# T5-2 *[122 marks]*
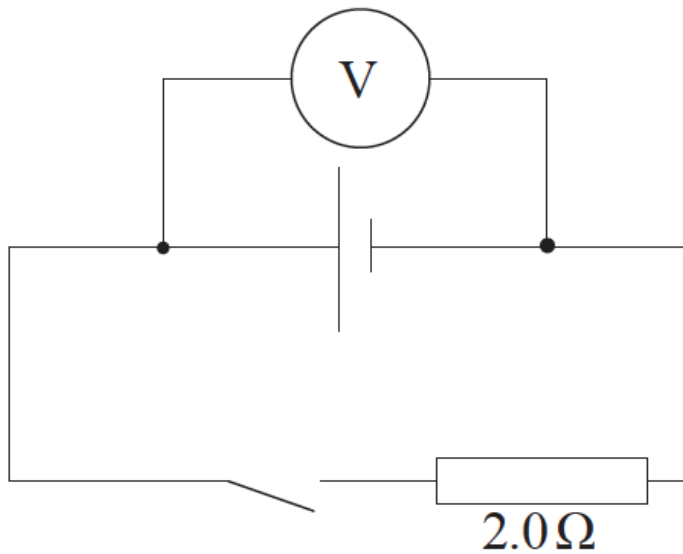
1. A cell is connected in series with a 2.0Ω resistor and a switch. The voltmeter is connected across the cell and reads 12V when the switch is open and 8.0V when the switch is closed.   *[1 mark]*



2.0Ω

What is the internal resistance of the cell?

A. 1.0 Ω
B. 2.0 Ω
C. 3.0 Ω
D. 4.0 Ω

2. Which of the following is the SI unit of gravitational field strength?   *[1 mark]*

A. N
B. N m
C. $Nkg^{-1}$
D. $Nm^2kg^{-2}$

3. Which of the following is the best representation of the electric field lines around a negatively charged metal sphere?   *[1 mark]*
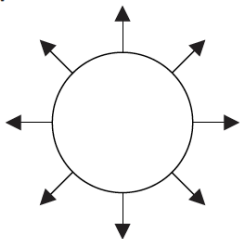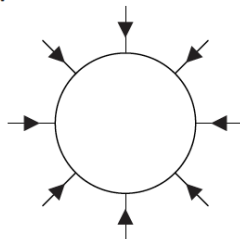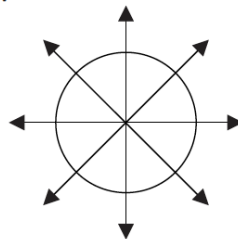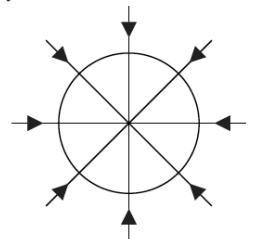
4. The diagram shows two long wires X and Y carrying identical currents in the same direction. *[1 mark]*
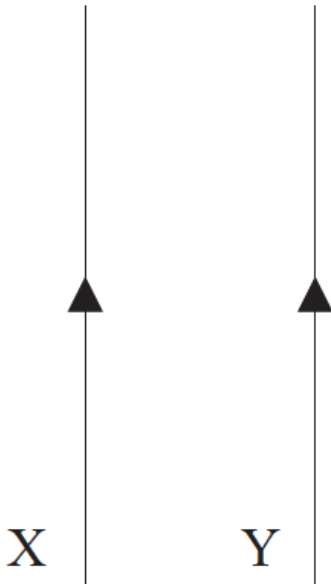


The direction of the force experienced by Y is

A. to the left.
B. to the right.
C. into the plane of the page.
D. out of the plane of the page.

5. A resistor has a resistance $R$. The potential difference across the resistor is $V$. Which of the following gives the energy dissipated in the resistor in time $t$? *[1 mark]*

A. $\frac{Vt}{R}$

B. $\frac{Rt}{V^2}$

C. $RV^2t$

D. $\frac{V^2t}{R}$

6. A metal wire X with length $L$ and radius $r$ has a resistance $R$. A wire Y of length $4L$ made from the same material as X has the same resistance $R$. What is the radius of Y? *[1 mark]*

A. $2r$

B. $4r$

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

D. $\frac{r}{4}$

7. Three identical filament lamps, X, Y and Z, are connected as shown to a battery of negligible internal resistance. *[1 mark]*
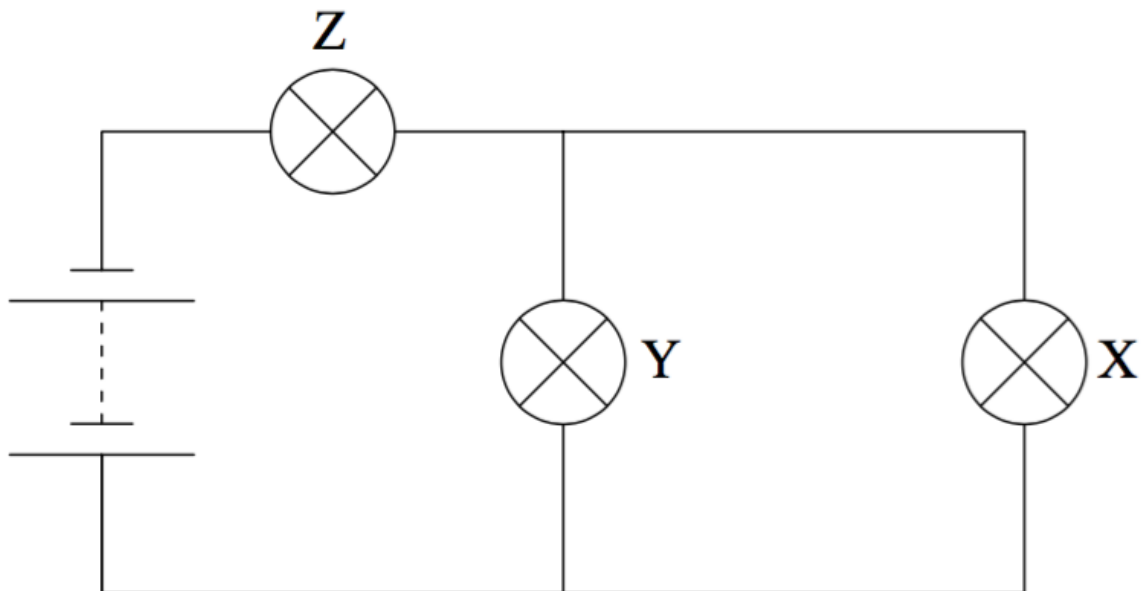


