Electricity-practice-1-Extended *[180 marks]*

A heater in an electric shower has a power of 8.5 kW when connected to a 240 V electrical supply. It is connected to the electrical supply by a copper cable.

The following data are available:

Length of cable = 10 m
Cross-sectional area of cable = 6.0 mm^2
Resistivity of copper = 1.7×10^{-8} Ω m

1a. Calculate the current in the copper cable. *[1 mark]*

1b. Calculate the resistance of the cable. *[2 marks]*

1c. Explain, in terms of electrons, what happens to the resistance of the cable as the temperature of the cable increases. *[3 marks]*

1d. The heater changes the temperature of the water by 35 K. The specific heat capacity of water is 4200 J kg^{-1} K^{-1}. *[4 marks]*

Determine the rate at which water flows through the shower. State an appropriate unit for your answer.

2a. State the quark structures of a meson and a baryon. *[2 marks]*

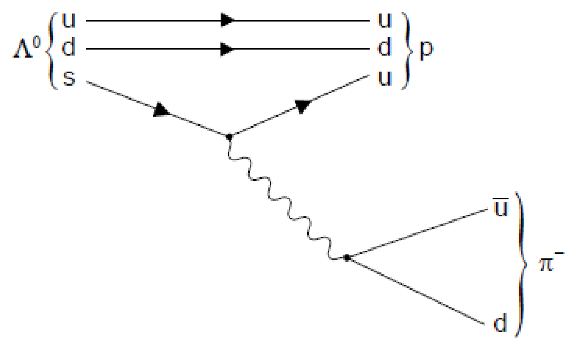
Meson: . . . .

. . . .

Baryon: . . . .

. . . .

A possible decay of a lambda particle (Λ^0) is shown by the Feynman diagram.



2b. Explain which interaction is responsible for this decay. *[2 marks]*

2c. Draw arrow heads on the lines representing $\bar{u}$ and d in the π^-. *[1 mark]*

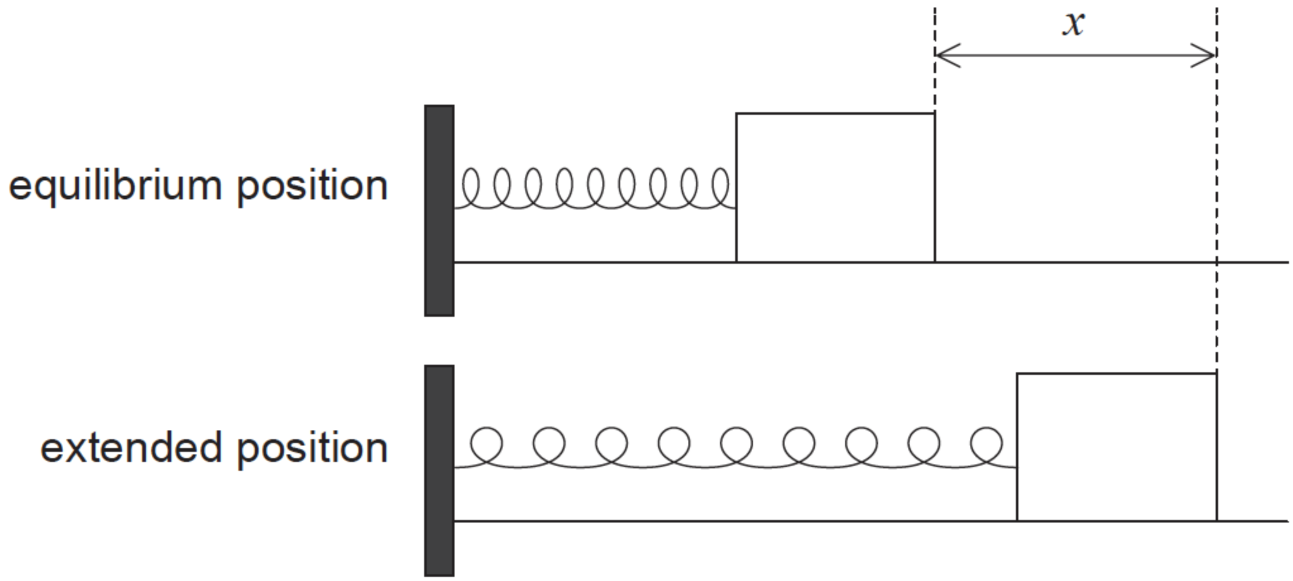
2d. Identify the exchange particle in this decay. *[1 mark]*

2e. Outline **one** benefit of international cooperation in the construction or use of high-energy particle accelerators. *[1 mark]*

This question is in two parts. **Part 1** is about simple harmonic motion (SHM). **Part 2** is about current electricity.

Part 1 Simple harmonic motion (SHM)

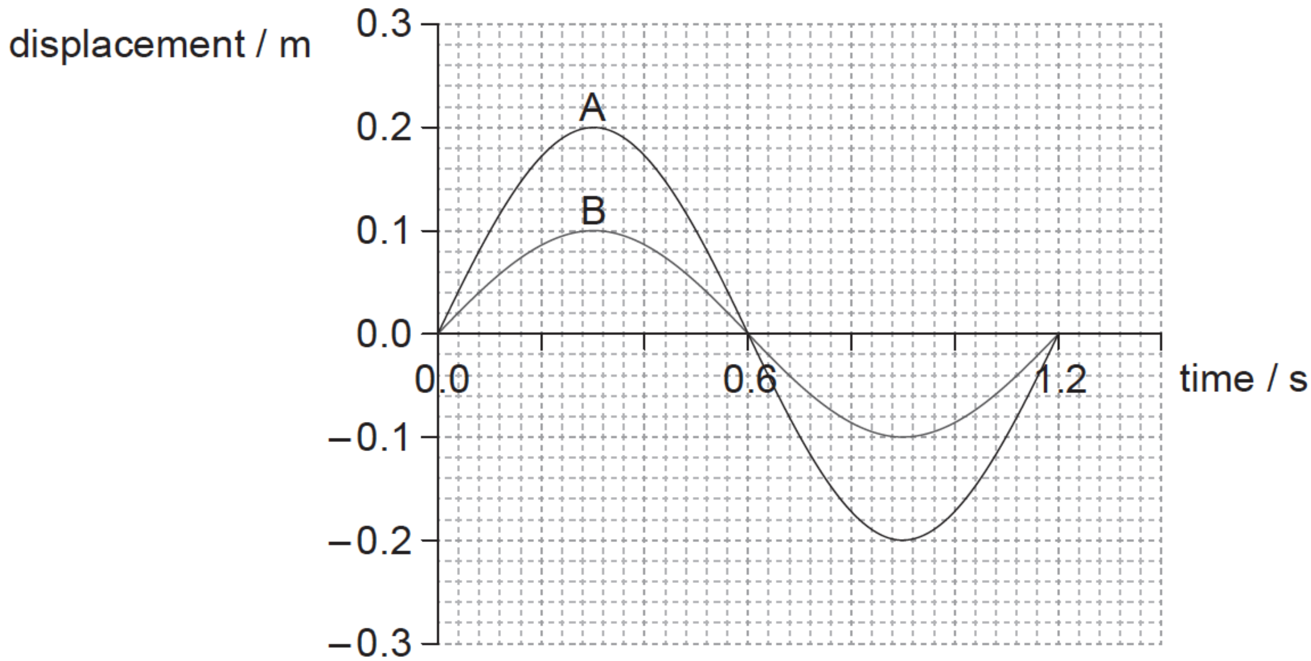
An object is placed on a frictionless surface. The object is attached by a spring fixed at one end and oscillates at the end of the spring with simple harmonic motion (SHM).



