T5-1 *[237 marks]*

1. A circuit is formed by connecting a resistor between the terminals of a battery of electromotive force (emf) 6 V. The battery has internal resistance. Which statement is correct when 1 C of charge flows around the complete circuit? *[1 mark]*

A. 6 V is the potential difference across the resistor.

B. 6 J of thermal energy is dissipated in the battery.

C. 6 J of chemical energy is transformed in the battery.

D. 6 J of thermal energy is dissipated in the resistor.

2. An ion follows a circular path in a uniform magnetic field. Which single change decreases the radius of the path? *[1 mark]*

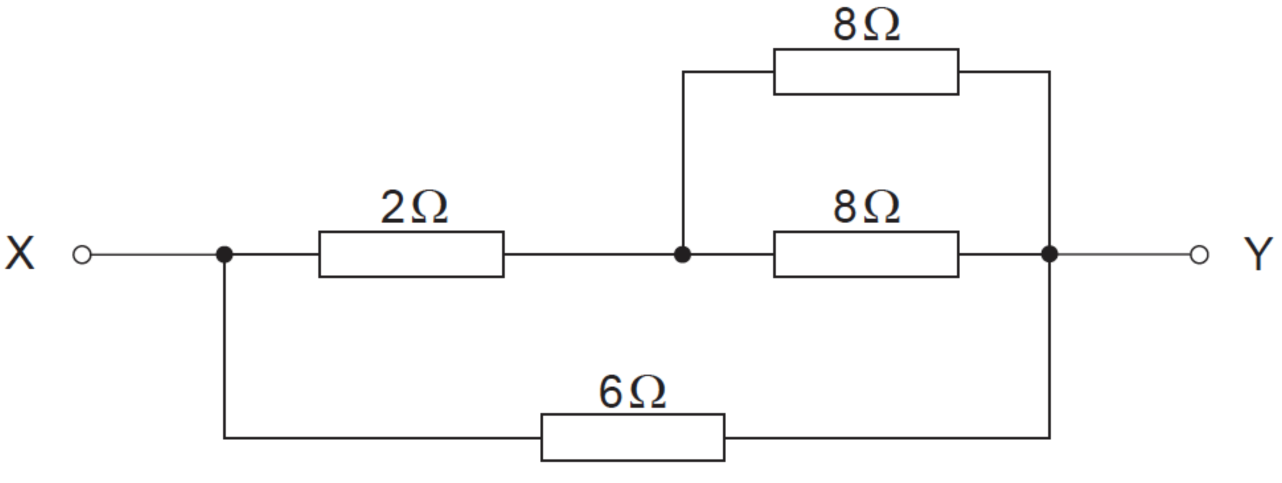
A. Increasing the mass of the ion

B. Increasing the charge of the ion

C. Increasing the speed of the ion

D. Decreasing the magnetic flux density of the field

3. Four resistors are connected as shown. *[1 mark]*



What is the total resistance between X and Y?

A. 3 Ω

B. 4 Ω

C. 6 Ω

D. 24 Ω

4. What is the definition of electric current? *[1 mark]*

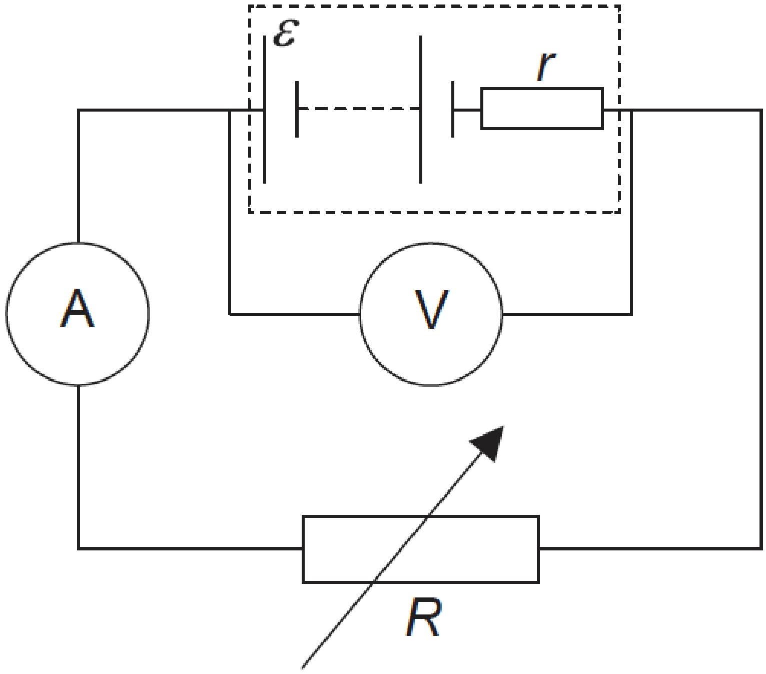
A. The ratio of potential difference across a component to the resistance of the component

B. The power delivered by a battery per unit potential difference

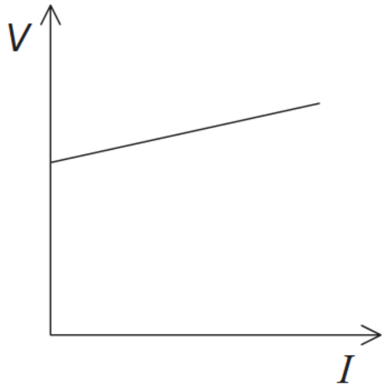
C. The rate of flow of electric charge

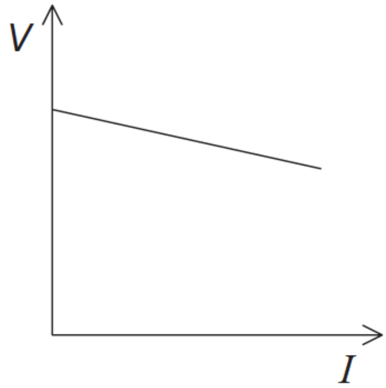
D. The energy per unit charge dissipated in a power supply

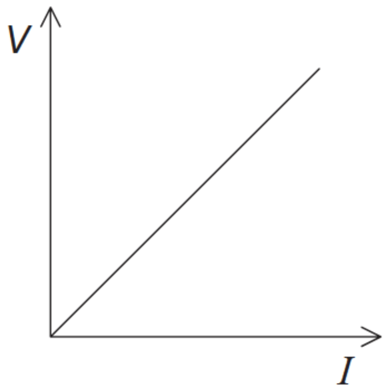
5. The diagram shows a circuit used to investigate internal resistance of a cell. *[1 mark]*

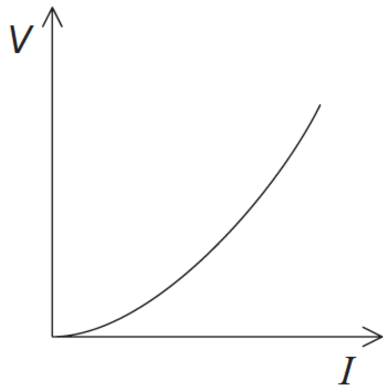


The variable resistor *R* is adjusted and the values of potential difference *V* across the cell and current *I* are recorded. Which graph shows the variation of *V* with *I*?

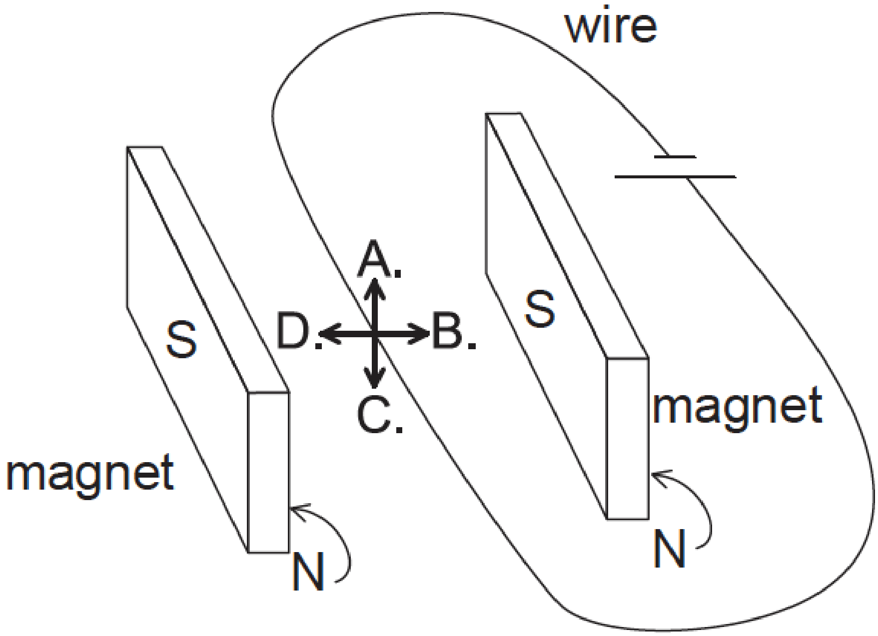
A. 

B. 

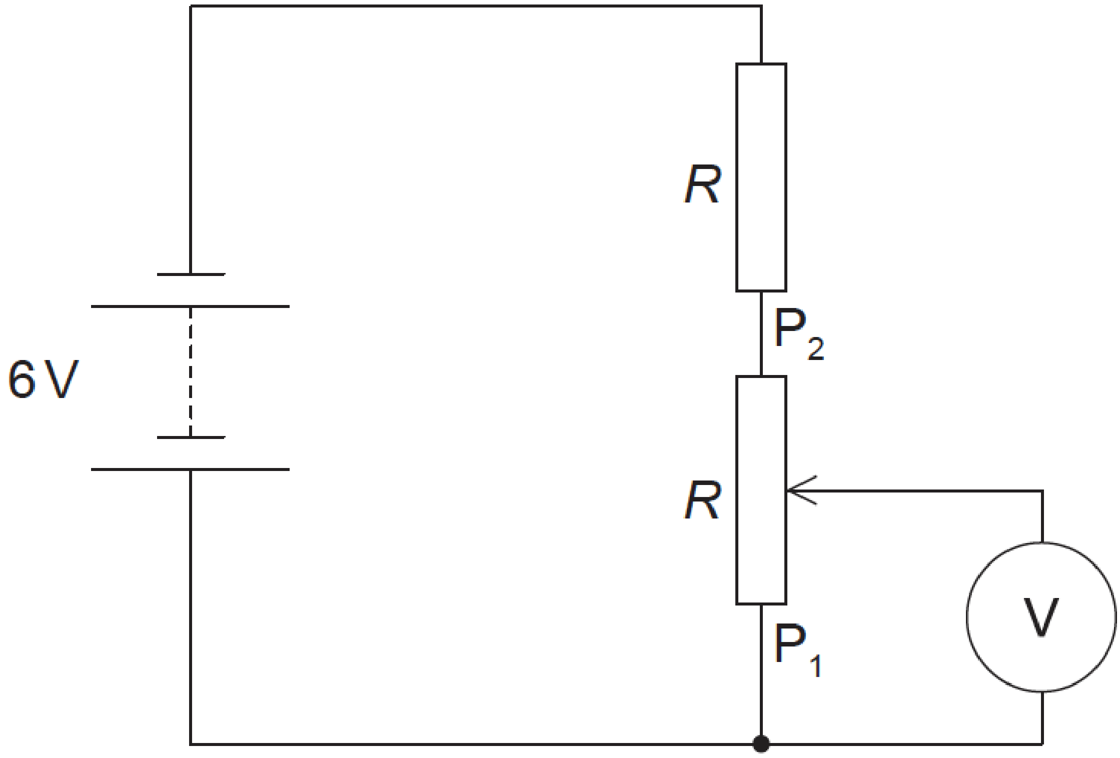
C. 

D. 

6. A long, straight, current-carrying wire is placed between a pair of magnets as shown. What is the direction of the force on the wire? *[1 mark]*

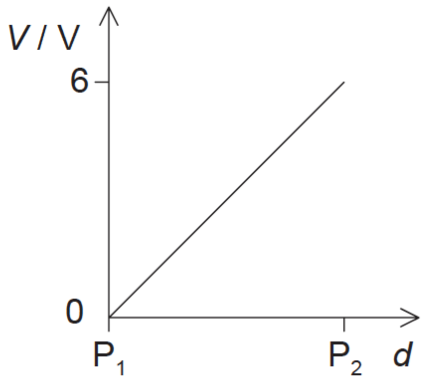


7. The diagram shows an electric circuit containing a potentiometer of maximum resistance *R*. The potentiometer is connected in series with a resistor also of resistance *R*. The electromotive force (emf) of the battery is 6 V and its internal resistance is negligible. *[1 mark]*

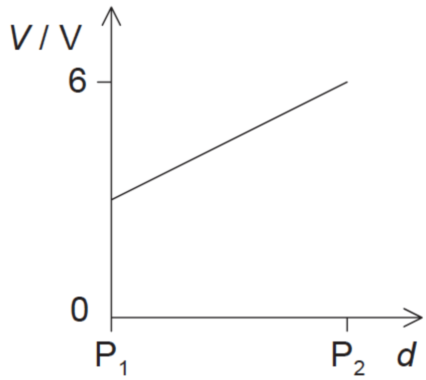


The slider on the potentiometer is moved from P_1 to P_2. Which graph shows the variation of the voltmeter V reading with slider distance *d*?

A.



B.