The filament of lamp X breaks. Which of the following correctly describes the change in brightness of lamp Y and of lamp Z?

|  | Lamp Y | Lamp Z |
|---|---|---|
| A. | increase | increase |
| B. | decrease | increase |
| C. | increase | decrease |
| D. | decrease | decrease |

8. Which of the following is the correct way of connecting an ammeter and of connecting a voltmeter in a circuit designed to measure the characteristics of a thermistor? [1 mark]

| | **Ammeter** | **Voltmeter** |
|---|---|---|
| A. | in series with thermistor | in series with thermistor |
| B. | in parallel with thermistor | in series with thermistor |
| C. | in series with thermistor | in parallel with thermistor |
| D. | in parallel with thermistor | in parallel with thermistor |

9. Coulomb's law refers to electric charges that are [1 mark]

A. on any charged objects.
B. charged hollow spheres.
C. charged solid spheres.
D. point charges.

10. Which of the following will **not** give rise to a magnetic field? [1 mark]

A. A moving electron
B. A moving neutron
C. A proton and electron moving away from each other
D. A proton and electron moving towards each other

11. The ampere is defined in terms of [1 mark]

A. power dissipated in a wire of known length, cross-sectional area and resistivity.

B. potential difference across a resistance of known value.

C. number of electrons flowing past a point in a circuit in a given time.

D. force per unit length between parallel current-carrying conductors.

12. A battery of emf 6.0V is connected to a $2.0\Omega$ resistor. The current in the circuit is 2.0A. The internal resistance of the battery is [1 mark]

A. zero.

B. $1.0\ \Omega$.

C. $3.0\ \Omega$.

D. $4.0\ \Omega$.

13. Which of the following gives the resistances of an ideal ammeter and an ideal voltmeter?                    *[1 mark]*

|  | **Resistance of ideal ammeter** | **Resistance of ideal voltmeter** |
|---|---|---|
| A. | infinite | infinite |
| B. | zero | infinite |
| C. | infinite | zero |
| D. | zero | zero |

14. Three parallel wires, X, Y and Z, carry equal currents into the page.                    *[1 mark]*

X            Y            Z
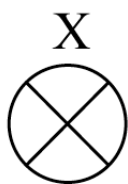


Which arrow represents the direction of the magnetic force on wire Z?

A. 

B. 

C. 

D. 
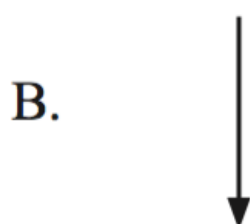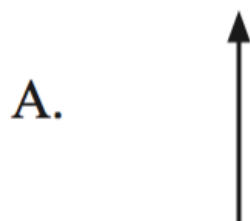
15. A proton p is at rest between the poles of two horizontal magnets as shown below. [1 mark]

top

| S | N |
|---|---|

• 
p

| S | N |
|---|---|
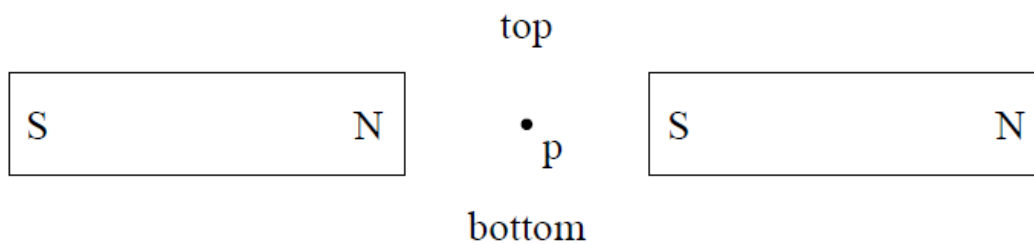
bottom

The magnetic force on the proton is

A. from left to right.

B. from top to bottom.

C. into the plane of the paper.

D. zero.


**Part 2** Electric potential difference and electric circuits

16a. Ionized hydrogen atoms are accelerated from rest in the vacuum between two vertical parallel conducting [2 marks]
plates. The potential difference between the plates is $V$. As a result of the acceleration each ion gains an energy of $1.9 \times 10^{-18}$ J.

Calculate the value of $V$.

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16b. 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 $1.44 \times 10^{-18}$ 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.

. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

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17. The magnitude of gravitational field strength $g$ is defined from the equation shown below.    *[4 marks]*

$$g = \frac{F_g}{m}$$

The magnitude of electric field strength $E$ is defined from the equation shown below.

$$E = \frac{F_E}{q}$$

For each of these defining equations, state the meaning of the symbols

(i) $F_g$.

(ii) $F_E$.

(iii) $m$.

(iv) $q$.

