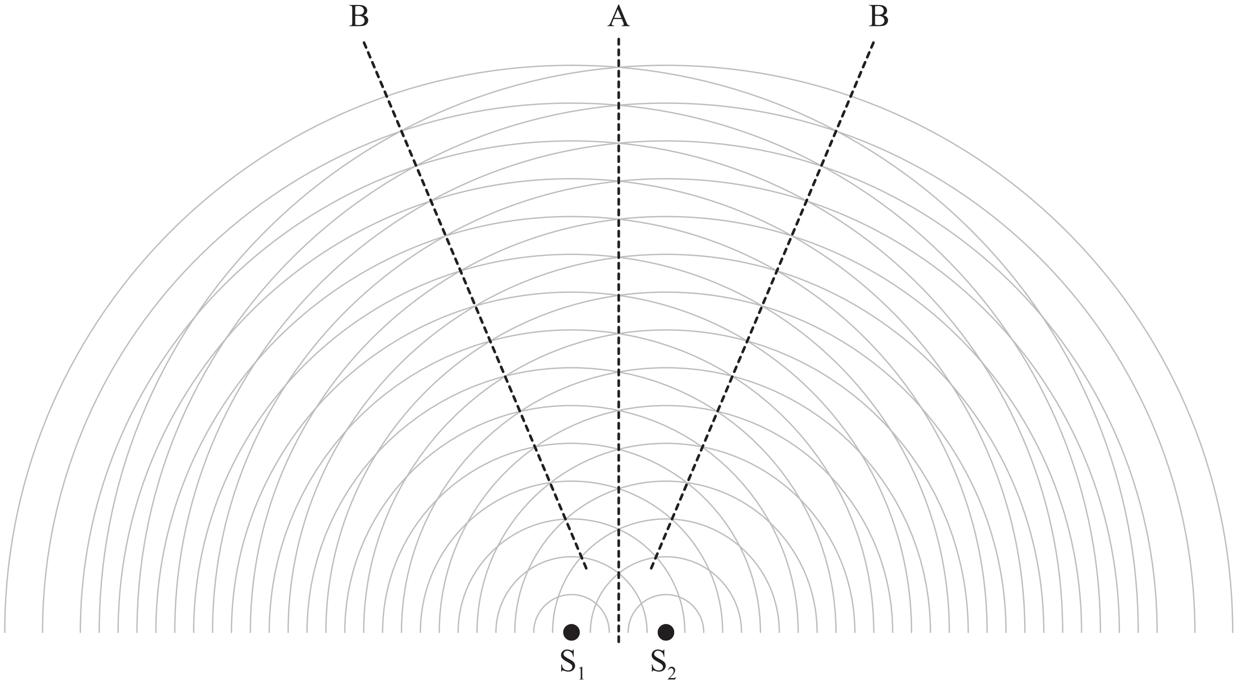
. . . .

. . . .

(This question continues on the following page)

(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]*

. . . .

. . . .

. . . .

. . . .

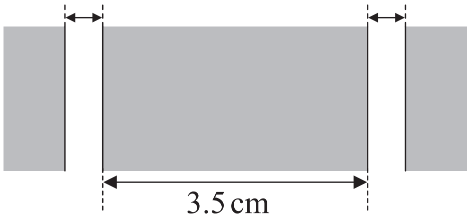
(ii) On the diagram above, draw another line, labelled C, along which the waves interfere constructively. *[1]*

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

(This question continues on the following page)

(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]*

. . . .

. . . .

. . . .

. . . .

(This question continues on the following page)

(Question B3 continued)

Part 2 Nuclear decay

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

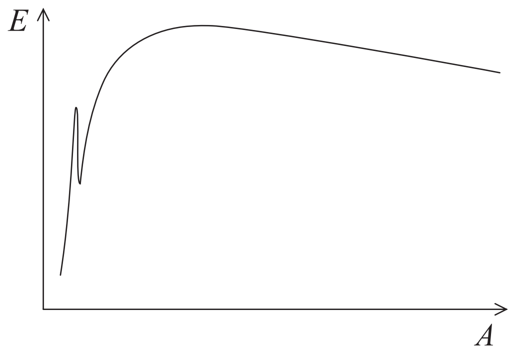
. . . .