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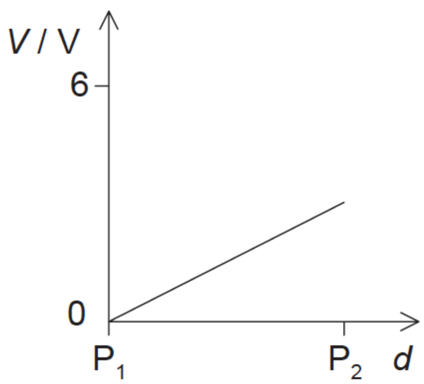

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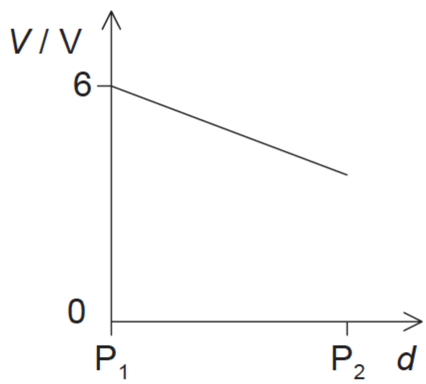
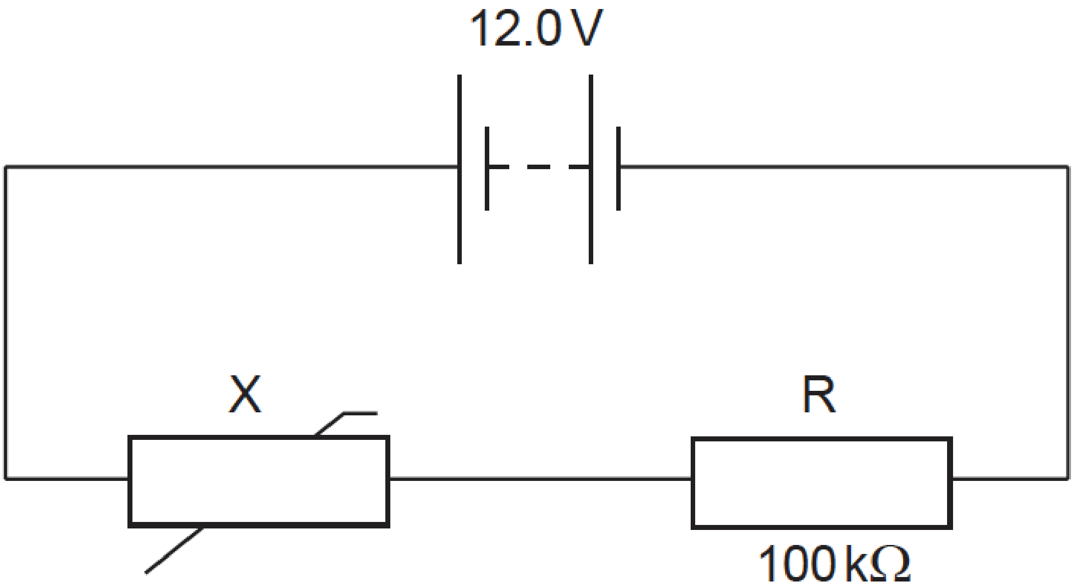


This question is in two parts. Part 1 is about a thermistor circuit. Part 2 is about vibrations and waves.

Part 1 Thermistor circuit

The circuit shows a negative temperature coefficient (NTC) thermistor X and a 100 kΩ fixed resistor R connected across a battery.



The battery has an electromotive force (emf) of 12.0 V and negligible internal resistance.

8a. (i) Define *electromotive force (emf)*. *[2 marks]*

(ii) State how the emf of the battery can be measured.

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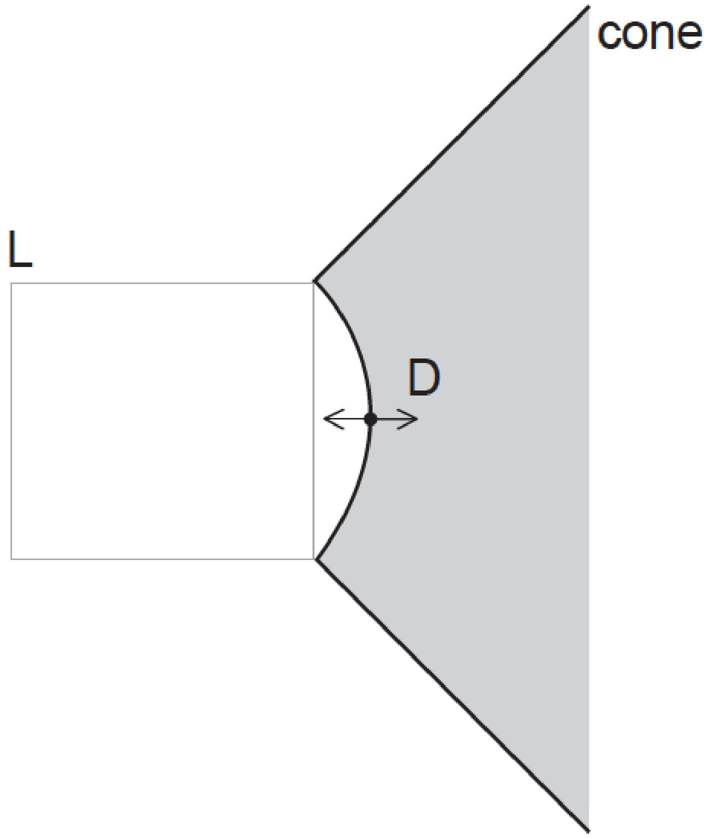
Part 2 Vibrations and waves

The cone and dust cap D of a loudspeaker L vibrates with a frequency of 1.25 kHz with simple harmonic motion (SHM).



8b. Define *simple harmonic motion (SHM)*. *[2 marks]*

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8c. D has mass 6.5×10^{-3} kg and vibrates with amplitude 0.85 mm. *[4 marks]*

(i) Calculate the maximum acceleration of D.

(ii) Determine the total energy of D.

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8d. The sound waves from the loudspeaker travel in air with speed 330 ms^{-1}. *[2 marks]*

(i) Calculate the wavelength of the sound waves.

(ii) Describe the characteristics of sound waves in air.

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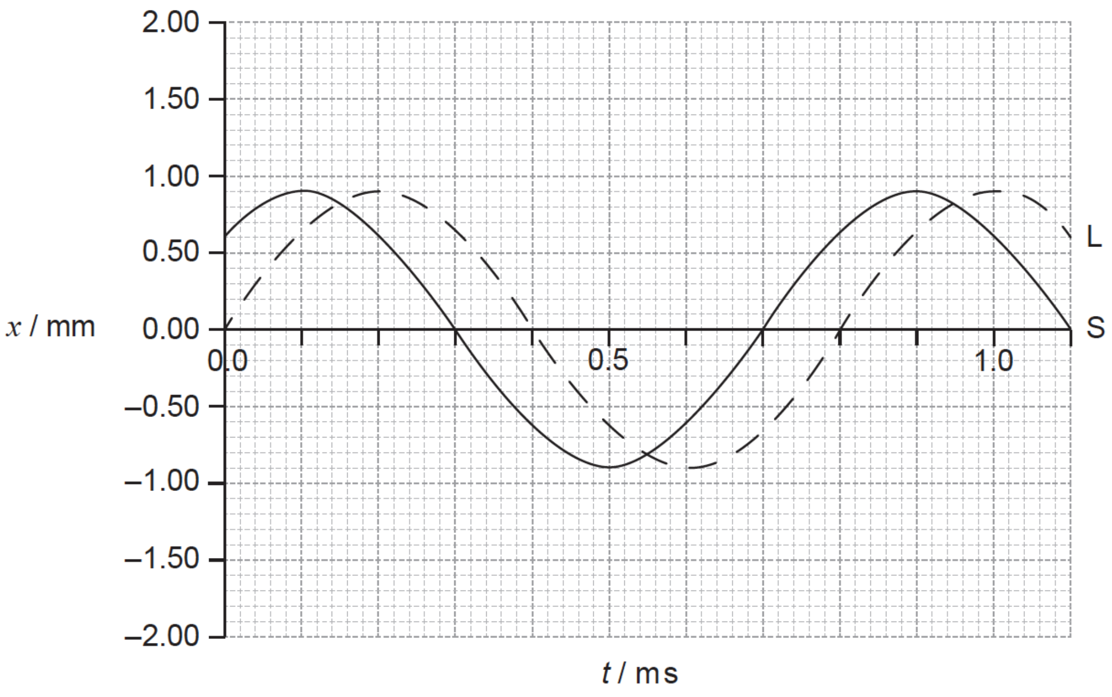
8e. A second loudspeaker S emits the same frequency as L but vibrates out of phase with L. The graph below shows the variation with time *t* of the displacement *x* of the waves emitted by S and L. *[6 marks]*



(i) Deduce the relationship between the phase of L and the phase of S.

(ii) On the graph, sketch the variation with *t* of *x* for the wave formed by the superposition of the two waves.

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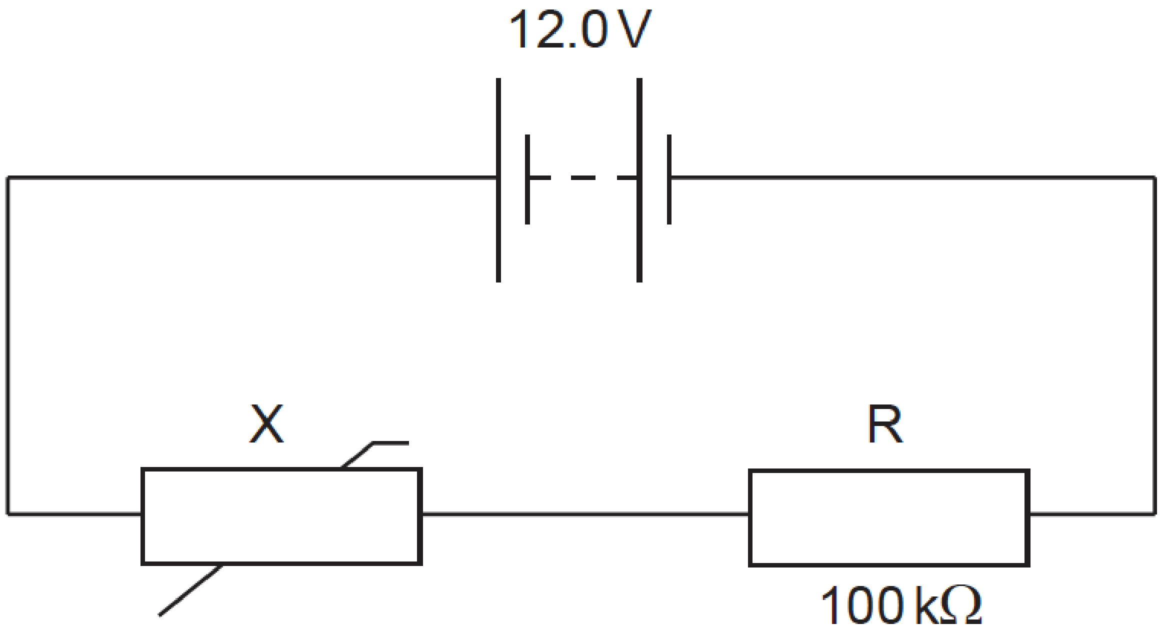
This question is about a thermistor circuit.

The circuit shows a negative temperature coefficient (NTC) thermistor X and a 100 kΩ fixed resistor R connected across a battery.



The battery has an electromotive force (emf) of 12.0 V and negligible internal resistance.

9a. Define *electromotive force (emf)*. *[1 mark]*

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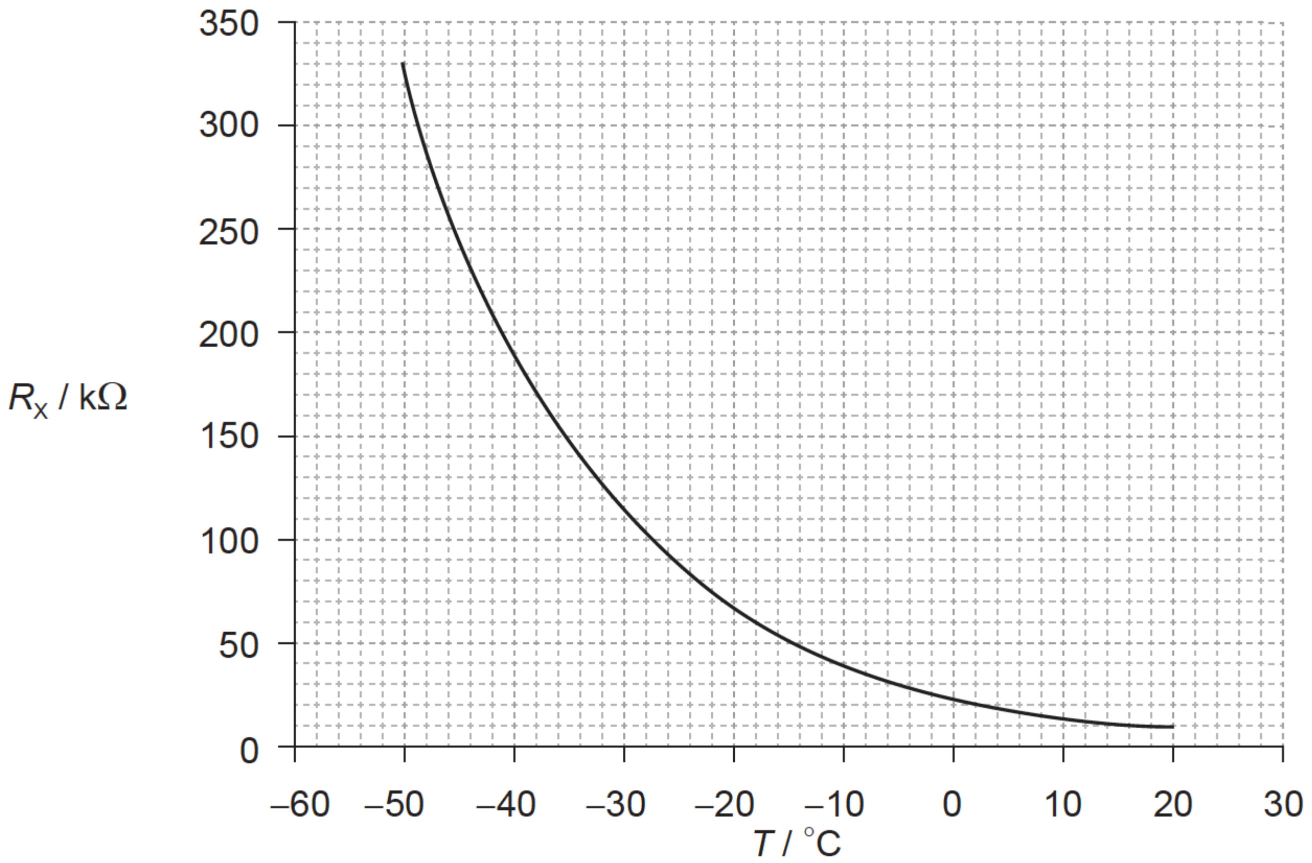
9b. The graph below shows the variation with temperature T of the resistance R_X of the thermistor. *[7 marks]*



(i) Determine the temperature of X when the potential difference across R is 4.5 V.