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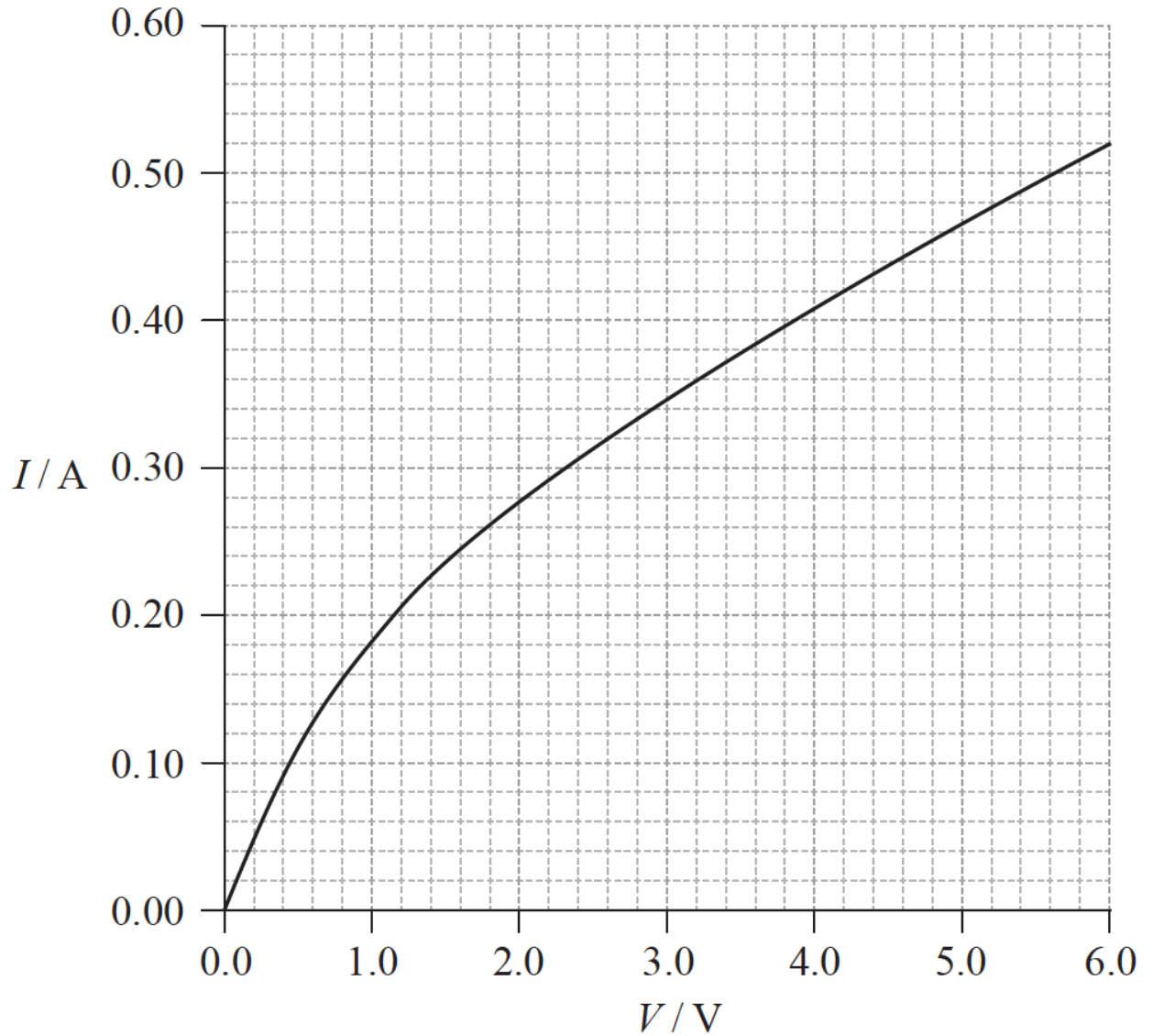
**Part 2** Electric current and resistance

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



18a. (i) Define the electrical *resistance* of a component.                                                 *[3 marks]*

(ii) Explain whether or not the filament obeys Ohm's law.

18b. (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 $5.8 \times 10^{-7} \Omega$ m. Calculate the radius of the filament.

. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

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18c. Two identical filament lamps are connected in series with a cell of emf 6.0 V and negligible internal resistance. *[2 marks]*
Using the graph on page 26, calculate the total power dissipated in the circuit.

. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

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This question is in **two** parts. **Part 1** is about fields, electric potential difference and electric circuits. **Part 2** is about thermodynamic cycles.

**Part 1** Fields, electric potential difference and electric circuits

19a. The magnitude of gravitational field strength $g$ is defined from the equation shown below.                    *[4 marks]*

$$g = \frac{F_g}{m}$$

The magnitude of electric field strength $E$ is defined from the equation shown below.

$$E = \frac{F_E}{q}$$

For each of these defining equations, state the meaning of the symbols

(i) $F_g$.

(ii) $F_E$.

(iii) $m$.

(iv) $q$.

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19b. In a simple model of the hydrogen atom, the electron is regarded as being in a circular orbit about the proton.    *[3 marks]*
The magnitude of the electric field strength at the electron due to the proton is $E_p$ . The magnitude of the gravitational field strength at the electron due to the proton is $g_p$.

Determine the order of magnitude of the ratio shown below.

$$\frac{E_p}{g_p}$$

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This question is about the properties of tungsten.

20a. Tungsten is a conductor used as the filament of an electric lamp. The filament of the lamp is surrounded by glass which is an insulator.  *[2 marks]*

Outline, in terms of their atomic structure, the difference between the electrical properties of tungsten and of glass.

. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

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20b. A tungsten filament lamp is marked 6.0 V, 15 W.  *[3 marks]*

(i) Show that the resistance of the lamp at its working voltage is 2.4 Ω.

(ii) The length of the filament is 0.35 m and the resistivity of tungsten is $5.6\times10^{-7}$ Ω m at its working voltage.

Calculate the cross-sectional area of the tungsten filament.

. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

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20c. The diagram shows part of a potential divider circuit used to measure the current-potential difference (*I–V*)    *[2 marks]*
characteristic of the bulb.
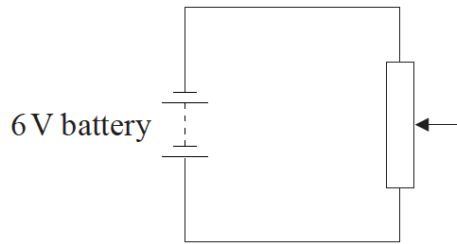


Draw the complete circuit showing the correct position of the bulb, ammeter and voltmeter.