The tension F in the spring is given by $F = k\,x$ where x is the extension of the spring and k is a constant.

3a. Show that $\omega^2 = \frac{k}{m}$. *[2 marks]*

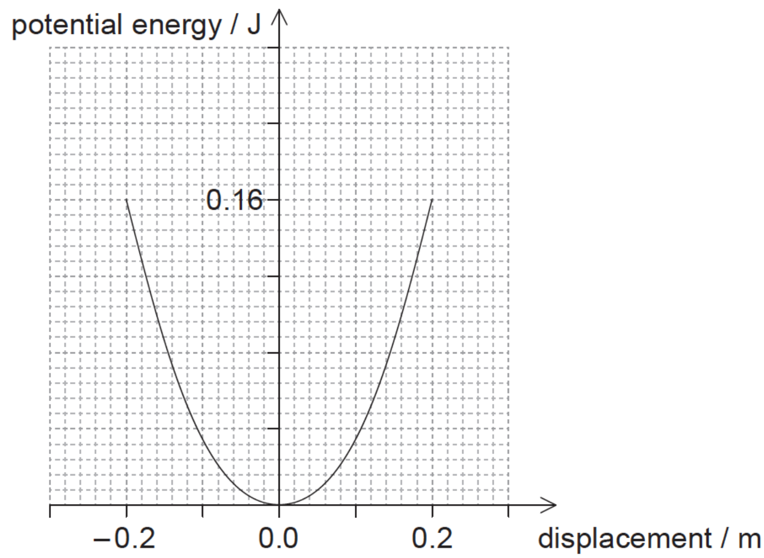
3b. One cycle of the variation of displacement with time is shown for two separate mass–spring systems, A and B. *[3 marks]*



(i) Calculate the frequency of the oscillation of A.

(ii) The springs used in A and B are identical. Show that the mass in A is equal to the mass in B.

3c. The graph shows the variation of the potential energy of A with displacement. *[5 marks]*



On the axes,

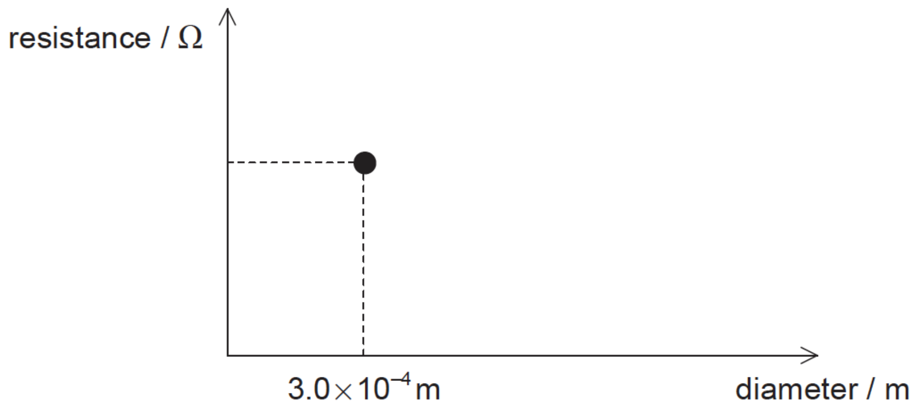
(i) draw a graph to show the variation of kinetic energy with displacement for the mass in A. Label this A.

(ii) sketch a graph to show the variation of kinetic energy with displacement for the mass in B. Label this B.

3d. A 24 Ω resistor is made from a conducting wire. *[4 marks]*

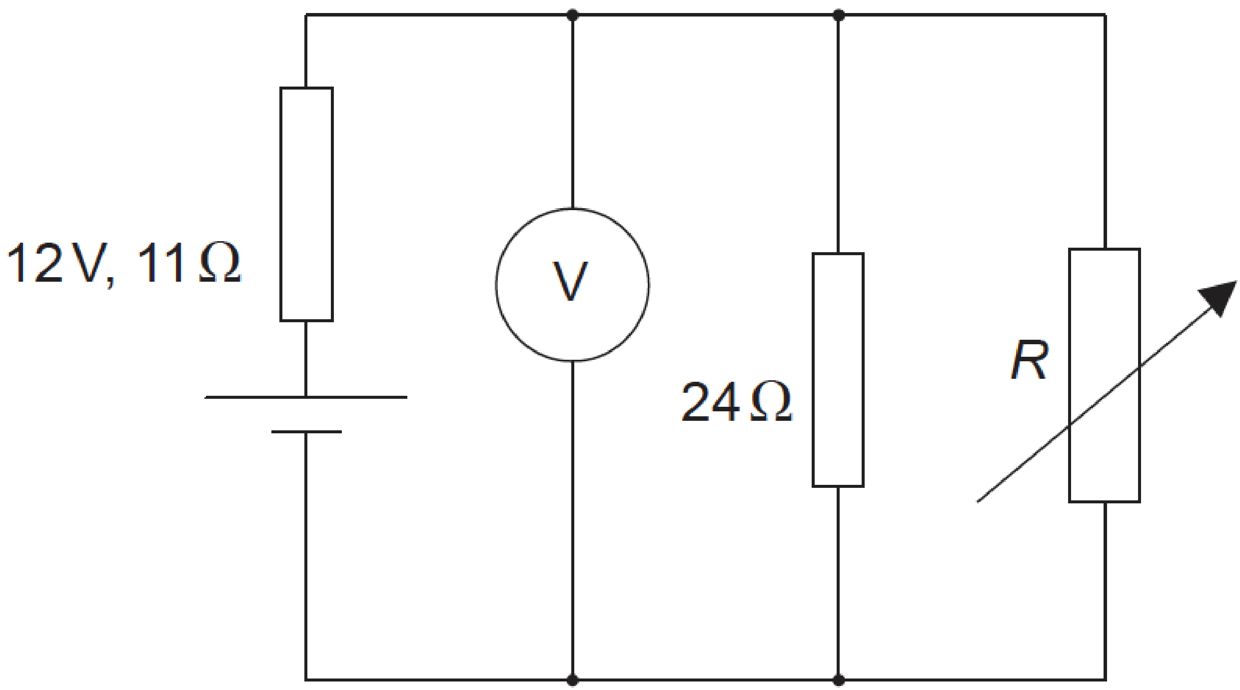
(i) The diameter of the wire is 0.30 mm and the wire has a resistivity of 1.7×10^{-8} Ωm. Calculate the length of the wire.