(ii) State the range of temperatures for which the change in the resistance of the thermistor is most sensitive to changes in temperature.

(iii) State and explain the effect of a decrease in temperature on the ratio $\frac{\text{voltage across X}}{\text{voltage across R}}$.

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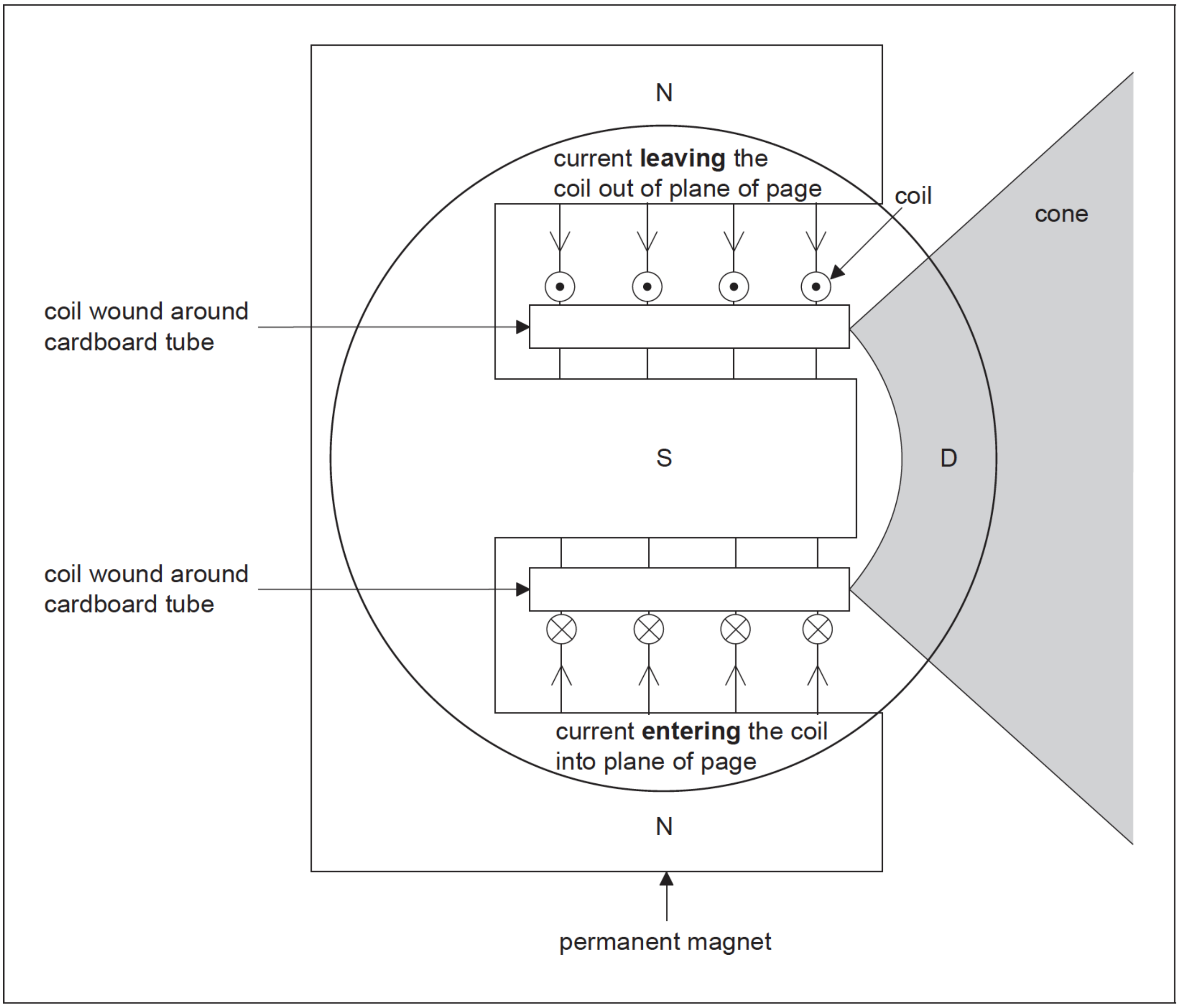
This question is in two parts. **Part 1** is about the electrical and magnetic characteristics of a loudspeaker. **Part 2** is about vibrations and waves.

Part 1 Electrical and magnetic characteristics of a loudspeaker

The diagram shows the main features of a loudspeaker L. A current-carrying coil is positioned within the magnetic field provided by a permanent magnet. The diagram also shows the directions of the magnetic field and of the current in the coil at a particular instant. The dust cap D prevents dust from blocking the gap between the cardboard tube and the south pole of the magnet.



The coil consists of 150 turns, each of average diameter 2.5 cm. The magnetic field of the permanent magnet has strength 0.40 mT. The peak current in the coil is 0.45 mA.

10a. Identify, **on the diagram**, the direction of the force on the coil with the current directions shown. *[2 marks]*

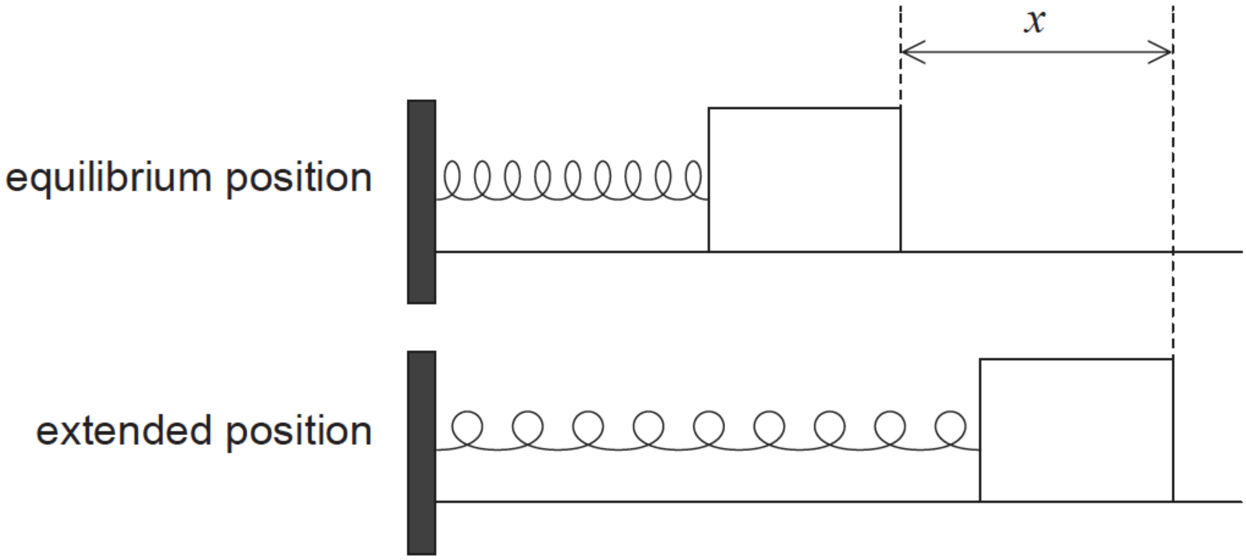
10b. Calculate the maximum magnetic force acting on the coil. *[3 marks]*

10c. Explain, with reference to electromagnetic induction, the effect of the motion of the coil on the current. *[3 marks]*

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.

11a. Show that $\omega^2 = \frac{k}{m}$. *[2 marks]*

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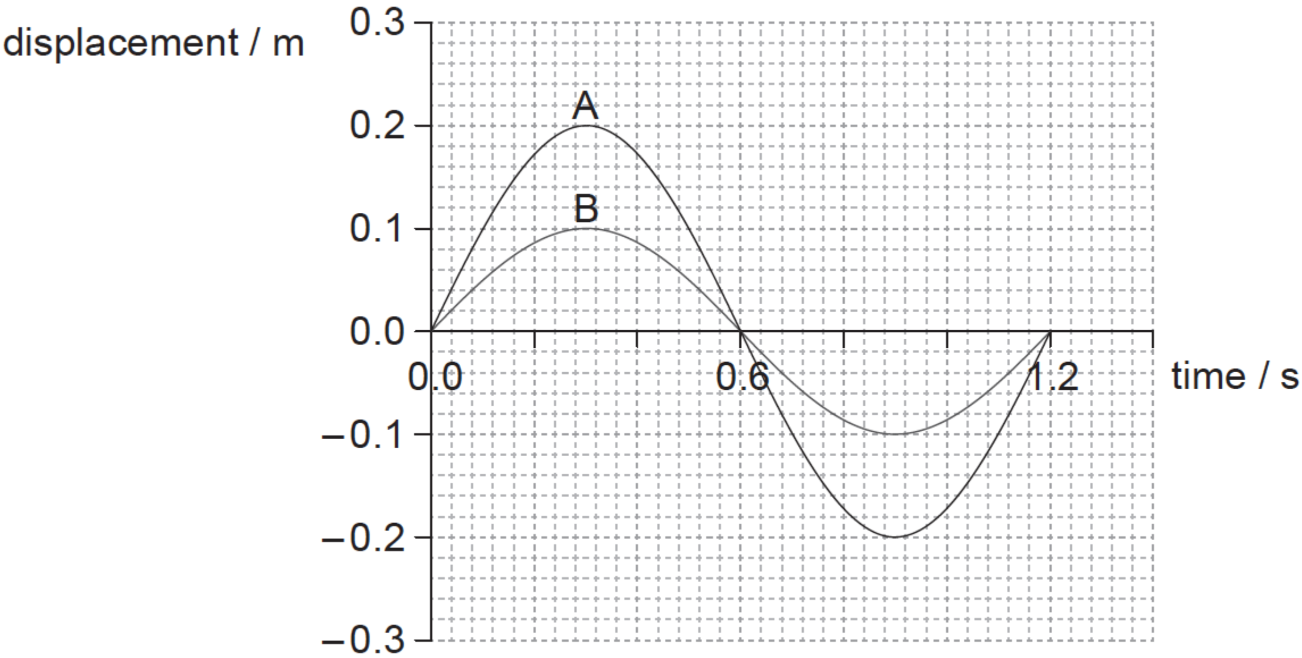
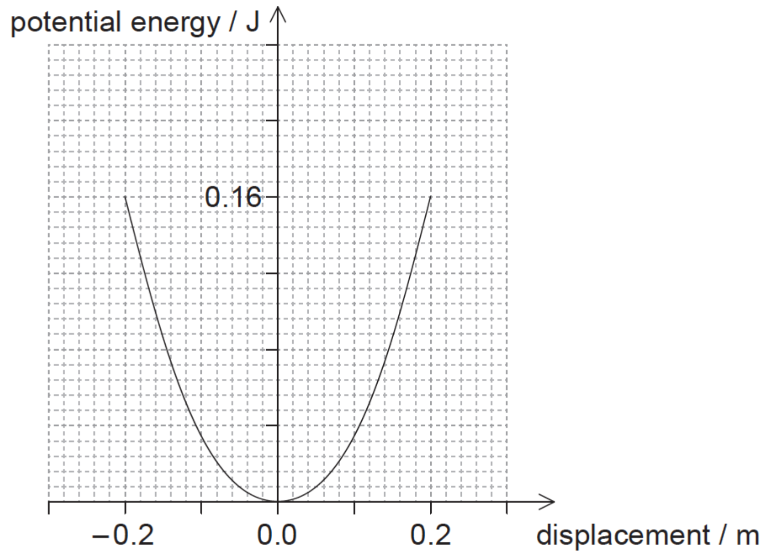
11b. One cycle of the variation of displacement with time is shown for two separate mass–spring systems, A and B. *[3 marks]*



(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.

11c. The graph shows the variation of the potential energy of A with displacement. *[5 marks]*



On the axes,

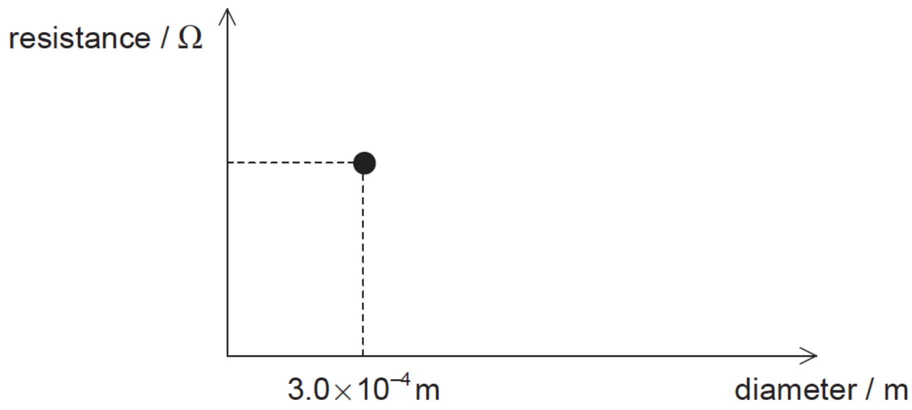
(i) draw a graph to show the variation of kinetic energy with displacement for the mass in A. Label this A.

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

11d. 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.