**Part 2** Electric motor

An electric motor is used to raise a load.

21a. Whilst being raised, the load accelerates uniformly upwards. The weight of the cable is negligible compared to the weight of the load.   *[6 marks]*

(i) Draw a labelled free-body force diagram of the forces acting on the accelerating load. The dot below represents the load.

●

(ii) The load has a mass of 350 kg and it takes 6.5 s to raise it from rest through a height of 8.0 m.

Determine the tension in the cable as the load is being raised.

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21b. The electric motor can be adjusted such that, after an initial acceleration, the load moves at constant speed.     *[4 marks]*
The motor is connected to a 450 V supply and with the load moving at constant speed, it takes the motor 15 s to raise the load through 7.0 m.

(i) Calculate the power delivered to the load by the motor.

(ii) The current in the motor is 30 A. Estimate the efficiency of the motor.

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This question is in **two** parts. **Part 1** is about the properties of tungsten. **Part 2** is about the properties of a gas.

**Part 1** Properties of tungsten

An isolated nucleus of an atom of the metal tungsten contains 74 protons.
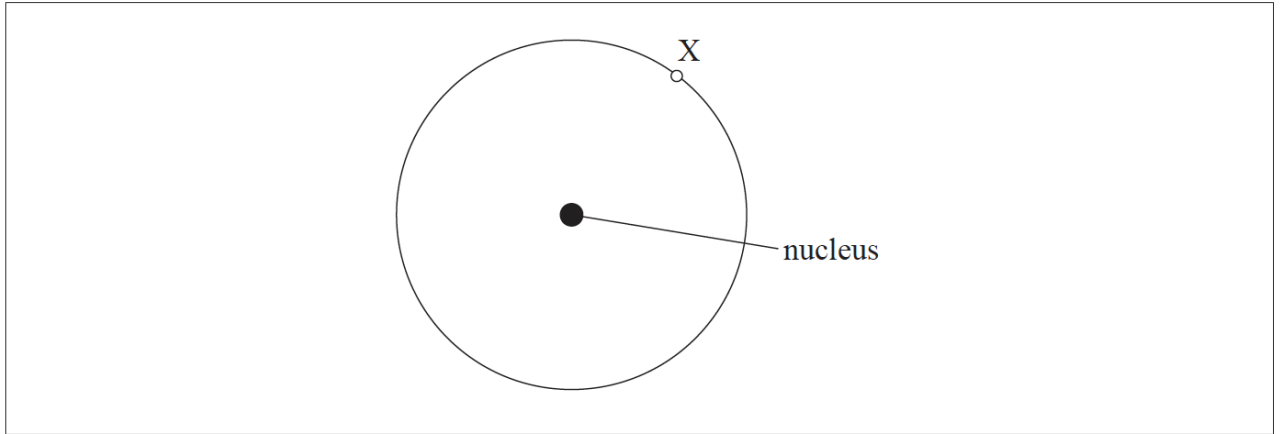


Point X is 140 pm from the nucleus.

22a. (i) On the diagram above, draw an arrow to show the direction of the electric field at point X. [3 marks]

(ii) Assuming the nucleus acts as a point charge, determine the magnitude of the electric field strength at point X.

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22b. (d) The diagram shows part of a potential divider circuit used to measure the current-potential difference (*I*–*V*)   *[4 marks]*
characteristic of the bulb.



6 V battery
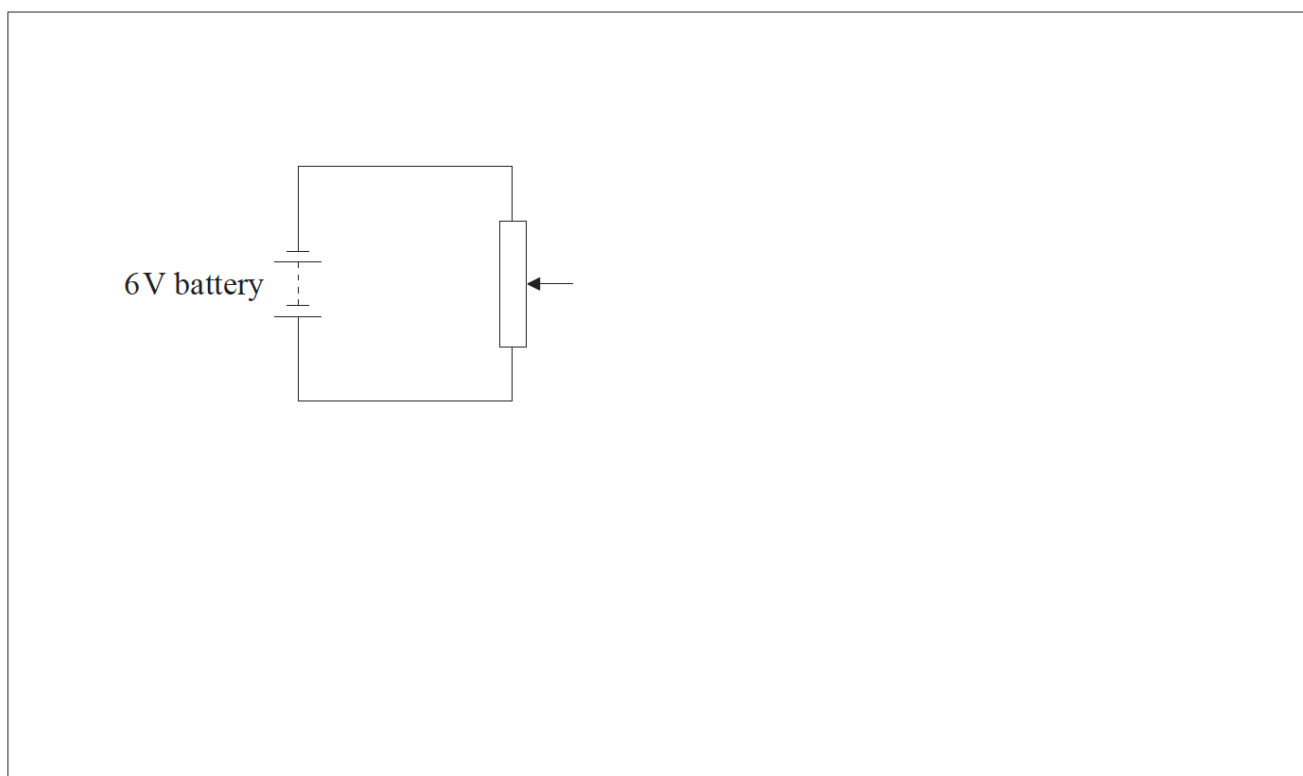
(i) Draw the complete circuit showing the correct position of the bulb, ammeter and voltmeter.