(ii) On the axes, draw a graph to show how the resistance of the wire in (d)(i) varies with the diameter of the wire when the length is constant. The data point for the diameter of 0.30 mm has already been plotted for you.



3e. The 24 Ω resistor is covered in an insulating material. Explain the reasons for the differences between the electrical properties of the insulating material and the electrical properties of the wire. *[3 marks]*

3f. An electric circuit consists of a supply connected to a 24Ω resistor in parallel with a variable resistor of resistance *R*. The supply has an emf of 12V and an internal resistance of 11Ω. *[8 marks]*



Power supplies deliver maximum power to an external circuit when the resistance of the external circuit equals the internal resistance of the power supply.

(i) Determine the value of *R* for this circuit at which maximum power is delivered to the external circuit.

(ii) Calculate the reading on the voltmeter for the value of *R* you determined in (f)(i).

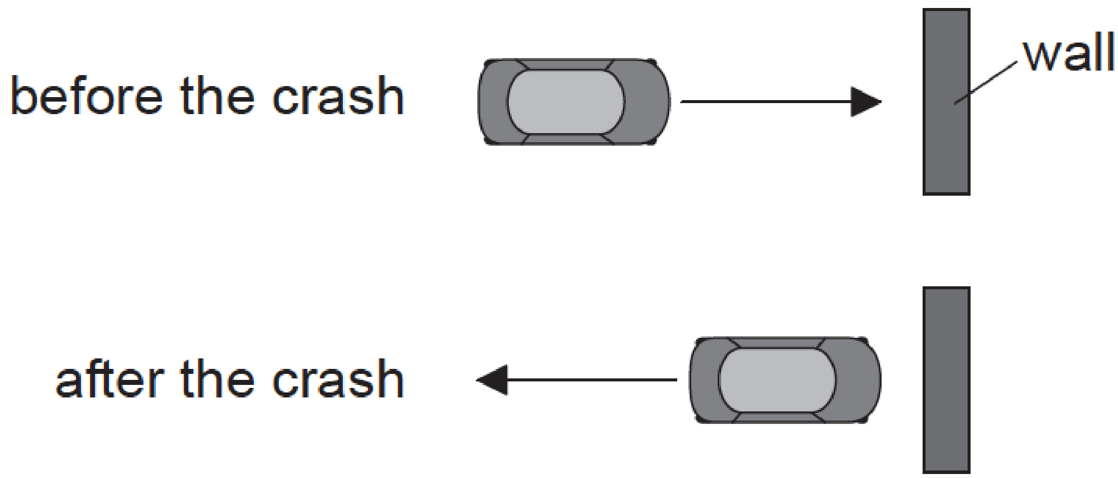
(iii) Calculate the total power dissipated in the circuit when the maximum power is being delivered to the external circuit.

This question is in two parts. **Part 1** is about momentum. **Part 2** is about electric point charges.

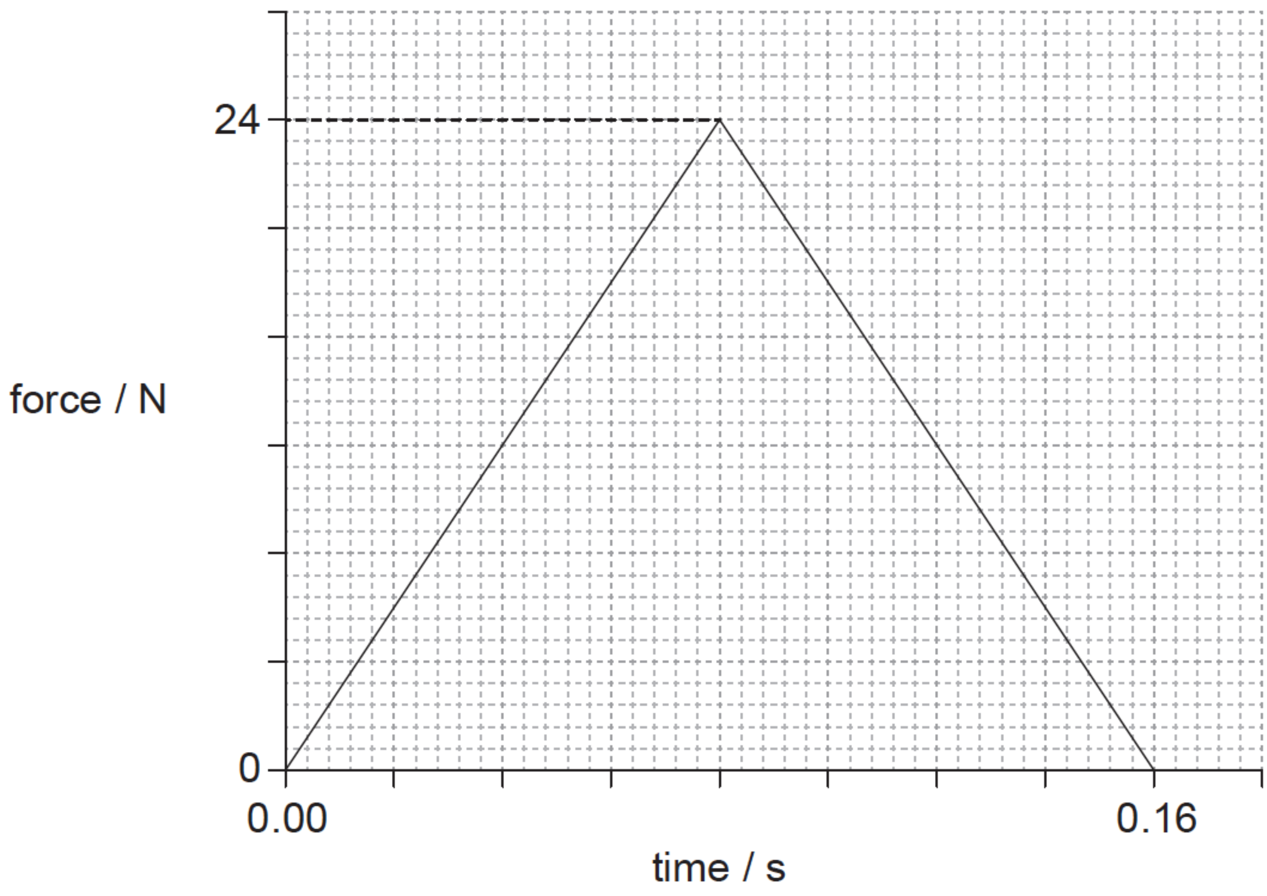
Part 1 Momentum

4a. State the law of conservation of linear momentum. *[2 marks]*

4b. A toy car crashes into a wall and rebounds at right angles to the wall, as shown in the plan view. *[9 marks]*



The graph shows the variation with time of the force acting on the car due to the wall during the collision.