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11e. 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]*

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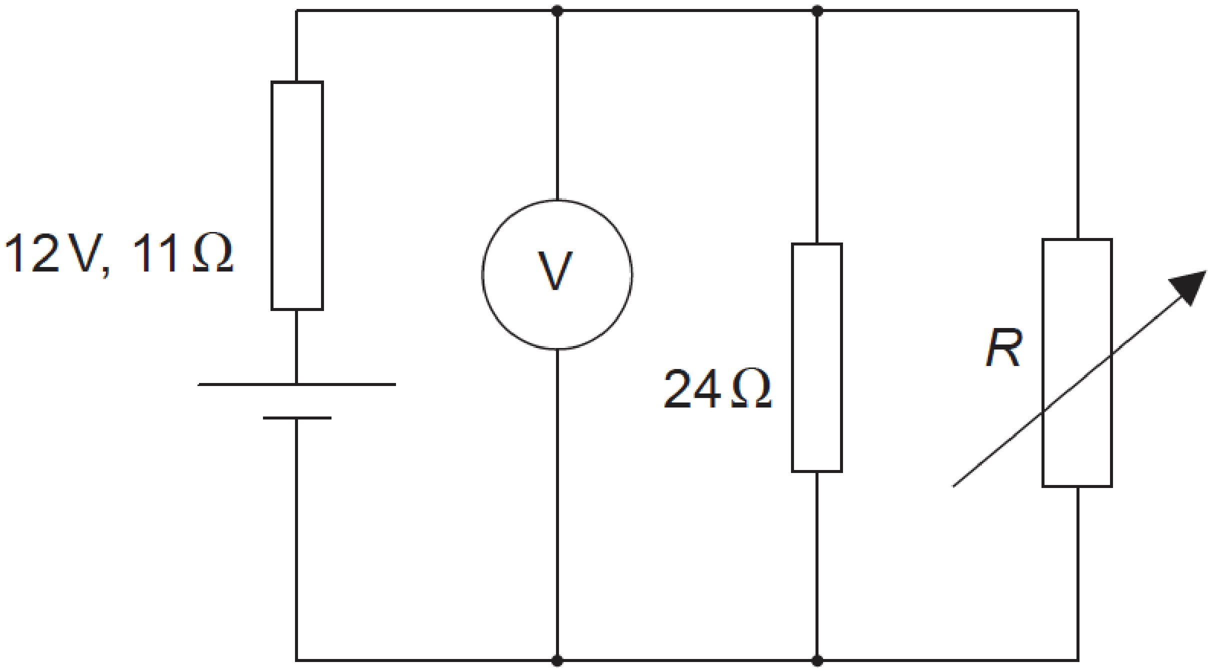
11f. An electric circuit consists of a supply connected to a 24Ω resistor in parallel with a variable resistor of resistance *R*. The supply has an emf of 12V and an internal resistance of 11Ω. *[8 marks]*



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.

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

Part 1 Momentum

12a. State the law of conservation of linear momentum. *[2 marks]*

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12b. 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]*

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Part 2 Electric point charges

12c. Define *electric field strength* at a point in an electric field. *[2 marks]*

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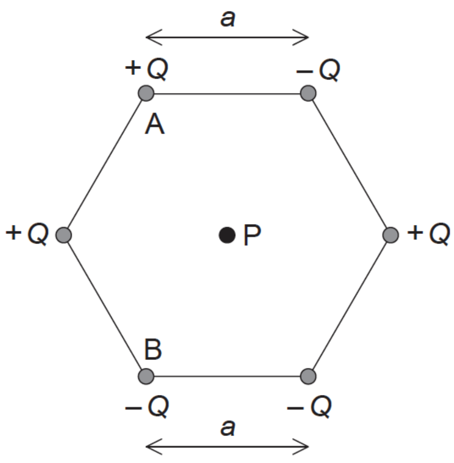
12d. Six point charges of equal magnitude Q are held at the corners of a hexagon with the signs of the charges as shown. Each side of the hexagon has a length a. *[8 marks]*



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.

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This question is in two parts. **Part 1** is about current electricity. **Part 2** is about atoms.

Part 1 Current electricity

13a. A 24Ω resistor is made from a conducting wire. *[8 marks]*

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

(ii) A potential difference of 12V is applied between the ends of the wire. Calculate the acceleration of a free electron in the wire.

(iii) Suggest why the average speed of the free electron does not keep increasing even though it is being accelerated.

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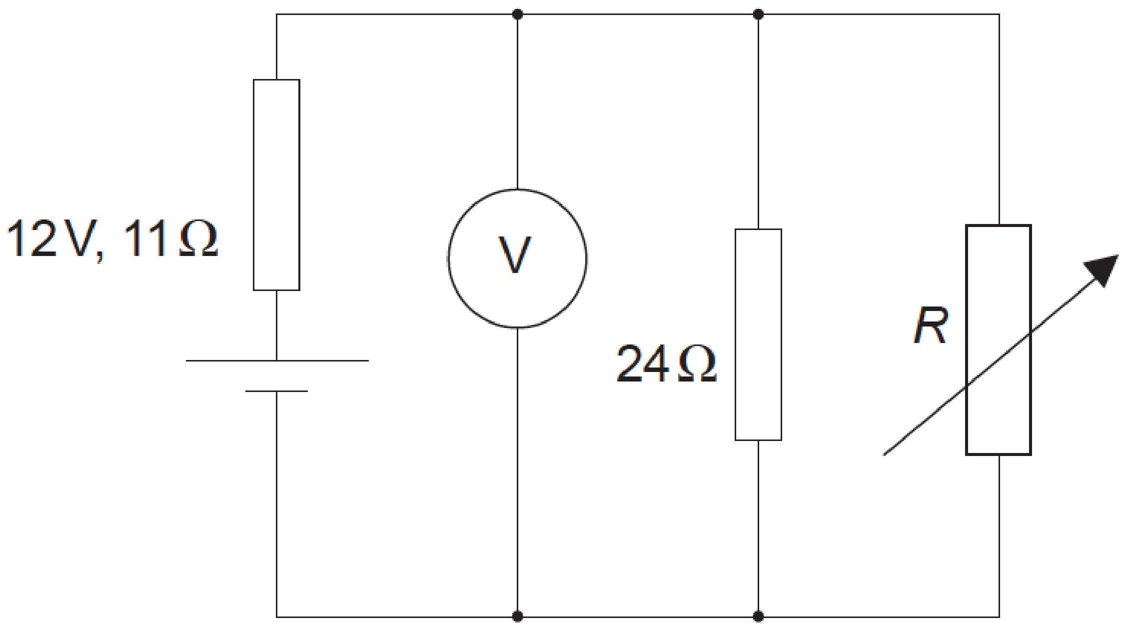
13b. An electric circuit consists of a supply connected to a 24Ω resistor in parallel with a variable resistor of resistance *R*. The supply has an emf of 12V and an internal resistance of 11Ω. *[7 marks]*



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 (b)(i).

(iii) Calculate the power dissipated in the 24Ω resistor when the maximum power is being delivered to the external circuit.

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Part 2 Atoms

13c. State what is meant by the wavefunction of an electron. *[1 mark]*

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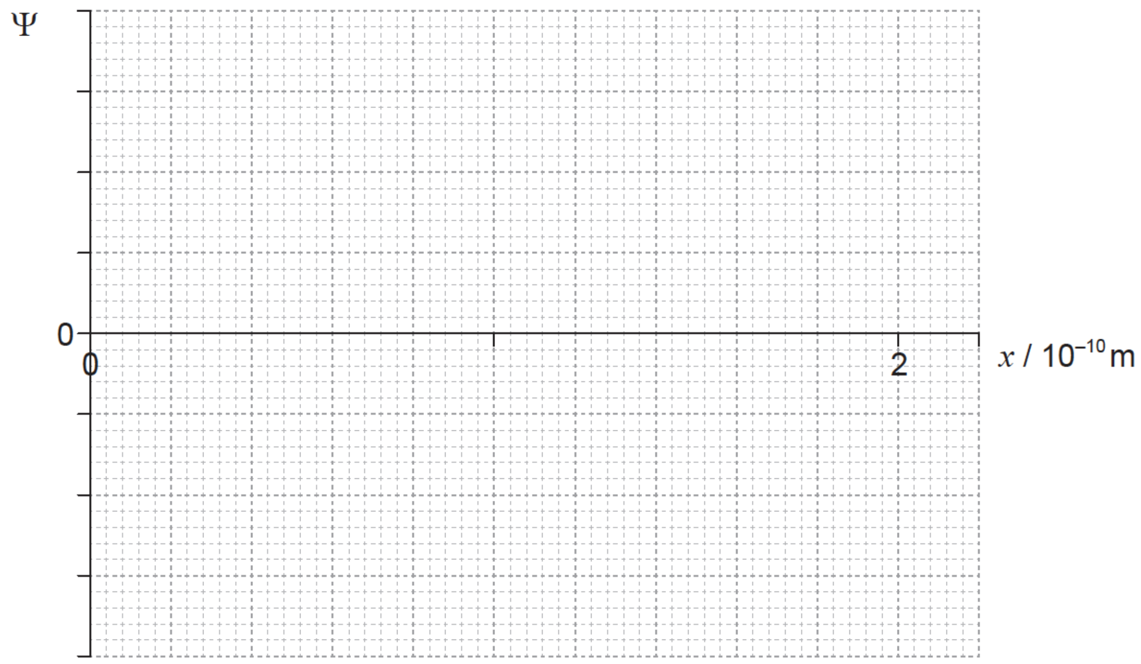
13d. An electron is confined in a length of 2.0×10^{-10} m. *[9 marks]*

(i) Determine the uncertainty in the momentum of the electron.

(ii) The electron has a momentum of 2.0×10^{-23}Ns. Determine the de Broglie wavelength of the electron.

(iii) On the axes, sketch the variation of the wavefunction Ψ of the electron in (d)(ii) with distance *x*. You may assume that $\Psi = 0$ when $x = 0$.

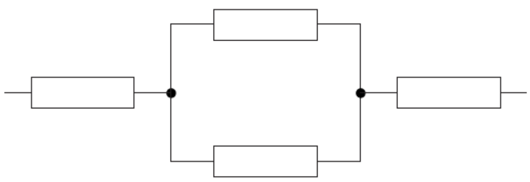


(iv) Identify the feature of your graph in (d)(iii) that gives the probability of finding the electron at a particular position and at a particular time.

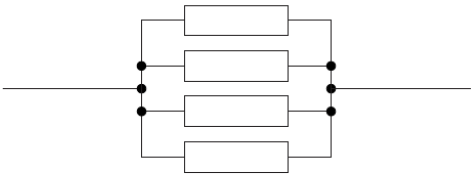
14. Each of the resistors in the arrangements below has resistance R. Each arrangement is connected, in turn, to a power supply of constant emf and negligible internal resistance. In which arrangement is the current in the power supply greatest? *[1 mark]*

A.

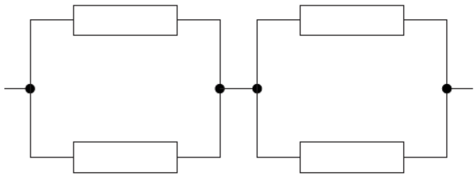
B.



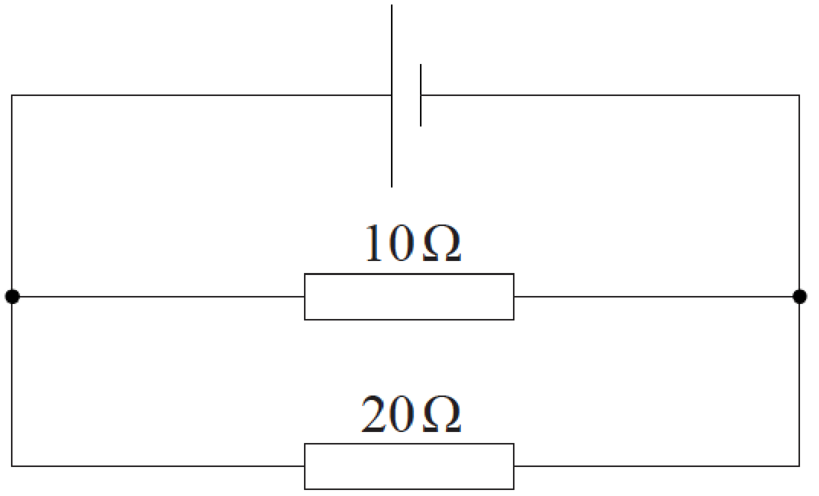
C.



D.



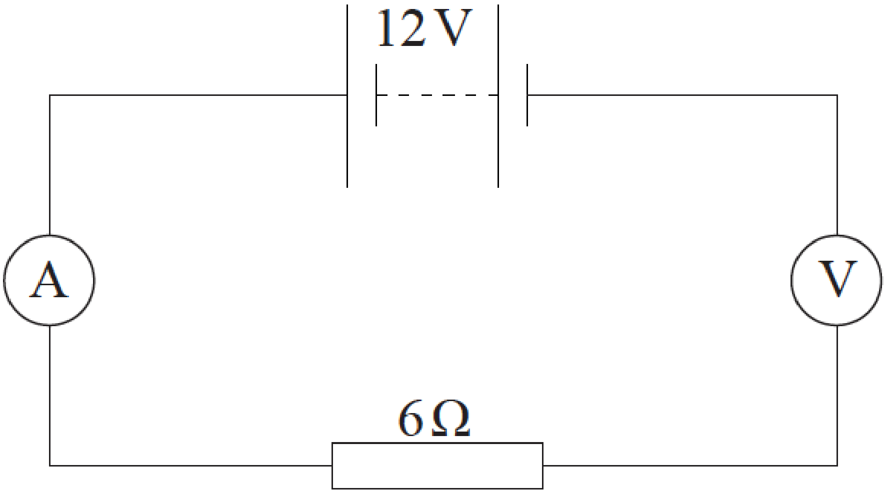
15. Two resistors of resistance 10 Ω and 20 Ω are connected in parallel to a cell of negligible internal resistance. *[1 mark]*



The energy dissipated in the 10 Ω resistor in one second is *Q*. What is the energy dissipated in one second in the 20 Ω resistor?

A. $\frac{Q}{4}$
B. $\frac{Q}{2}$
C. 2Q
D. 4Q

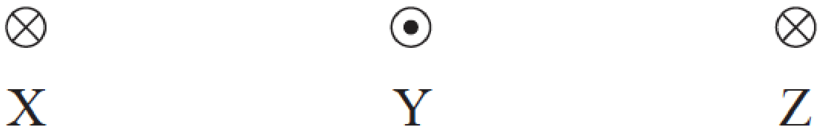
16. A battery of emf 12 V and negligible internal resistance is connected to a resistor of constant resistance 6 Ω, an ideal ammeter and an ideal voltmeter. *[1 mark]*



What is the reading on the ammeter and on the voltmeter?