(ii) On the axes provided, sketch a graph to show how the current in the bulb varies with the potential difference.



current

potential difference
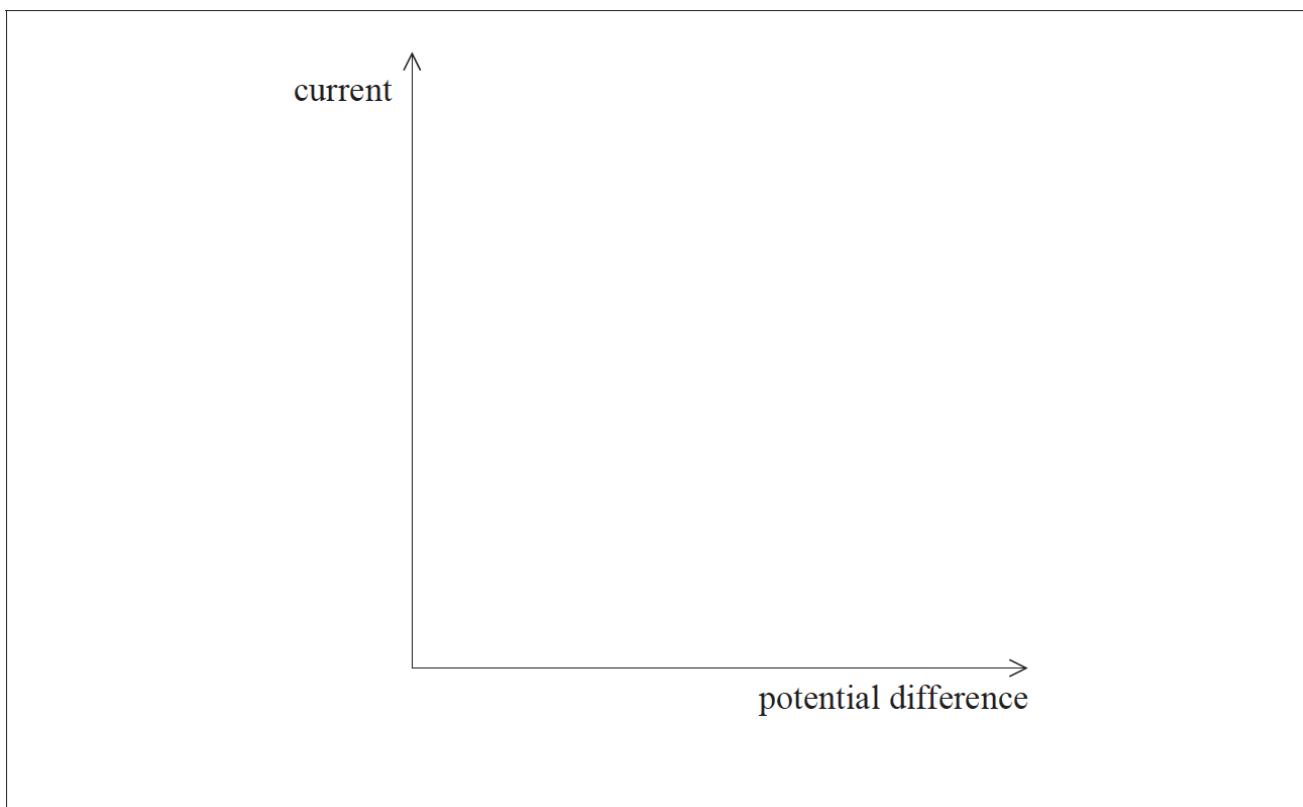
**22c.** A student sets up a different circuit to measure the *I–V* graph. The cell has an emf of 6.0 V and negligible internal resistance. The variable resistor has a minimum resistance of zero and a maximum resistance of 5.0 Ω. [3 marks]

6.0 V

0–5.0 Ω
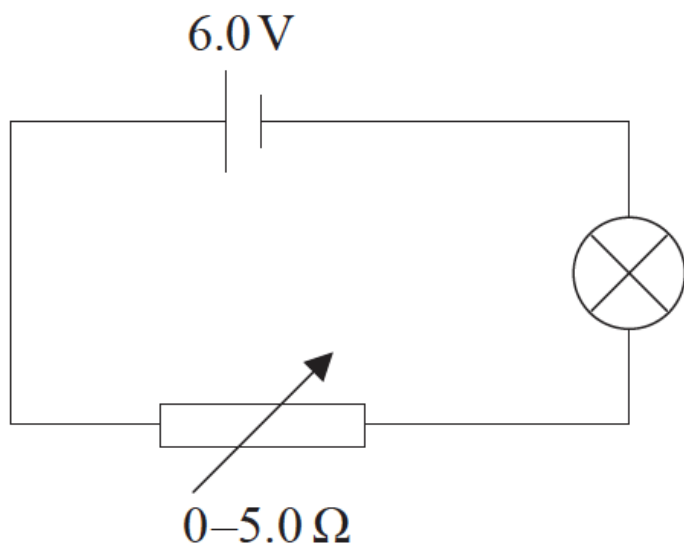
Explain, with a calculation, why this circuit will not allow for a full range of potential difference from 0 V to 6 V across the bulb. Assume that the resistance of the lamp remains constant at a value of 2.4 Ω.