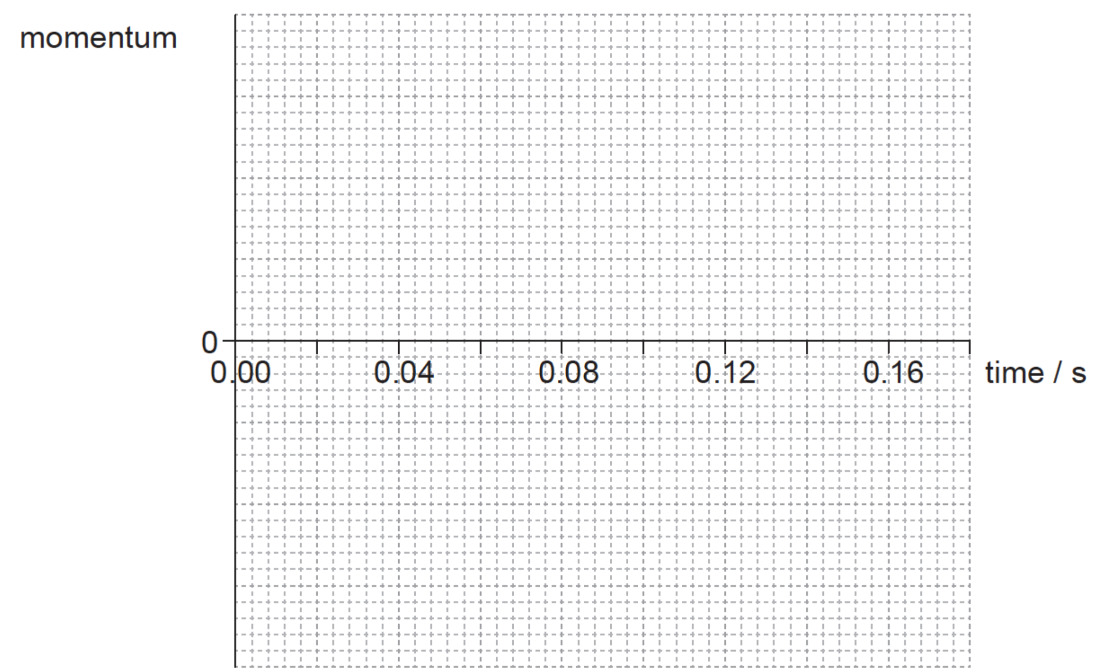


The kinetic energy of the car is unchanged after the collision. The mass of the car is 0.80 kg.

(i) Determine the initial momentum of the car.

(ii) Estimate the average acceleration of the car before it rebounds.

(iii) On the axes, draw a graph to show how the momentum of the car varies during the impact. You are not required to give values on the y-axis.

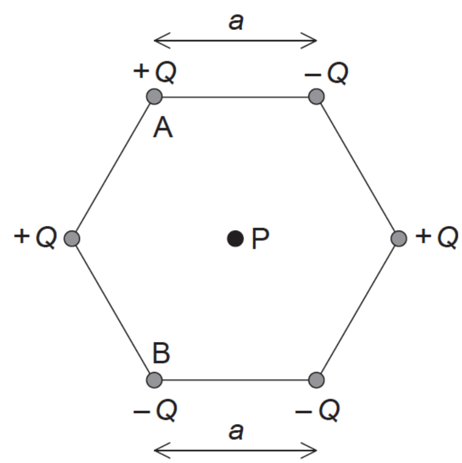


4c. Two identical toy cars, A and B are dropped from the same height onto a solid floor without rebounding. Car A is unprotected whilst car B is in a box with protective packaging around the toy. Explain why car B is less likely to be damaged when dropped. *[4 marks]*

Part 2 Electric point charges

4d. Define *electric field strength* at a point in an electric field. *[2 marks]*

4e. Six point charges of equal magnitude Q are held at the corners of a hexagon with the signs of the charges as shown. Each side of the hexagon has a length a. *[8 marks]*



P is at the centre of the hexagon.

(i) Show, using Coulomb's law, that the magnitude of the electric field strength at point P due to **one** of the point charges is

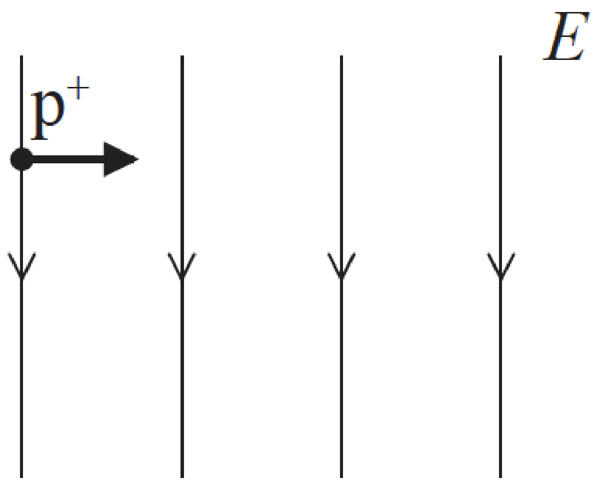
$$\frac{kQ}{a^2}$$

(ii) On the diagram, draw arrows to represent the direction of the field at P due to point charge A (label this direction A) and point charge B (label this direction B).

(iii) The magnitude of Q is 3.2 μC and length a is 0.15 m. Determine the magnitude and the direction of the electric field strength at point P due to all six charges.

This question is about electric and magnetic fields.

A proton travelling to the right with horizontal speed $1.6\times10^4 ms^{-1}$ enters a uniform electric field of strength *E*. The electric field has magnitude $2.0\times10^3 NC^{-1}$ and is directed downwards.