	Ammeter reading / A	Voltmeter reading / V
A.	2.0	0
B.	2.0	12
C.	0	0
D.	0	12

17. Three parallel wires, X, Y and Z, carry equal currents. The currents in X and Z are directed into the page. The current in Y is directed out of the page. *[1 mark]*



Which arrow shows the direction of the magnetic force experienced by wire Z?

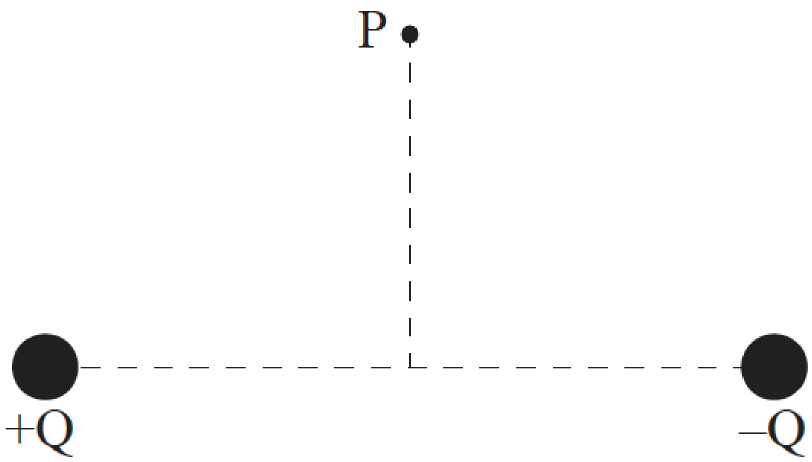
A. 

B. 

C. 

D. 

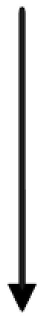
18. Point P is at the same distance from two charges of equal magnitude and opposite sign. *[1 mark]*

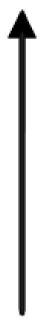


What is the direction of the electric field at point P?

A. 

B. 

C. 

D. 

19. Which of the following is a statement of Ohm’s law? *[1 mark]*

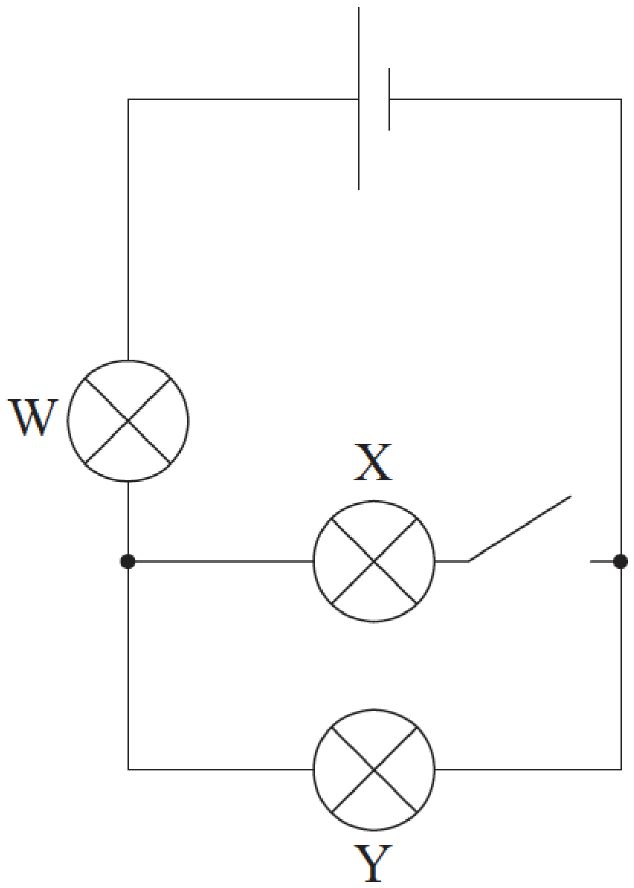
A. The resistance of a conductor is constant.

B. The current in a conductor is inversely proportional to the potential difference across the conductor provided the temperature is constant.

C. The resistance of a conductor is constant provided that the temperature is constant.

D. The current in a conductor is proportional to the potential difference across it.

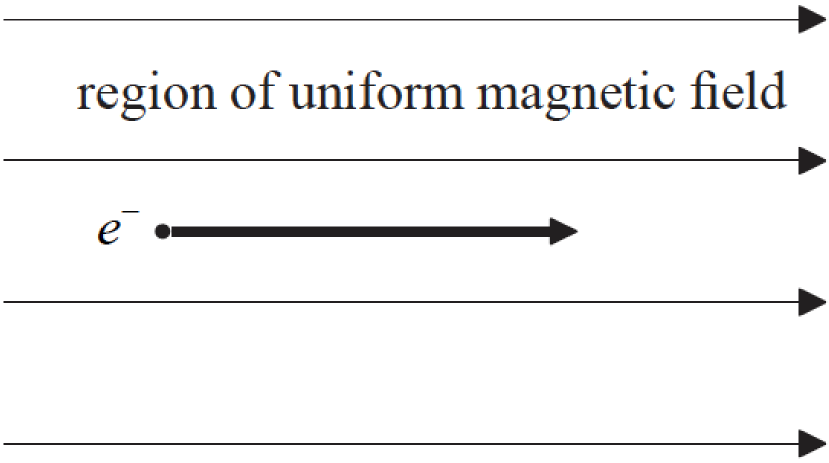
20. Three identical filament lamps W, X and Y are connected in the circuit as shown. The cell has negligible internal resistance. *[1 mark]*



When the switch is closed, all the lamps light. Which of the following correctly describes what happens to the brightness of lamp W and lamp Y when the switch is opened?

	Lamp W	**Lamp Y**
A.	decreases	decreases
B.	increases	decreases
C.	decreases	increases
D.	increases	increases

21. An electron is travelling in a region of uniform magnetic field. At the instant shown, the electron is moving parallel to the field direction. *[1 mark]*



The magnetic force on the electron is

A. upwards.

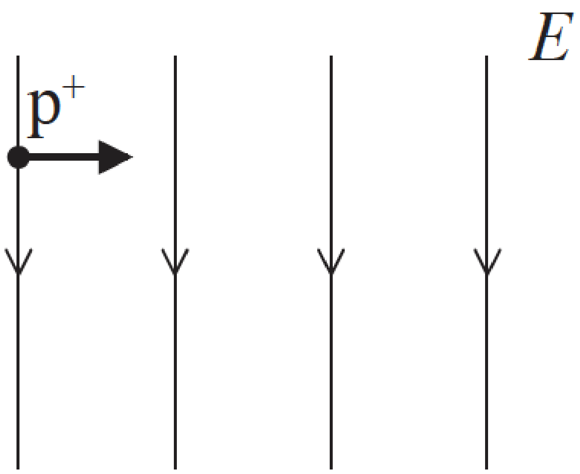
B. downwards.

C. to the right.

D. zero.

This question is about electric and magnetic fields.

A proton travelling to the right with horizontal speed $1.6 \times 10^4 ms^{-1}$ enters a uniform electric field of strength *E*. The electric field has magnitude $2.0 \times 10^3 NC^{-1}$ and is directed downwards.



22a. Calculate the magnitude of the electric force acting on the proton when it is in the electric field. *[2 marks]*

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22b. 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.

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23. A cylindrical resistor of volume *V* and length *l* has resistance *R*. The resistor has a uniform circular cross-section. *[1 mark]*
What is the resistivity of the material from which the resistor is made?

A. $\frac{V}{Rl^2}$

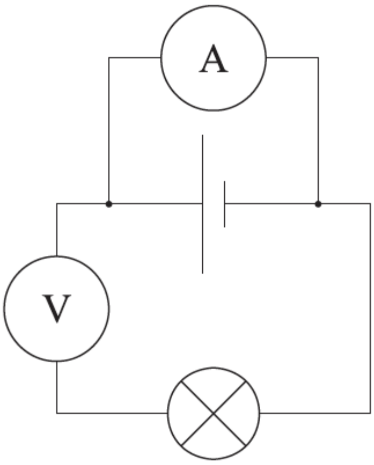
B. $\frac{V^2R}{l}$

C. $\frac{VR}{l^2}$

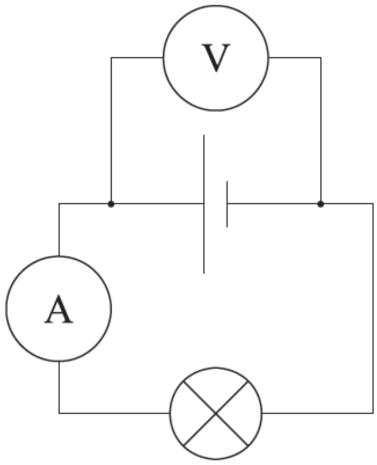
D. $\frac{V^2}{Rl}$

24. A lamp is connected to an electric cell and it lights at its working voltage. The lamp is then connected to the same cell in a circuit with an ideal ammeter and an ideal voltmeter. Which circuit allows the lamp to light at the original brightness? *[1 mark]*

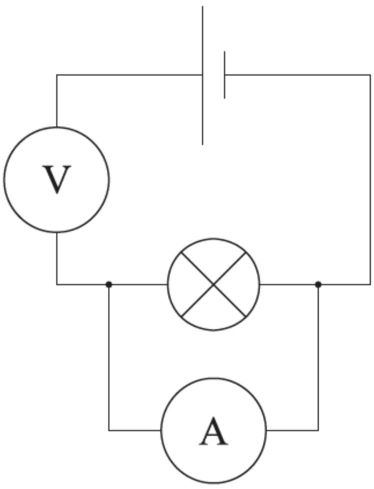
A.



B.



C.



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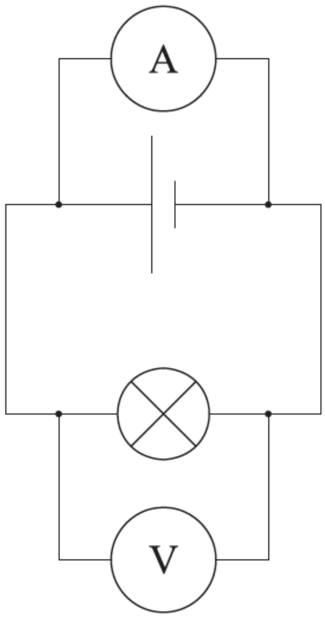
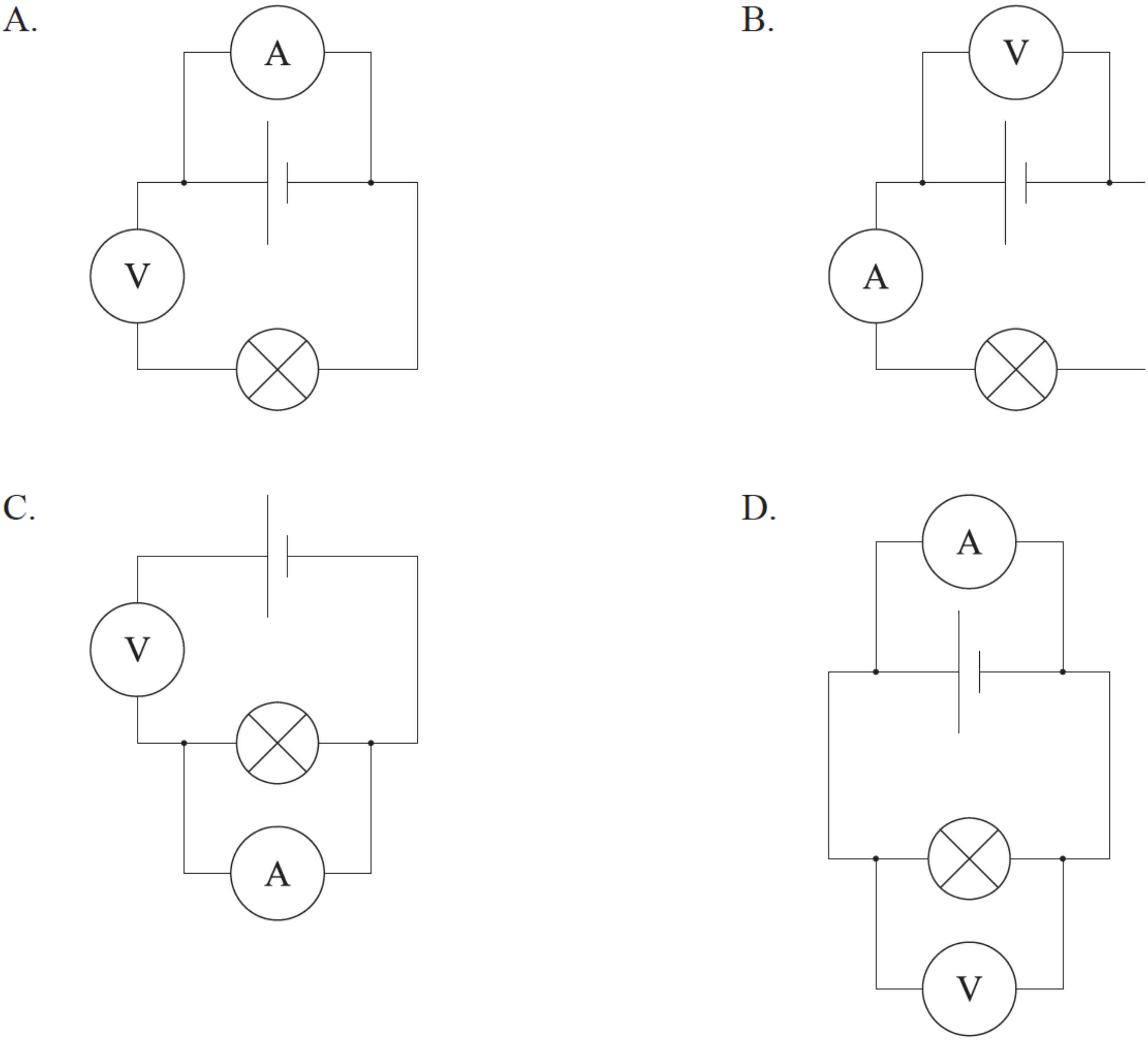
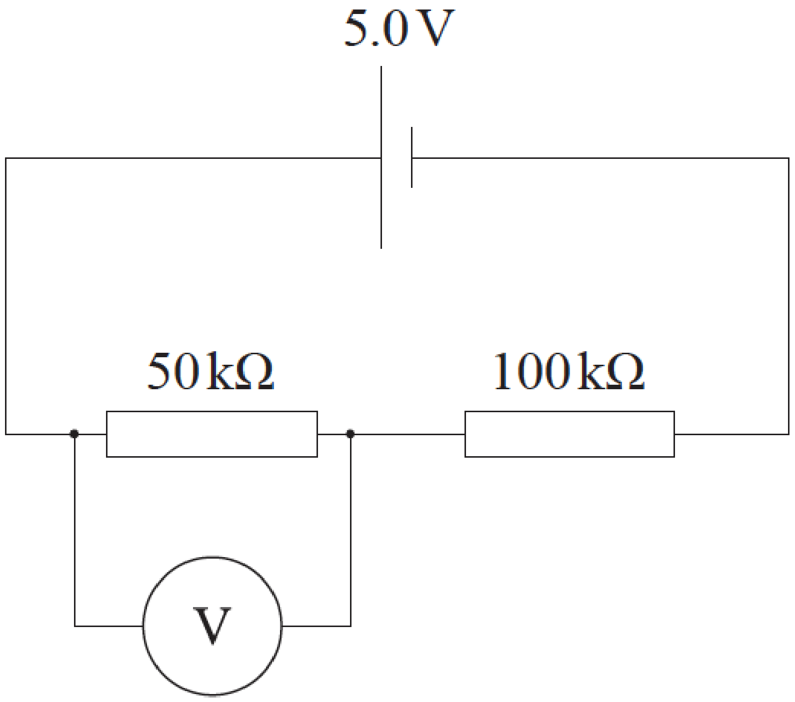