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

**Part 1** Lighting system

**23a.** State Ohm's law. [1 mark]

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

fuse

6.0 V

6 V, 9 W lamps

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.

24. Two electrodes, separated by a distance $d$, in a vacuum are maintained at a constant potential difference. An electron, accelerated from one electrode to the other, gains kinetic energy $E_k$.    [1 mark]

The distance between the electrodes is now changed to $\frac{1}{3}d$.

What is the gain in kinetic energy of an electron that is accelerated from one electrode to the other?

A. $\frac{E_k}{3}$
B. $E_k$
C. $3E_k$
D. $9E_k$

25. The graph shows the $I$–$V$ characteristics of two resistors.    [1 mark]



$I/\text{A}$

$V/\text{V}$
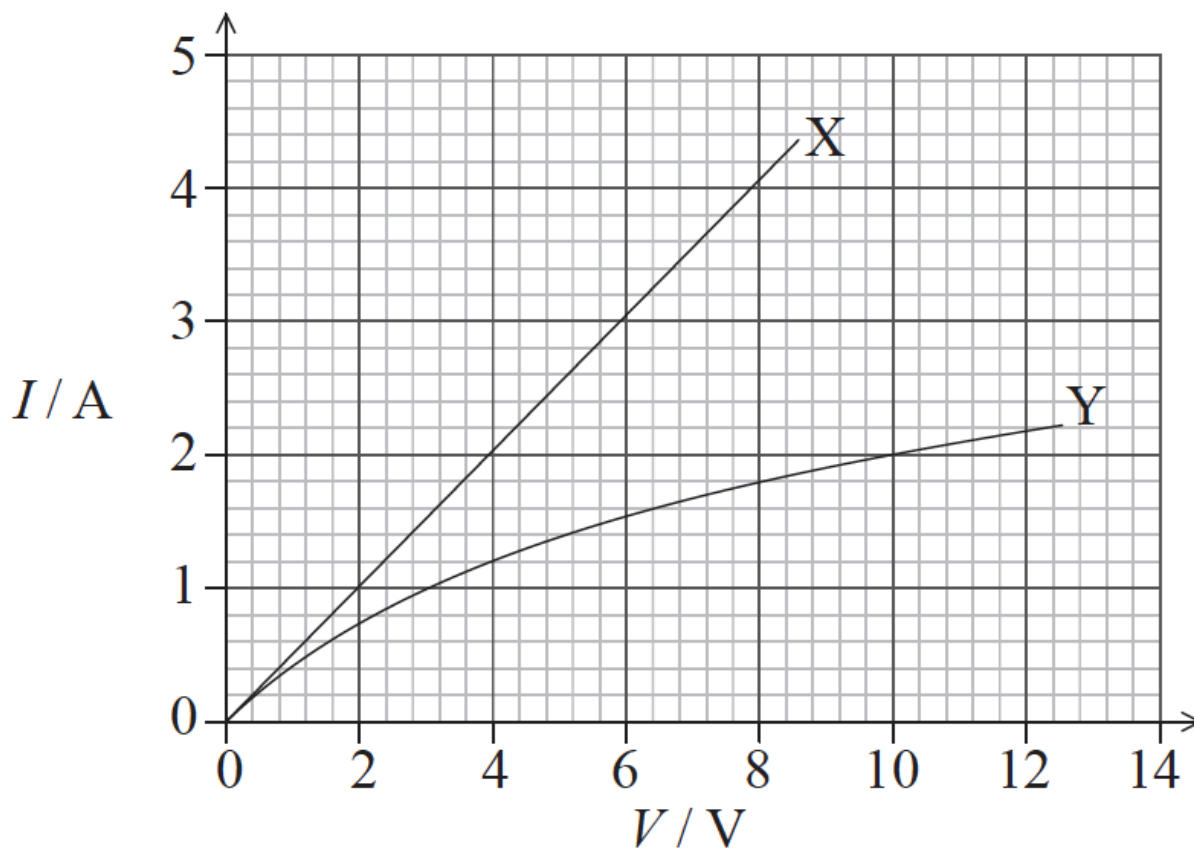
When resistors X and Y are connected in series, the current in the resistors is 2.0 A. What is the resistance of the series combination of X and Y?

A. 7.0 Ω

B. 1.3 Ω

C. 1.1 Ω

D. 0.14 Ω

26. Two isolated point charges, -7 µC and +2 µC, are at a fixed distance apart. At which point is it possible for the electric field strength to be zero?    [1 mark]



A        B        C        D
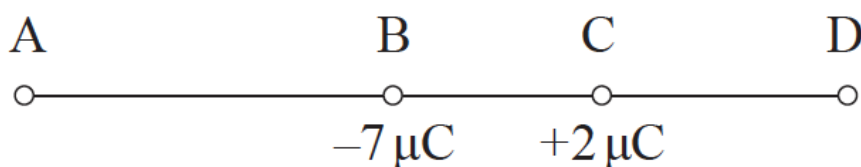
$-7\,\mu\text{C}$    $+2\,\mu\text{C}$        (not to scale)

27. A long straight wire carries an electric current perpendicularly out of the paper. Which of the following represents *[1 mark]* the magnetic field pattern due to the current?