5a. Calculate the magnitude of the electric force acting on the proton when it is in the electric field. *[2 marks]*

5b. A uniform magnetic field is applied in the same region as the electric field. A second proton enters the field region with the same velocity as the proton in (a). This second proton continues to move horizontally. *[5 marks]*

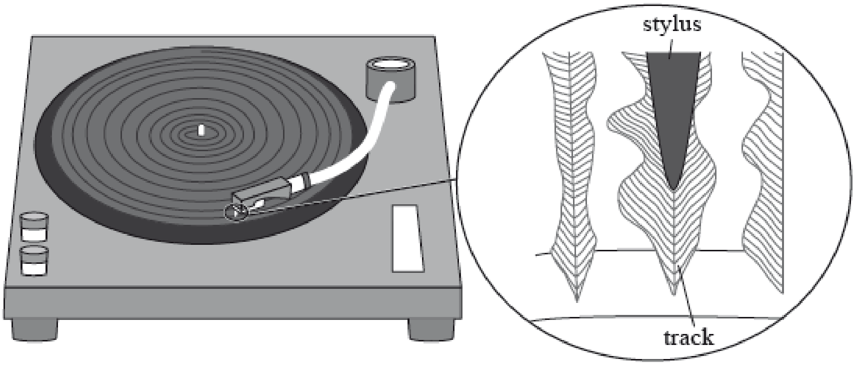
(i) Determine the magnitude and direction of the magnetic field.

(ii) An alpha particle enters the field region at the same point as the second proton, moving with the same velocity. Explain whether or not the alpha particle will move in a straight line.

This question is in **two** parts. **Part 1** is about simple harmonic motion (SHM) and sound. **Part 2** is about electric and magnetic fields.

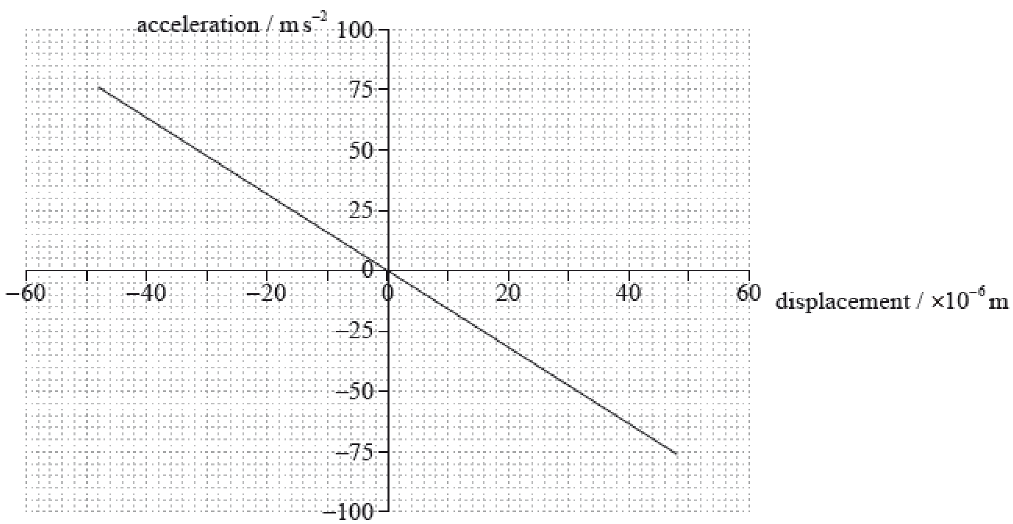
Part 1 Simple harmonic motion (SHM) and sound

The diagram shows a section of continuous track of a long-playing (LP) record. The stylus (needle) is placed in the track of the record.



As the LP record rotates, the stylus moves because of changes in the width and position of the track. These movements are converted into sound waves by an electrical system and a loudspeaker.

A recording of a single-frequency musical note is played. The graph shows the variation in horizontal acceleration of the stylus with horizontal displacement.



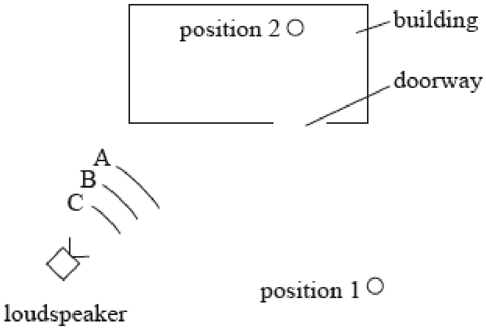
6a. Explain why the graph shows that the stylus undergoes simple harmonic motion. *[4 marks]*

6b. (i) Using the graph on page 14, show that the frequency of the note being played is about 200 Hz. *[5 marks]*

(ii) On the graph on page 14, identify, with the letter P, the position of the stylus at which the kinetic energy is at a maximum.

Sound is emitted from a loudspeaker which is outside a building. The loudspeaker emits a sound wave that has the same frequency as the recorded note.

A person standing at position 1 outside the building and a person standing at position 2 inside the building both hear the sound emitted by the loudspeaker.



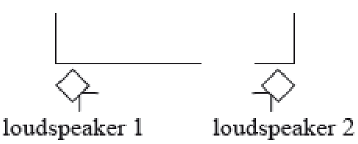
A, B and C are wavefronts emitted by the loudspeaker.

6c. (i) Draw rays to show how the person at **position 1** is able to hear the sound emitted by the loudspeaker. *[4 marks]*

(ii) The speed of sound in the air is $330\ \mathrm{m\,s^{-1}}$. Calculate the wavelength of the note.

(iii) The walls of the room are designed to absorb sound. Explain how the person at **position 2** is able to hear the sound emitted by the loudspeaker.

6d. The arrangement in (c) is changed and another loudspeaker is added. Both loudspeakers emit the same recorded note in phase with each other. *[3 marks]*



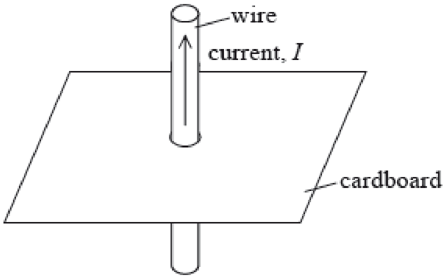
Outline why there are positions between the loudspeakers where the sound can only be heard faintly.

Part 2 Electric and magnetic fields

Electrical leads used in physics laboratories consist of a central conductor surrounded by an insulator.