25. A lamp is connected to an electric cell and it lights at its working voltage. The lamp is then connected to the same cell in a circuit with an ideal ammeter and an ideal voltmeter. Which circuit allows the lamp to light at the original brightness? *[1 mark]*



26. A voltmeter of resistance 50kΩ is used to measure the electric potential difference in a circuit, as shown. The cell has an electromotive force (emf) of 5.0V and negligible internal resistance. *[1 mark]*



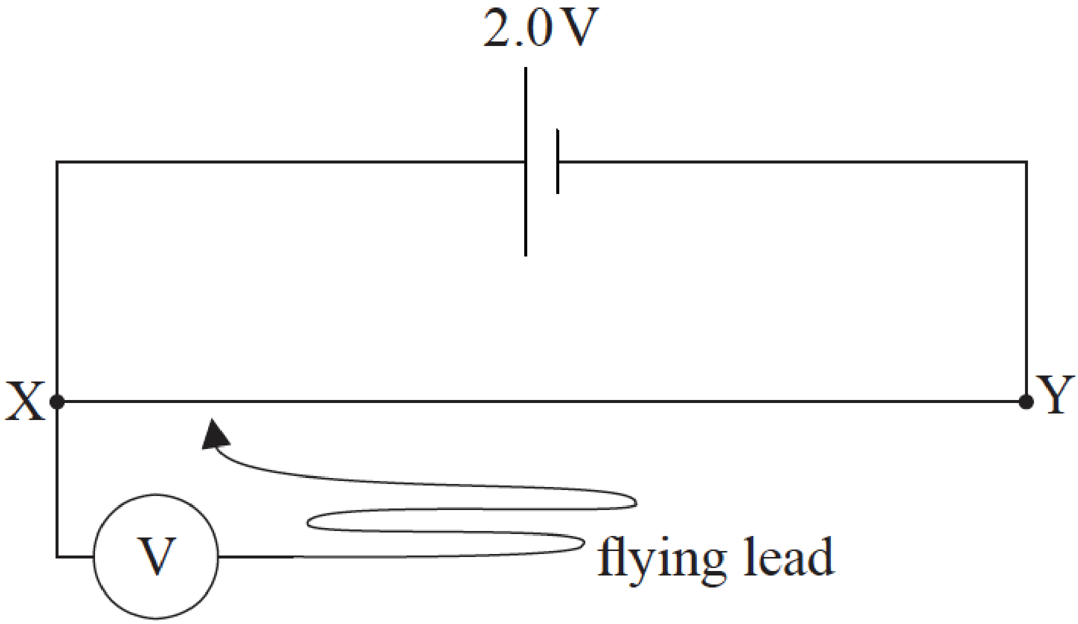
What is the reading on the voltmeter?

A. 1.0 V
B. 1.7 V
C. 4.0 V
D. 5.0 V

27. An ideal ammeter is used to measure the current in a resistor. Which of the following gives the resistance of an ideal ammeter and the way it is connected to the resistor? *[1 mark]*

	Resistance	Connection
A.	infinite	in parallel
B.	infinite	in series
C.	zero	in parallel
D.	zero	in series

28. A cell with an emf of 2.0 V and negligible internal resistance is connected across a 1.00 m length of uniform resistance wire XY. The free end of the flying lead can be connected to any position on the wire. *[1 mark]*



What is the voltmeter reading when the flying lead is connected 0.25m from end X?

A. 0.00 V
B. 0.50 V
C. 1.50 V
D. 2.00 V

29. An electron has a kinetic energy of 4.8×10^{-10}J. What is the equivalent value of this kinetic energy? *[1 mark]*

A. 3.0 eV
B. 3.0 keV
C. 3.0 MeV
D. 3.0 GeV

30. The magnetic field produced by a current in a straight wire is in *[1 mark]*

A. the same direction as the current.
B. the opposite direction to the current.
C. the same plane as the wire.
D. any plane perpendicular to the wire.

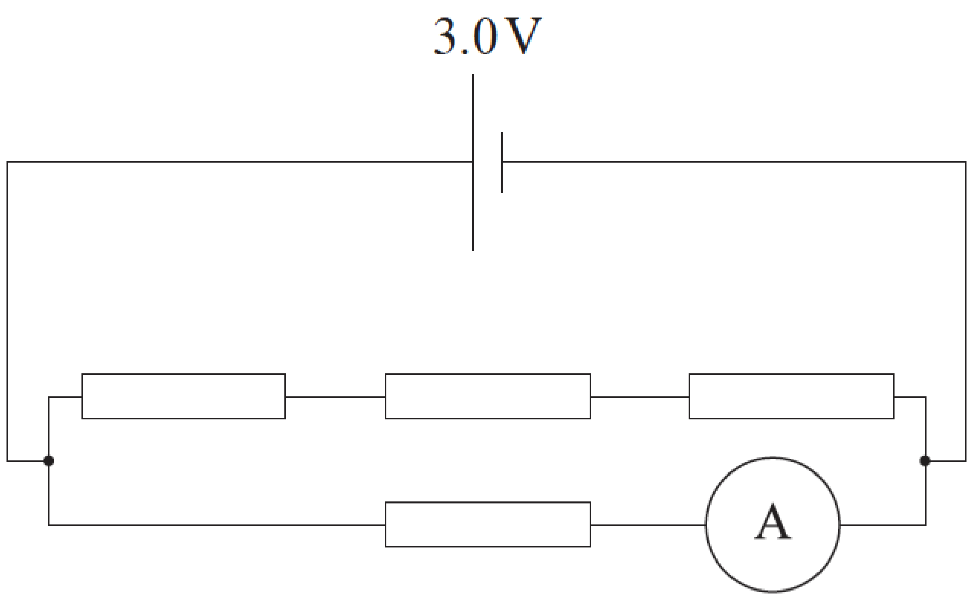
31. An ideal ammeter is used to measure the current in a resistor. Which of the following gives the resistance of an ideal ammeter and the way it is connected to the resistor? *[1 mark]*

	Resistance	Connection
A.	infinite	in parallel
B.	infinite	in series
C.	zero	in parallel
D.	zero	in series

32. A resistor X of resistance *R* is made of wire of length *L* and cross-sectional area *A*. Resistor Y is made of the same material but has a length 4*L* and a cross-sectional area 2*A*. X and Y are connected in series. What is the total resistance of the combination? *[1 mark]*

A. 1.5*R*
B. 2*R*
C. 3*R*
D. 9*R*

33. Each of the resistors in the circuit has a resistance of 2.0 Ω. The cell has an emf of 3.0 V and negligible internal resistance. The ammeter has negligible resistance. *[1 mark]*

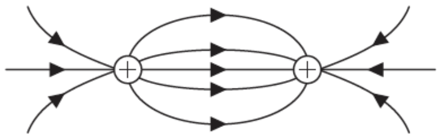


What is the ammeter reading?

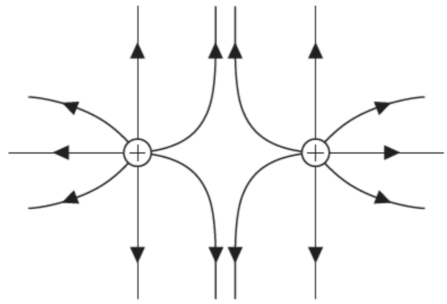
A. 0.4 A
B. 0.5 A
C. 1.5 A
D. 2.0 A

34. Which diagram represents the pattern of electric field lines of two small positive point charges held at the positions shown? *[1 mark]*

A.



B.



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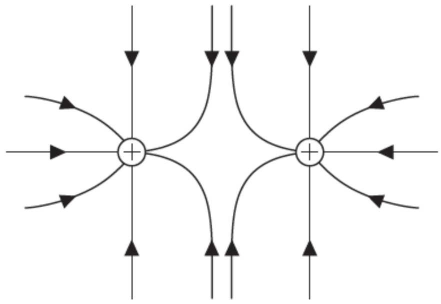
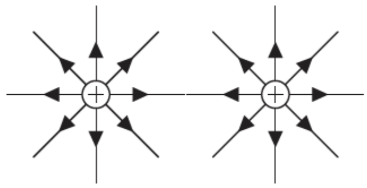
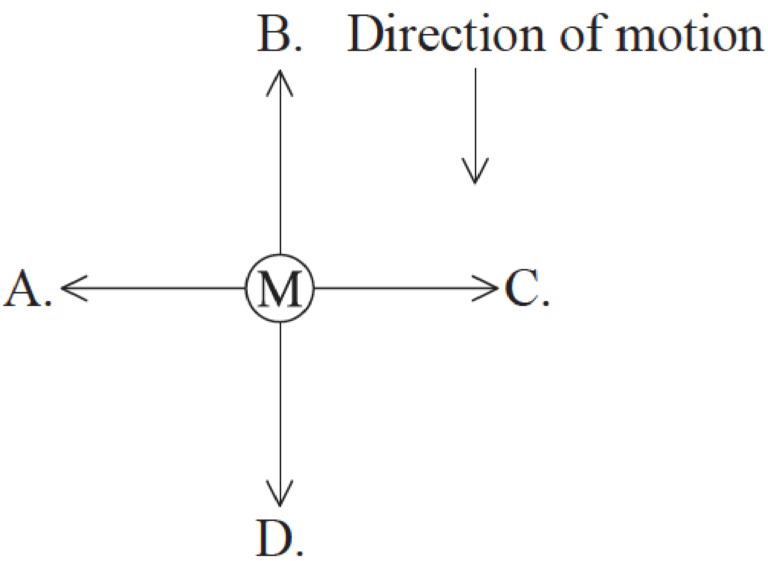


D.



35. A metal rod M is falling vertically within a horizontal magnetic field. The metal rod and magnetic field are directed into the paper. What is the direction of the initial force acting on the metal rod that is predicted by Lenz’s law? *[1 mark]*



36a. Define *electric field strength*. *[2 marks]*

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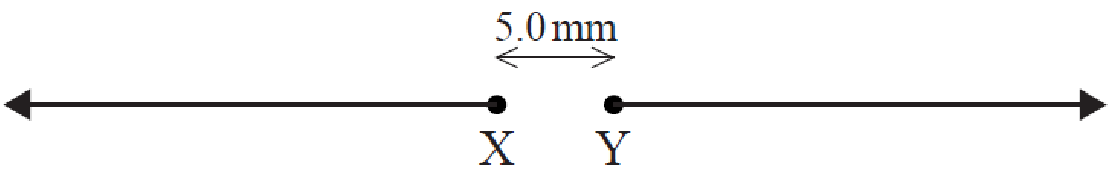
36c. The diagram shows two isolated electrons, X and Y, initially at rest in a vacuum. The initial separation of the electrons is 5.0 mm. The electrons subsequently move apart in the directions shown. *[8 marks]*

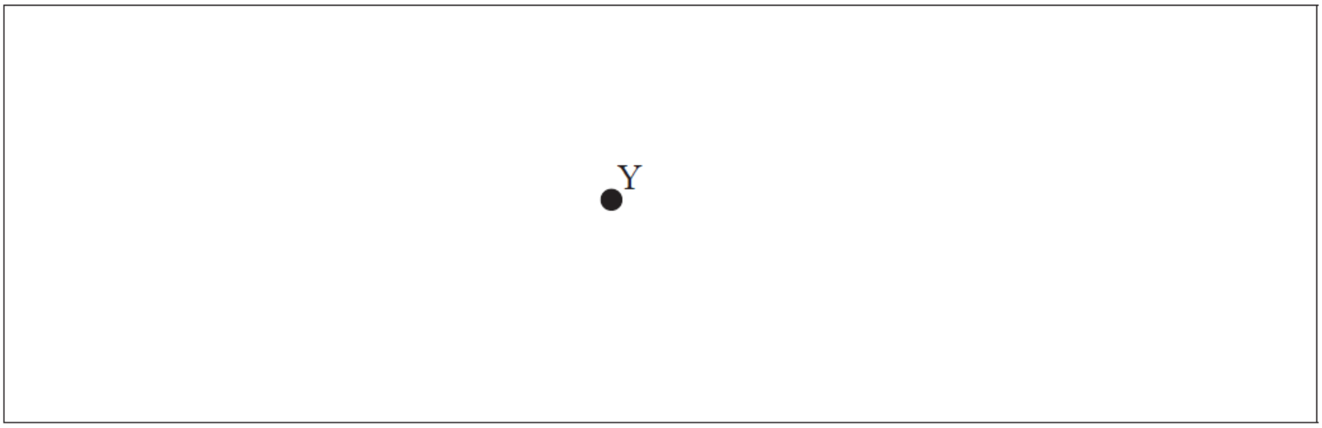


(i) Show that the initial electric force acting on each electron due to the other electron is approximately 9×10^{-24}N.