A.          B.          C.          D.
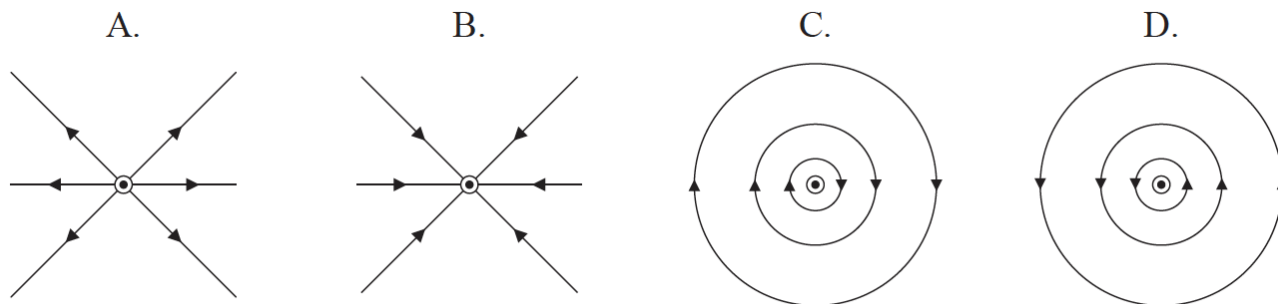


28. Which nucleons in a nucleus are involved in the Coulomb interaction and the strong short-range nuclear *[1 mark]* interaction?

| | Coulomb interaction | Strong short-range interaction |
|---|---|---|
| A. | protons | protons, neutrons |
| B. | protons | neutrons |
| C. | protons | protons |
| D. | protons, neutrons | neutrons |

The diagram below shows a uniform electric field of strength **E**. The field is in a vacuum. *[1 mark]*

uniform electric field
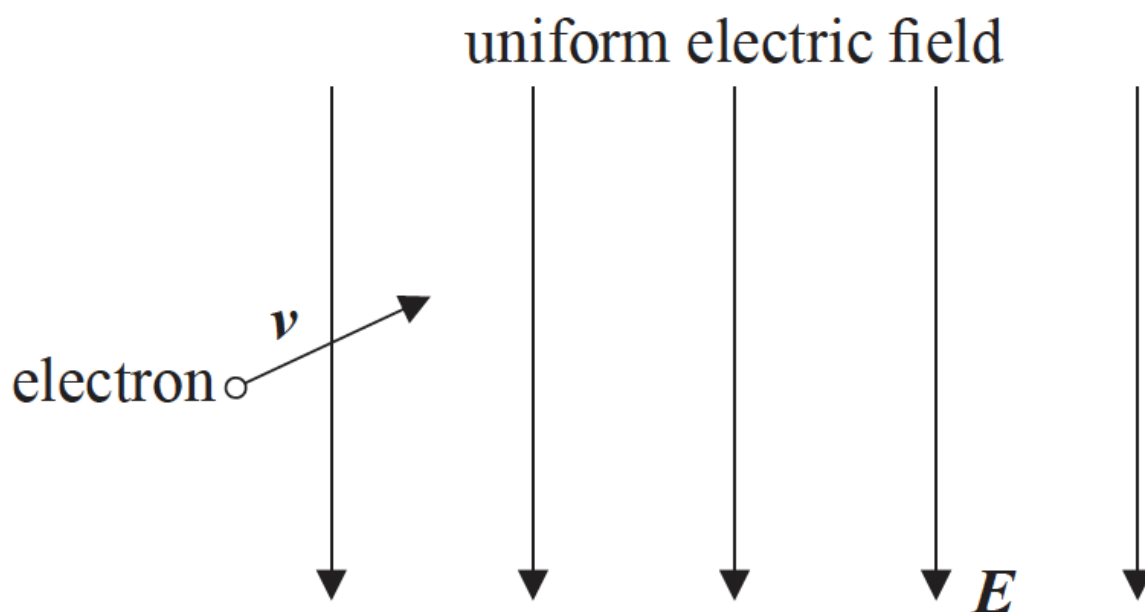


An electron enters the field with a velocity **v** in the direction shown. The electron is moving in the plane of the paper. The path followed by the electron will be

A. parabolic.

B. in the direction of **E**.

C. in the direction of **v**.

D. circular.

30. Two resistors, of resistance $R_1$ and $R_2$, are connected in series with a cell of emf $\varepsilon$ and negligible internal resistance.     *[1 mark]*

$$\varepsilon$$
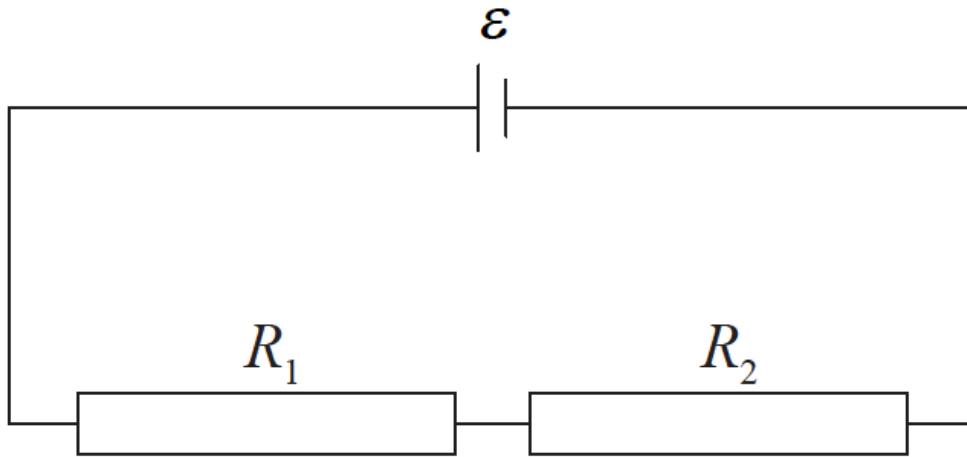
$$R_1 \qquad\qquad R_2$$

Which expression gives the potential difference across the resistor of resistance $R_1$?