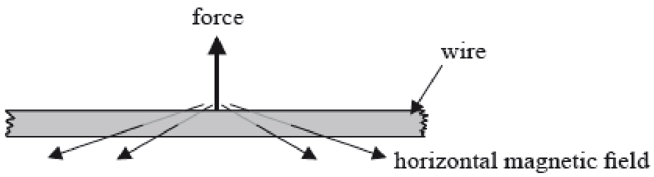
6e. Distinguish between an insulator and a conductor. *[2 marks]*

6f. The diagram shows a current I in a vertical wire that passes through a hole in a horizontal piece of cardboard. *[3 marks]*



On the cardboard, draw the magnetic field pattern due to the current.

6g. (i) The diagram shows a length of copper wire that is horizontal in the magnetic field of the Earth. *[4 marks]*



The wire carries an electric current and the force on the wire is as shown. Identify, with an arrow, the direction of electron flow in the wire.

(ii) The horizontal component of the magnetic field of the Earth at the position of the wire is $40\ \mu\mathrm{T}$. The mass per unit length of the wire is $1.41 \times 10^{-4}\ \mathrm{kg\,m^{-2}}$. The net force on the wire is zero. Determine the current in the wire.

This question is in **two** parts. **Part 1** is about the motion of a car. **Part 2** is about electricity.

Part 1 Motion of a car

7a. A car accelerates uniformly along a straight horizontal road from an initial speed of $12\ \mathrm{m\,s^{-1}}$ to a final speed of $28\ \mathrm{m\,s^{-1}}$ in a distance of 250 m. The mass of the car is 1200 kg. Determine the rate at which the engine is supplying kinetic energy to the car as it accelerates. *[4 marks]*

A car is travelling along the straight horizontal road at its maximum speed of $56\ \mathrm{m\,s^{-1}}$. The power output required at the wheels is 0.13 MW.

7b. A car is travelling along a straight horizontal road at its maximum speed of $56\ \mathrm{m\,s^{-1}}$. The power output required at the wheels is 0.13 MW. *[5 marks]*

(i) Calculate the total resistive force acting on the car when it is travelling at a constant speed of $56\ \mathrm{m\,s^{-1}}$.

(ii) The mass of the car is 1200 kg. The resistive force F is related to the speed v by $F \propto v^2$. Using your answer to (b)(i), determine the maximum theoretical acceleration of the car at a speed of $28\ \mathrm{m\,s^{-1}}$.

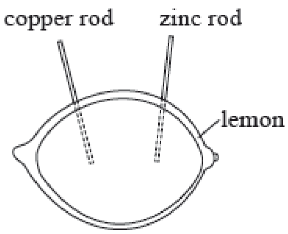
A driver moves the car in a horizontal circular path of radius 200 m. Each of the four tyres will not grip the road if the frictional force between a tyre and the road becomes less than 1500 N.

7c. (i) Calculate the maximum speed of the car at which it can continue to move in the circular path. Assume that the radius of the path is the same for each tyre. *[6 marks]*

(ii) While the car is travelling around the circle, the people in the car have the sensation that they are being thrown outwards. Outline how Newton's first law of motion accounts for this sensation.

Part 2 Electricity

A lemon can be used to make an electric cell by pushing a copper rod and a zinc rod into the lemon.



A student constructs a lemon cell and connects it in an electrical circuit with a variable resistor. The student measures the potential difference *V* across the lemon and the current *I* in the lemon.

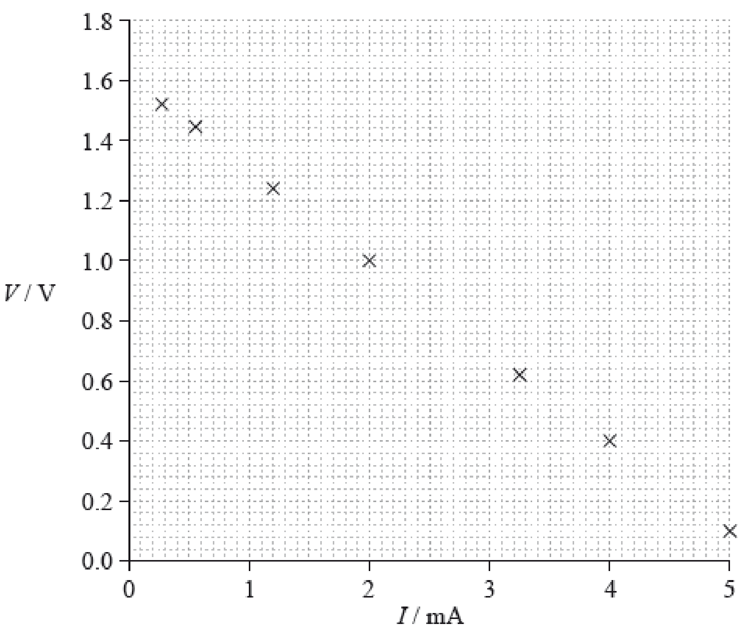
7d. (i) Draw a circuit diagram of the experimental arrangement that will enable the student to collect the data for the graph. *[10 marks]*

(ii) Show that the potential difference V across the lemon is given by

$$V = E - Ir$$

where E is the emf of the lemon cell and r is the internal resistance of the lemon cell.

(iii) The graph shows how V varies with I.



Using the graph, estimate the emf of the lemon cell.

(iv) Determine the internal resistance of the lemon cell.

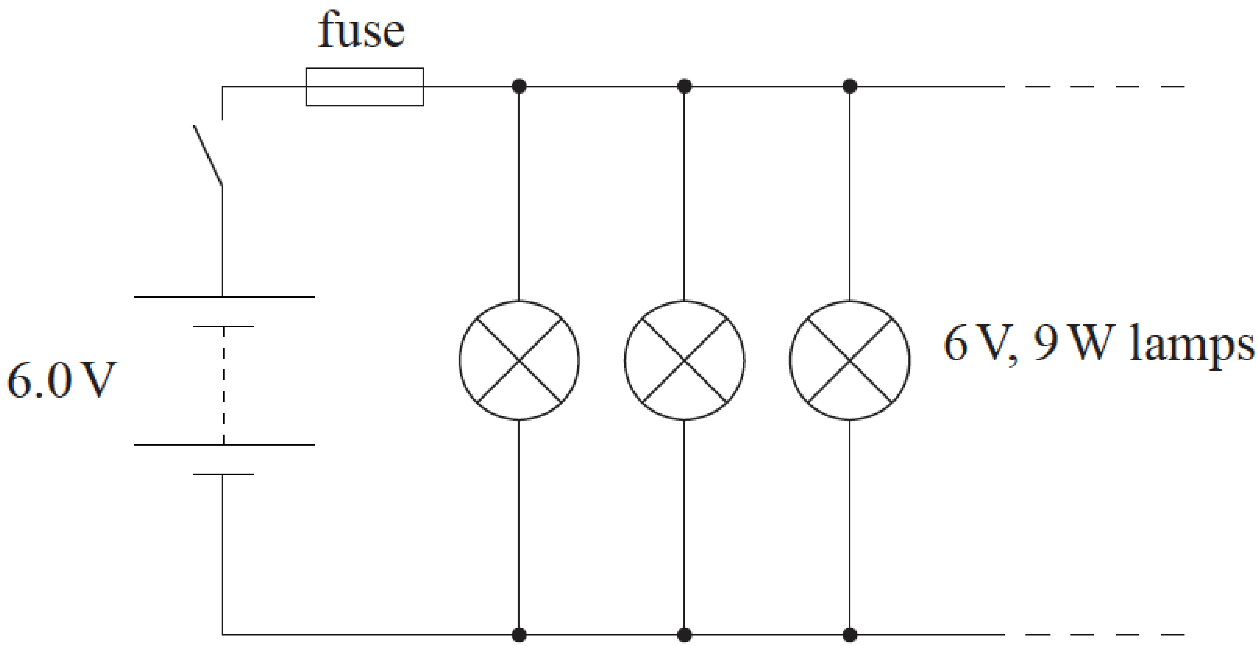
(v) The lemon cell is used to supply energy to a digital clock that requires a current of $6.0\ \mu\text{A}$. The clock runs for 16 hours. Calculate the charge that flows through the clock in this time.