(ii) Calculate the initial acceleration of one electron due to the force in (c)(i).

(iii) Discuss the motion of one electron after it begins to move.

(iv) The diagram shows Y as seen from X, at one instant. Y is moving into the plane of the paper. For this instant, draw on the diagram the shape and direction of the magnetic field produced by Y.



This question is about alternative energy supplies.

A small island community requires a peak power of 850 kW. Two systems are available for supplying the energy: using wind power or photovoltaic cells.

37a. (i) Outline, with reference to the energy conversions in the machine, the main features of a conventional horizontal-axis wind generator. *[7 marks]*

(ii) The mean wind speed on the island is 8.0 ms^{-1}. Show that the maximum power available from a wind generator of blade length 45 m is approximately 2 MW.

Density of air = 1.2 kg m^{-3}

(iii) The efficiency of the generator is 24%. Deduce the number of these generators that would be required to provide the islanders with enough power to meet their energy requirements.

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37b. Distinguish between photovoltaic cells and solar heating panels. *[2 marks]*

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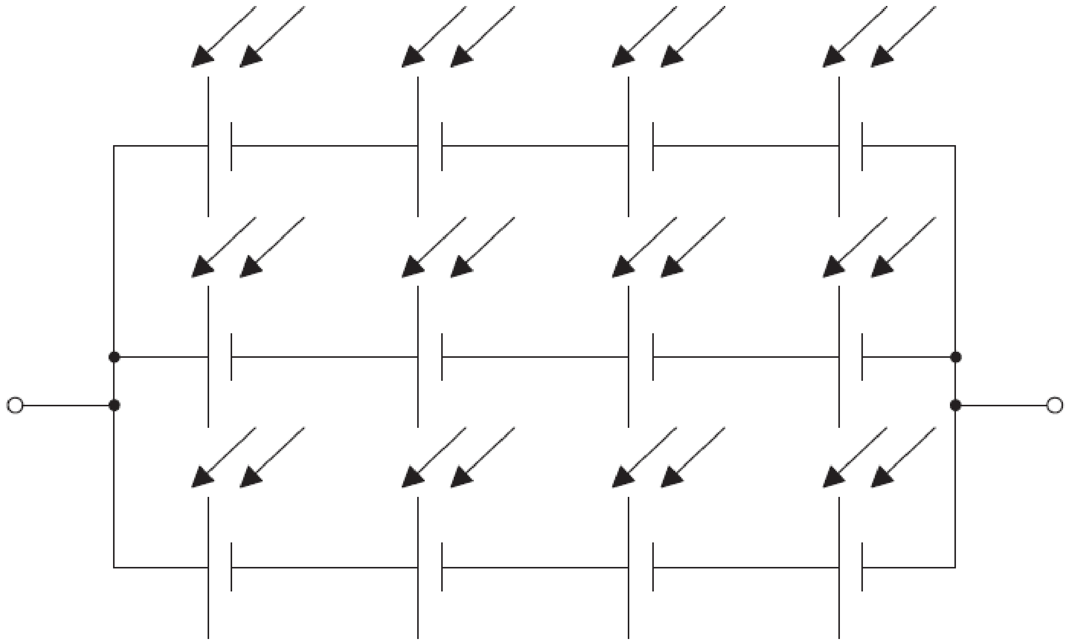
37c. The diagram shows 12 photovoltaic cells connected in series and in parallel to form a module to provide electrical power. *[8 marks]*

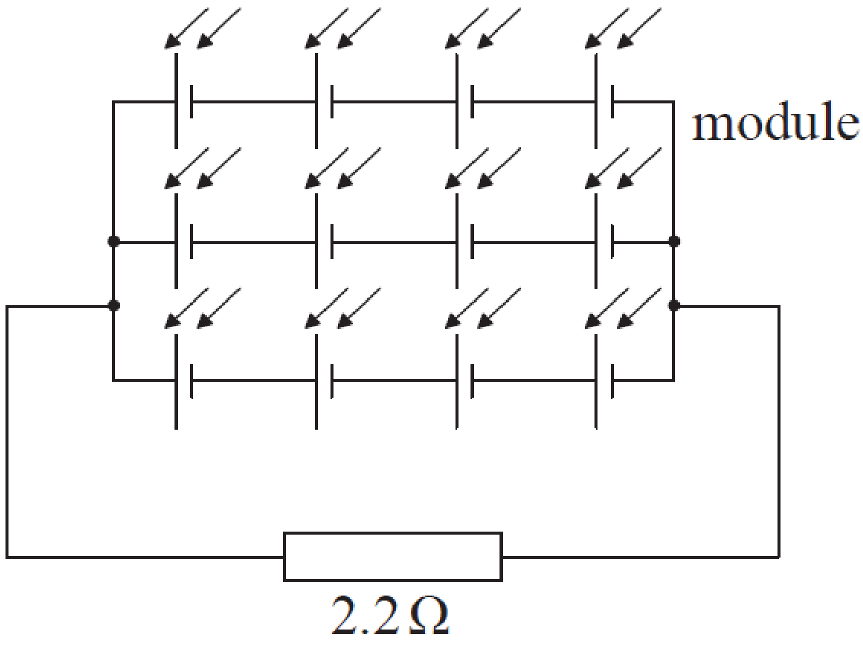


Each cell in the module has an emf of 0.75V and an internal resistance of 1.8Ω.

(i) Calculate the emf of the module.

(ii) Determine the internal resistance of the module.

(iii) The diagram below shows the module connected to a load resistor of resistance 2.2Ω.



Calculate the power dissipated in the load resistor.

(iv) Discuss the benefits of having cells combined in series and parallel within the module.

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37d. The intensity of the Sun's radiation at the position of the Earth's orbit (the solar constant) is approximately $1.4\times10^{3}\text{Wm}^{-2}$. *[5 marks]*

(i) Explain why the average solar power per square metre arriving at the Earth is 3.5×10^{2} W.

(ii) State why the solar constant is an approximate value.

(iii) Photovoltaic cells are approximately 20% efficient. Estimate the minimum area needed to supply an average power of 850kW over a 24 hour period.

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This question is in two parts. **Part 1** is about electric charge and electric circuits. **Part 2** is about momentum.

Part 1 Electric charge and electric circuits

38a. State Coulomb's law. *[2 marks]*

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38b. In a simple model of the hydrogen atom, the electron can be regarded as being in a circular orbit about the proton. The radius of the orbit is 2.0×10^{-10} m. *[7 marks]*

(i) Determine the magnitude of the electric force between the proton and the electron.

(ii) Calculate the magnitude of the electric field strength *E* and state the direction of the electric field due to the proton at a distance of 2.0×10^{-10} m from the proton.

(iii) The magnitude of the gravitational field due to the proton at a distance of 2.0×10^{-10} m from the proton is *H*. Show that the ratio $\frac{H}{E}$ is of the order 10^{-28}C kg^{-1}.

(iv) The orbital electron is transferred from its orbit to a point where the potential is zero. The gain in potential energy of the electron is 5.4×10^{-19}J. Calculate the value of the potential difference through which the electron is moved.

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38c. An electric cell is a device that is used to transfer energy to electrons in a circuit. A particular circuit consists of a cell of emf ε and internal resistance r connected in series with a resistor of resistance 5.0 Ω. *[6 marks]*

(i) Define *emf of a cell.*

(ii) The energy supplied by the cell to one electron in transferring it around the circuit is 5.1×10^{-19}J. Show that the emf of the cell is 3.2V.

(iii) Each electron in the circuit transfers an energy of 4.0×10^{-19} J to the 5.0 Ω resistor. Determine the value of the internal resistance *r.*

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39. A copper wire with length L and radius r has a resistance R. *[1 mark]*

What is the radius of a copper wire with length $\frac{L}{2}$ and resistance R?

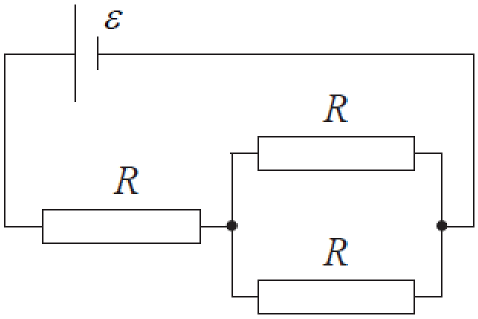
A. $2r$

B. $\sqrt{2}r$

C. $\frac{r}{\sqrt{2}}$

D. $\frac{r}{2}$

40. An electric circuit consists of three identical resistors of resistance R connected to a cell of emf ε and negligible internal resistance. *[1 mark]*



What is the magnitude of the current in the cell?

A. $\frac{\varepsilon}{3R}$

B. $\frac{2\varepsilon}{3R}$

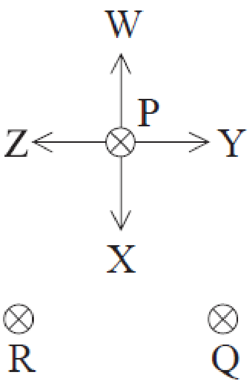
C. $\frac{3\varepsilon}{2R}$

D. $\frac{3\varepsilon}{R}$

41. A proton is accelerated from rest through a potential difference of 1000 V. What is the potential difference through which an alpha particle must be accelerated to gain the same kinetic energy as the accelerated proton? *[1 mark]*

A. 4000 V
B. 2000 V
C. 500 V
D. 250 V

42. Three wires, P, Q and R, carry equal currents directed into the plane of the paper. *[1 mark]*



Which arrow correctly identifies the direction of the magnetic force on wire P?

A. W
B. X
C. Y
D. Z

43. A copy wire with length L and radius r has a resistance R. *[1 mark]*

What is the radius of a copper wire with length $\frac{L}{2}$ and resistance R?

A. $2r$

B. $\sqrt{2}r$

C. $\frac{r}{\sqrt{2}}$

D. $\frac{r}{2}$

44. The electric potential is V_R at a point R in an electric field and at another point S the electric potential is V_S. Which of the following is the work done by the electric field on a point charge $+q$ as it moves from R to S? *[1 mark]*

A. V_R-V_S

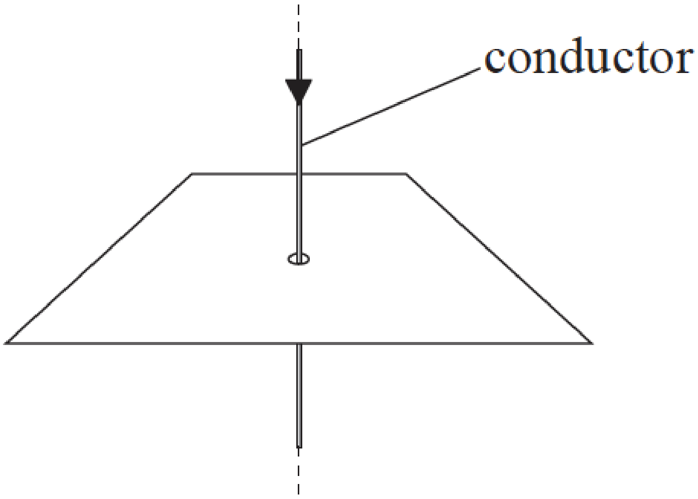
B. $q(V_R$-$V_S)$

C. V_S-V_R

D. $q(V_S$-$V_R)$

This question is about magnetic fields.

A long straight vertical conductor carries an electric current. The conductor passes through a hole in a horizontal piece of paper.



45a. State how a magnetic field arises. *[1 mark]*

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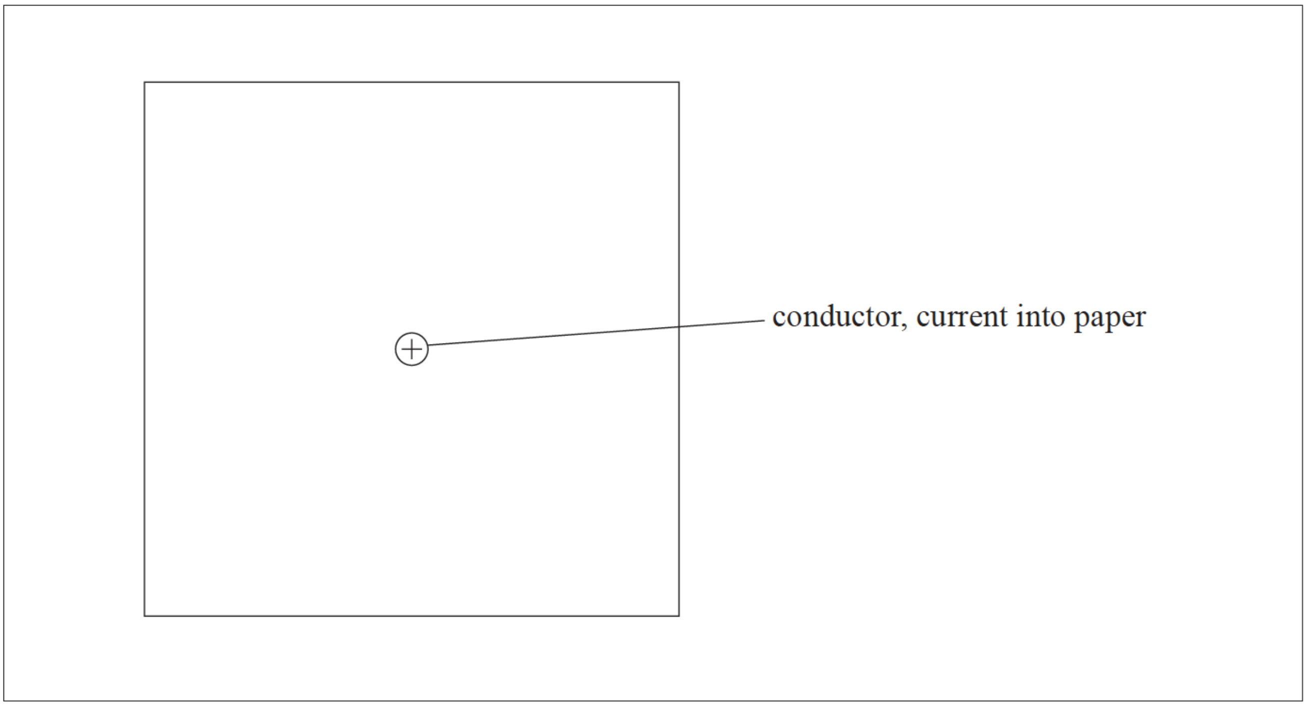
45b. On the diagram below, sketch the magnetic field pattern around the long straight current-carrying conductor. The direction of the current is into the plane of the paper. *[2 marks]*



This question is in **two** parts. **Part 1** is about electric fields and radioactive decay. **Part 2** is about change of phase.