. . . .

. . . .

. . . .

(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]*

. . . .

. . . .

. . . .

. . . .

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

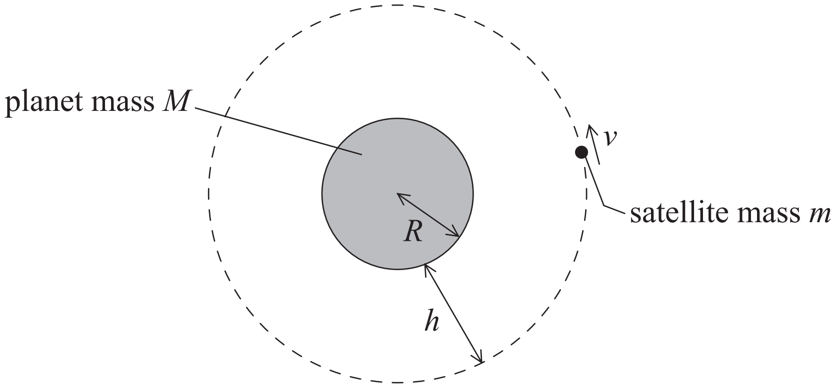
. . . .

. . . .

B4. This question is in **two** parts. **Part 1** is about gravitation and **Part 2** is about linear and circular motion.

Part 1 Gravitation

A spherical planet has radius R and mass M. A satellite of mass m orbits the planet with constant linear speed v at a height h above the planet's surface, as shown below (not to scale).



(a) Outline why

(i) although the satellite is moving at constant speed, it is not in equilibrium. *[2]*

. . . .

. . . .

. . . .

. . . .

(ii) an object in the satellite appears to be weightless. *[3]*

. . . .

. . . .

. . . .

(This question continues on the following page)

(Question B4, part 1 continued)

(b) For the satellite in its orbit,

(i) state an expression, in terms of *M*, *m*, *R* and *h*, for its potential energy. *[1]*

. . . .

. . . .

(ii) derive an expression, using the same terms as in (b)(i), for its kinetic energy. *[3]*

. . . .

. . . .

. . . .

. . . .

(c) The total energy of the satellite is reduced. Use your expressions in (b) to outline what change, if any, occurs in the radius of the orbit and the speed of the satellite. *[4]*

. . . .

. . . .

. . . .

. . . .

. . . .

(d) The force of friction between the satellite and the atmospheric air increases as the speed of the satellite increases. By reference to your answer in (c), suggest why small satellites will "burn up" as they re-enter the Earth's atmosphere. *[4]*

. . . .

. . . .

. . . .

. . . .

. . . .

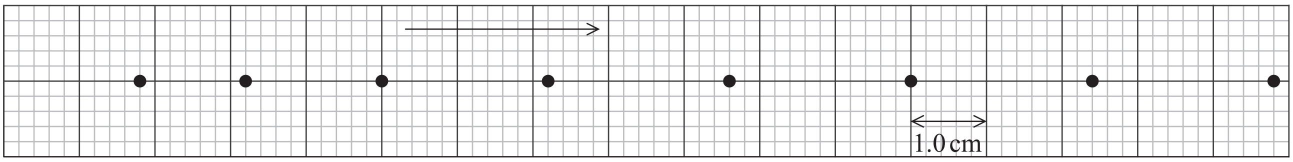
(This question continues on the following page)

(Question B4 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 $t=0$.

direction of motion



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

. . . .

(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]*

. . . .

. . . .

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

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

. . . .

. . . .

. . . .

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

. . . .

. . . .

. . . .

(This question continues on the following page)

(Question B4, part 2 continued)

(c) The car then turns a corner at constant speed. Passengers in the car who were sitting upright feel as if their upper bodies are being "thrown outwards".

(i) Identify the force acting on the car, and its line of action, that enables the car to turn the corner. *[2]*

. . . .

. . . .

. . . .

(ii) Explain why the passengers feel as if they are being "thrown outwards". *[3]*

. . . .

. . . .

. . . .

. . . .