This question is in **two** parts. **Part 1** is about a lighting system. **Part 2** is about a satellite.

Part 1 Lighting system

8a. State Ohm’s law. *[1 mark]*

8b. A lighting system is designed so that additional lamps can be added in parallel. *[8 marks]*



The diagram shows three 6V, 9W lamps connected in parallel to a supply of emf 6.0V and negligible internal resistance. A fuse in the circuit melts if the current in the circuit exceeds 13A.

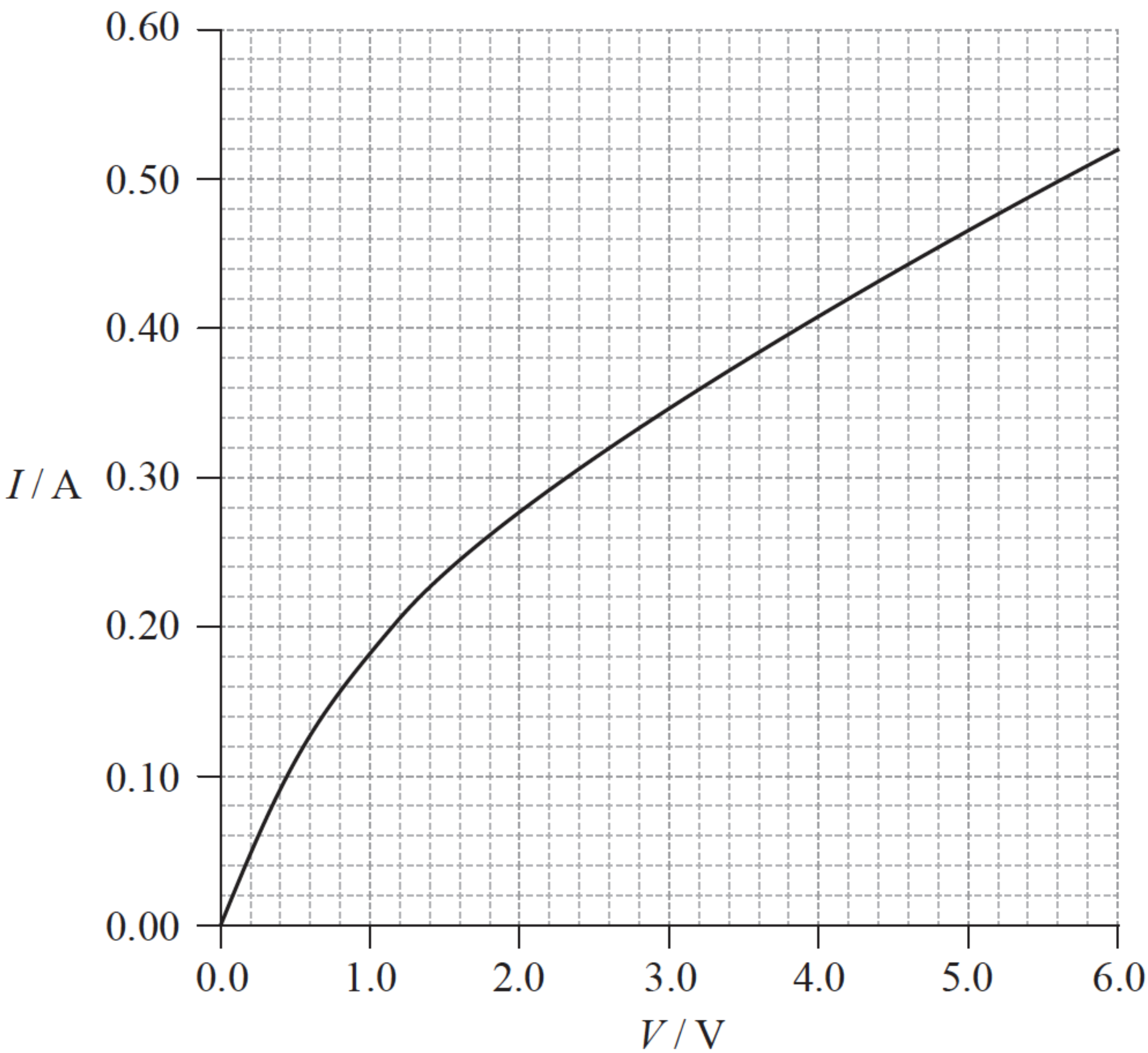
(i) Determine the maximum number of lamps that can be connected in parallel in the circuit without melting the fuse.

(ii) Calculate the resistance of a lamp when operating at its normal brightness.

(iii) By mistake, a lamp rated at 12V, 9W is connected in parallel with three lamps rated at 6V, 9W. Estimate the resistance of the circuit stating any assumption that you make.

Part 2 Electric current and resistance

The graph below shows how the current *I* in a tungsten filament lamp varies with potential difference *V* across the lamp.



9a. (i) Calculate the resistance of the filament lamp when the potential difference across it is 2.8 V. *[5 marks]*

(ii) The length of the filament in a lamp is 0.40 m. The resistivity of tungsten when the potential difference across it is 2.8 V is $5.8\times10^{-7}\,\Omega$ m. Calculate the radius of the filament.