Part 1 Electric fields and radioactive decay

46a. Define *electric field strength*. *[2 marks]*

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46b. A simple model of the proton is that of a sphere of radius 1.0×10^{-15}m with charge concentrated at the centre of the sphere. Estimate the magnitude of the field strength at the surface of the proton. *[2 marks]*

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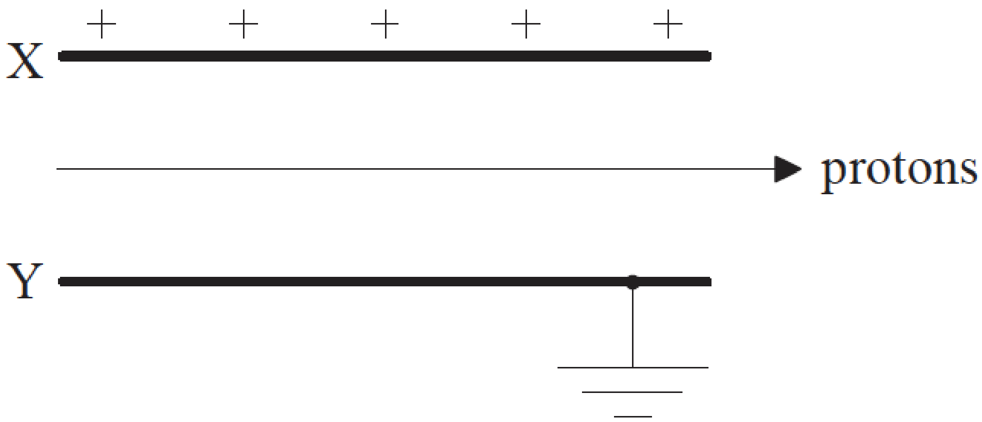
46c. Protons travelling with a speed of 3.9×10^{6}ms^{-1} enter the region between two charged parallel plates X and Y. Plate X is positively charged and plate Y is connected to earth. *[4 marks]*



A uniform magnetic field also exists in the region between the plates. The direction of the field is such that the protons pass between the plates without deflection.

(i) State the direction of the magnetic field.

(ii) The magnitude of the magnetic field strength is 2.3×10^{-4}T. Determine the magnitude of the electric field strength between the plates, stating an appropriate unit for your answer.

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46d. Protons can be produced by the bombardment of nitrogen-14 nuclei with alpha particles. The nuclear reaction equation for this process is given below. *[1 mark]*

$$^{14}_{7}\mathrm{N} + {}^{4}_{2}\mathrm{He} \rightarrow \mathrm{X} + {}^{1}_{1}\mathrm{H}$$

Identify the proton number and nucleon number for the nucleus X.

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46e. The following data are available for the reaction in (d). *[3 marks]*

Rest mass of nitrogen-14 nucleus =14.0031 u
Rest mass of alpha particle =4.0026 u
Rest mass of X nucleus =16.9991 u
Rest mass of proton =1.0073 u

Show that the minimum kinetic energy that the alpha particle must have in order for the reaction to take place is about 0.7 Me V.

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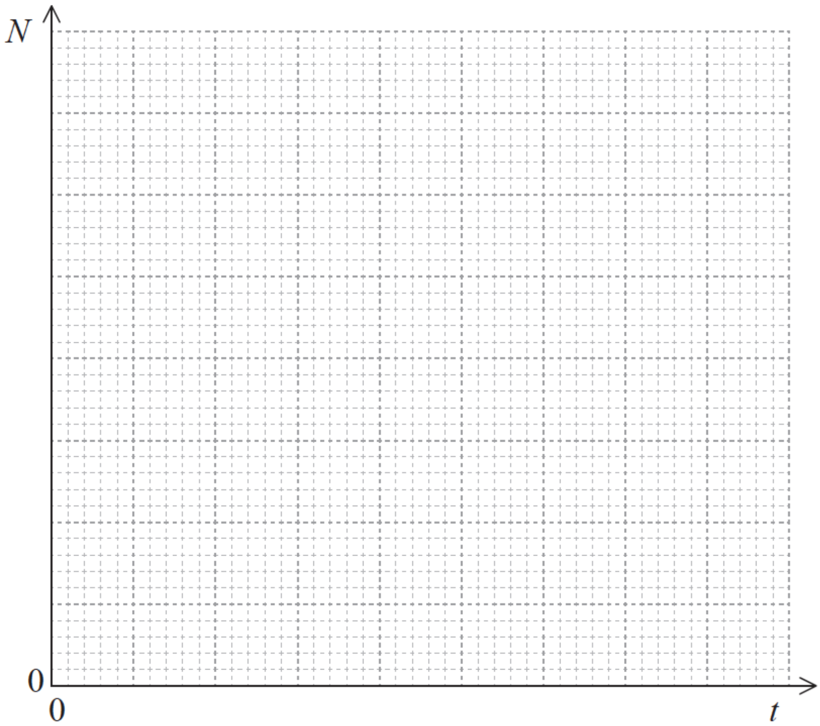
46f. A nucleus of another isotope of the element X in (d) decays with a half-life $T_{\frac{1}{2}}$ to a nucleus of an isotope of fluorine-19 (F-19). *[5 marks]*

(i) Define the terms *isotope* and *half-life*.

(ii) Using the axes below, sketch a graph to show how the number of atoms *N* in a sample of X varies with time *t*, from *t*=0 to $t = 3T_{\frac{1}{2}}$. There are N_0 atoms in the sample at *t*=0.



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Part 2 Change of phase

46g. Water at constant pressure boils at constant temperature. Outline, in terms of the energy of the molecules, the reason for this. *[2 marks]*

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46h. In an experiment to measure the specific latent heat of vaporization of water, steam at 100°C was passed into water in an insulated container. The following data are available. *[4 marks]*

Initial mass of water in container = 0.300kg
Final mass of water in container = 0.312kg
Initial temperature of water in container = 15.2°C
Final temperature of water in container = 34.6°C
Specific heat capacity of water = 4.18×10^{3} $\text{Jkg}^{-1}\text{K}^{-1}$

Show that the data give a value of about 1.8×10^{6} Jkg^{-1} for the specific latent heat of vaporization *L* of water.

46i. Explain why, other than measurement or calculation error, the accepted value of *L* is greater than that given in (h). *[2 marks]*

This question is in **two** parts. **Part 1** is about simple harmonic motion (SHM) and waves. **Part 2** is about voltage–current (*V*–*I*) characteristics.

Part 1 Simple harmonic motion (SHM) and waves

47a. A particle P moves with simple harmonic motion. State, with reference to the motion of P, what is meant by simple harmonic motion. *[2 marks]*

47b. The particle P in (b) is a particle in medium M_1 through which a transverse wave is travelling. *[5 marks]*

(i) Describe, in terms of energy propagation, what is meant by a transverse wave.

(ii) The speed of the wave through the medium is $0.40 ms^{-1}$. Calculate, using your answer to (b)(i), the wavelength of the wave.

(iii) The wave travels into another medium M_2. The refractive index of M_2 relative to M_1 is 1.8. Calculate the wavelength of the wave in M_2.

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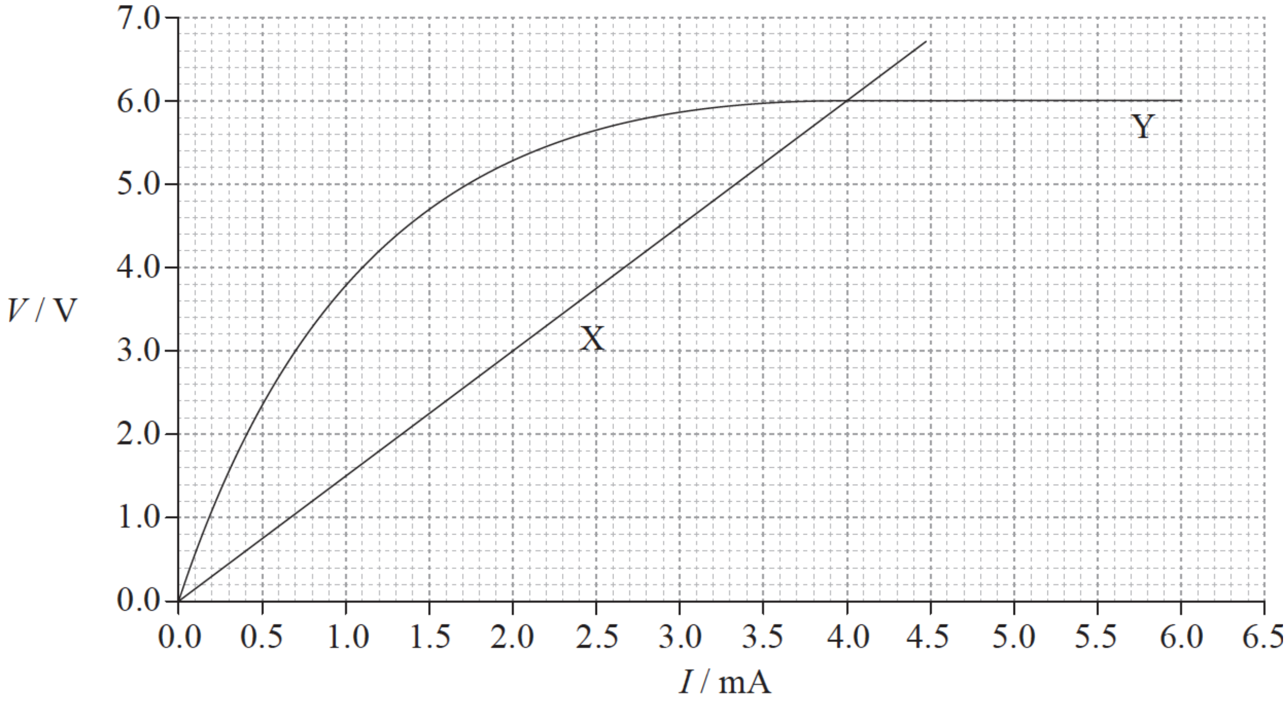
Part 2 Voltage–current (V–I) characteristics

The graph shows the voltage–current (V–I) characteristics, at constant temperature, of two electrical components X and Y.



47c. Outline, with reference to the graph and to Ohm's law, whether or not each component is ohmic. *[3 marks]*

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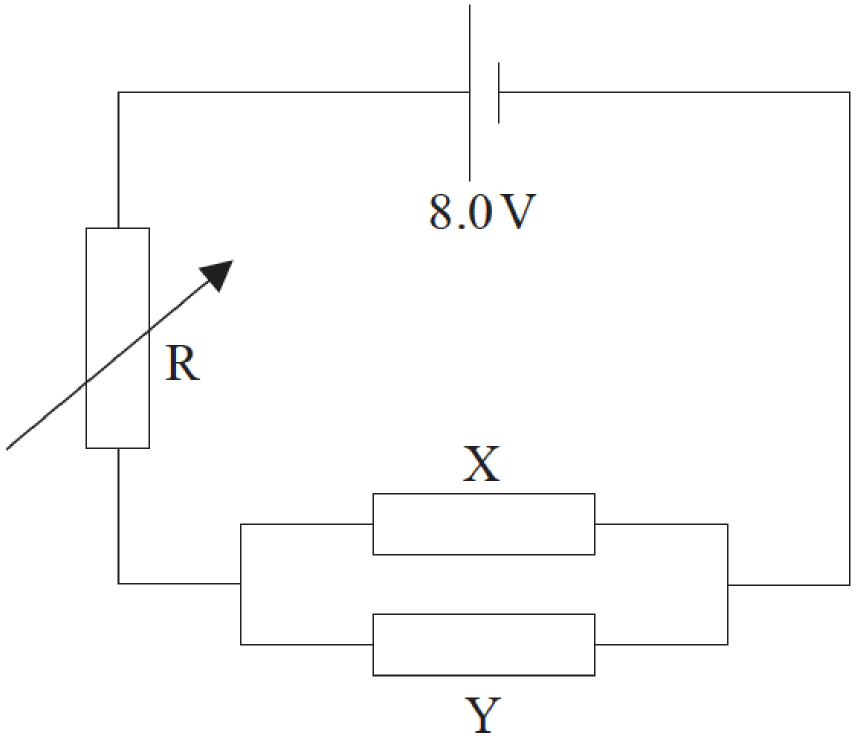
47d. Components X and Y are connected in parallel. The parallel combination is then connected in series with a variable resistor R and a cell of emf 8.0V and negligible internal resistance. *[8 marks]*



The resistance of R is adjusted until the currents in X and Y are equal.

(i) Using the graph, calculate the resistance of the parallel combination of X and Y.

(ii) Using your answer to (e)(i), determine the resistance of R.

(iii) Determine the power delivered by the cell to the circuit.