9b. Two identical filament lamps are connected in series with a cell of emf 6.0 V and negligible internal resistance. Using the graph on page 26, calculate the total power dissipated in the circuit. *[2 marks]*

Part 2 Electric potential difference and electric circuits

10a. Ionized hydrogen atoms are accelerated from rest in the vacuum between two vertical parallel conducting plates. The potential difference between the plates is *V*. As a result of the acceleration each ion gains an energy of 1.9×10^{-18} J. *[2 marks]*

Calculate the value of *V*.

10b. The plates in (a) are replaced by a cell that has an emf of 12.0 V and internal resistance 5.00 Ω. A resistor of resistance *R* is connected in series with the cell. The energy transferred by the cell to an electron as it moves through the resistor is 1.44×10^{-18} J. *[8 marks]*

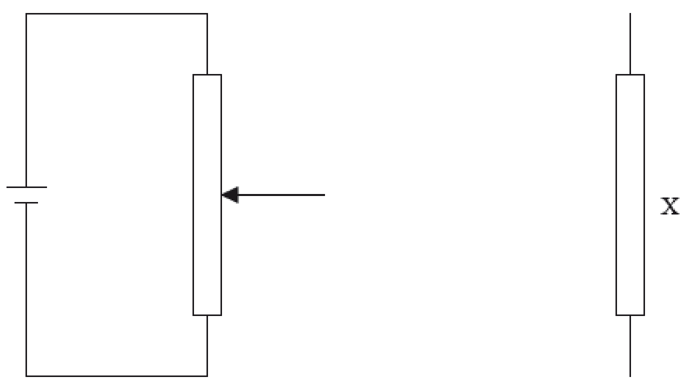
(i) Define *resistance* of a resistor.

(ii) Describe what is meant by internal resistance.

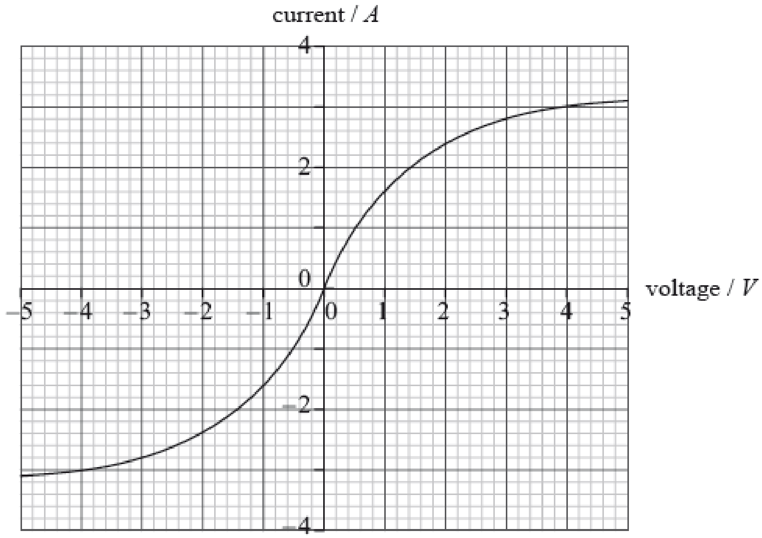
(iii) Show that the value of *R* is 15.0 Ω.

(iv) Calculate the total power supplied by the cell.

11a. Draw the complete diagram of the circuit that uses a potential divider, ammeter, voltmeter and cell to measure the current-voltage characteristics for component X. *[3 marks]*



11b. The graph shows the current-voltage characteristics for the component X. *[2 marks]*



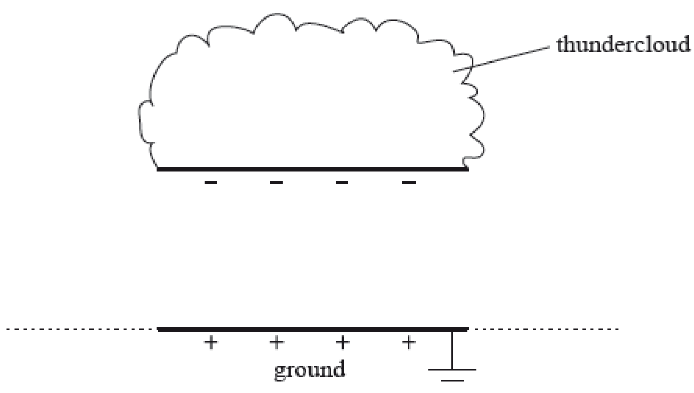
Component X is now connected across the terminals of a cell of emf 2.0 V and negligible internal resistance. Use the graph to show that the resistance of X is $0.83\ \Omega$.

This question is in **two** parts. **Part 1** is about a lightning discharge. **Part 2** is about fuel for heating.

Part 1 Lightning discharge

12a. Define *electric field strength*. *[2 marks]*

12b. A thundercloud can be modelled as a negatively charged plate that is parallel to the ground. *[3 marks]*



The magnitude of the charge on the plate increases due to processes in the atmosphere. Eventually a current discharges from the thundercloud to the ground.

On the diagram, draw the electric field pattern between the thundercloud base and the ground.

The magnitude of the electric field strength E between two infinite charged parallel plates is given by the expression

$$E = \frac{\sigma}{\varepsilon_0}$$

where σ is the charge per unit area on one of the plates.

A thundercloud carries a charge of magnitude 35 C spread over its base. The area of the base is $1.2 \times 10^7\ \mathrm{m}^2$.

12c. (i) Determine the magnitude of the electric field between the base of the thundercloud and the ground. *[12 marks]*

(ii) State **two** assumptions made in (c)(i).

1.

2.

(iii) When the thundercloud discharges, the average discharge current is 1.8 kA. Estimate the discharge time.

(iv) The potential difference between the thundercloud and the ground before discharge is $2.5 \times 10^8\ \mathrm{V}$. Determine the energy released in the discharge.

Part 2 Fuel for heating

12d. Define the *energy density* of a fuel. *[1 mark]*

A room heater burns liquid fuel and the following data are available.

Density of liquid fuel	$= 8.0 \times 10^2\ \mathrm{kg\,m^{-3}}$
Energy produced by $1\ \mathrm{m}^3$ of liquid fuel	$= 2.7 \times 10^{10}\ \mathrm{J}$
Rate at which fuel is consumed	$= 0.13\ \mathrm{g\,s^{-1}}$
Latent heat of vaporization of the fuel	$= 290\ \mathrm{kJ\,kg^{-1}}$

12e. (i) Use the data to calculate the power output of the room heater, ignoring the power required to convert the liquid fuel into a gas. *[5 marks]*

(ii) Show why, in your calculation in (b)(i), the power required to convert the liquid fuel into a gas at its boiling point can be ignored.

12f. State, in terms of molecular structure and their motion, **two** differences between a liquid and a gas. *[2 marks]*

1.

2.