A. $\left(\dfrac{R_1}{R_1+R_2}\right)\varepsilon$

B. $\left(\dfrac{R_1+R_2}{R_1}\right)\varepsilon$

C. $\left(\dfrac{R_2}{R_1+R_2}\right)\varepsilon$

D. $\left(\dfrac{R_1+R_2}{R_2}\right)\varepsilon$

31. Two isolated point charges, -7µC and +2µC, are at a fixed distance apart. At which point is it possible for the electric field strength to be zero?     *[1 mark]*

A          B      C          D
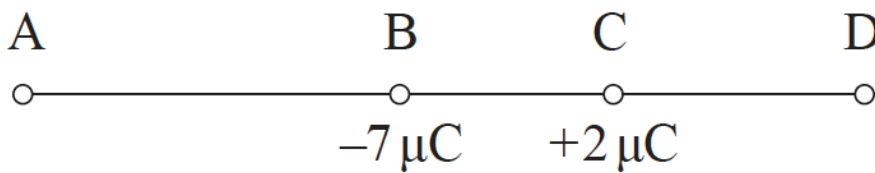
$-7\,\mu C$   $+2\,\mu C$          (not to scale)

32. A long straight wire carries an electric current perpendicularly out of the paper. Which of the following represents *[1 mark]* the magnetic field pattern due to the current?

A.                    B.                    C.                    D.
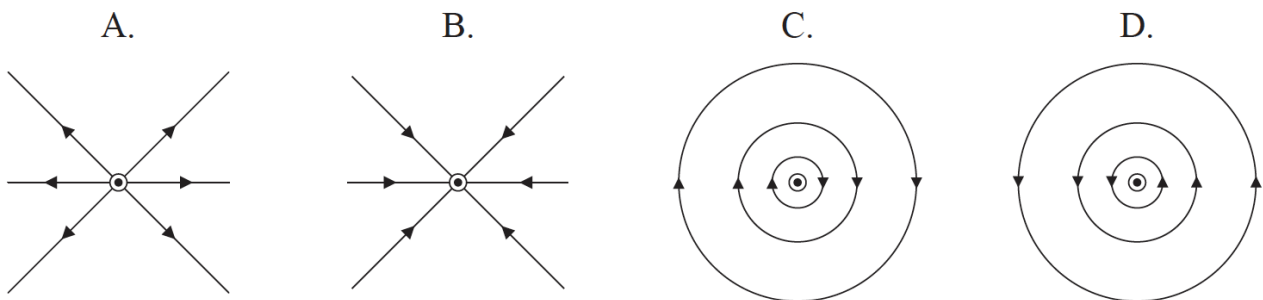
**Part 2** Electrical resistance

33a. A resistor of resistance 1.5Ω is made from copper wire of radius 0.18mm. The resistivity of copper is $1.7 \times 10^{-8}$ Ωm. Determine the length of copper wire used to make the resistor.    *[2 marks]*

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33b. The manufacturer of the resistor in (a) guarantees that the resistance is within 10% of 1.5Ω, provided that the   [6 marks]
power dissipation in the resistor does not exceed 1.0W.

(i) Suggest why the resistance of the resistor might be greater than 1.65Ω if the power dissipation in the resistor is greater than 1.0W.

(ii) Show that, for a power dissipation of 1.0W, the current in a resistor of resistance 1.5Ω is 0.82A.

(iii) The 1.5Ω resistor is connected in series with a variable resistor and battery of emf 6.0V and internal resistance 1.8Ω.
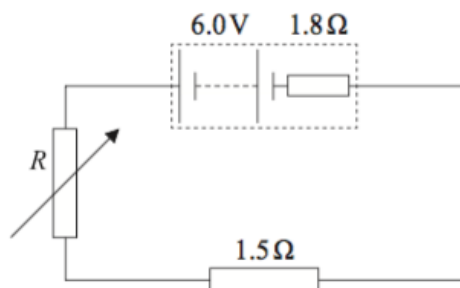


Estimate the resistance $R$ of the variable resistor that will limit the current to 0.82A.

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34. One electronvolt is equal to   [1 mark]

A. $1.6 \times 10^{-19}$ C.
B. $1.6 \times 10^{-19}$ J.
C. $1.6 \times 10^{-19}$ V.
D. $1.6 \times 10^{-19}$ W.

**35.** A battery of internal resistance 2 Ω is connected to an external resistance of 10 Ω. The current is 0.5 A. *[1 mark]*
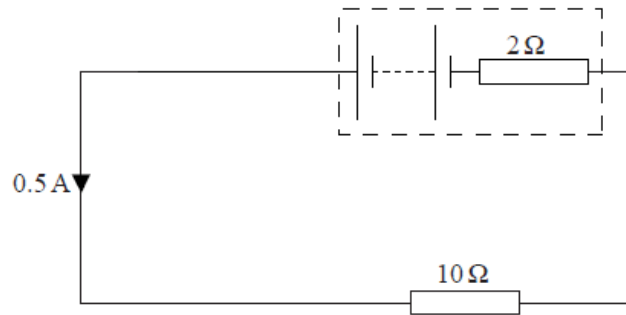


What is the emf of the battery?

A. 1.0 V
B. 5.0 V
C. 6.0 V
D. 24.0 V

**36.** An electron passes the north pole of a bar magnet as shown below. *[1 mark]*
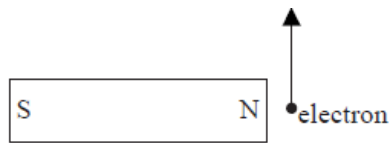


What is the direction of the magnetic force on the electron?

A. Into the page
B. Out of the page
C. To the left
D. To the right

**37.** A positively charged particle follows a circular path as shown below. *[1 mark]*



Which of the following electric fields could have caused the charged particle to follow the above path?

A.



B.



C.



D.
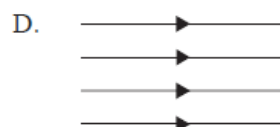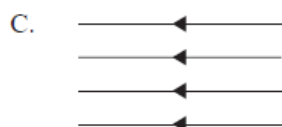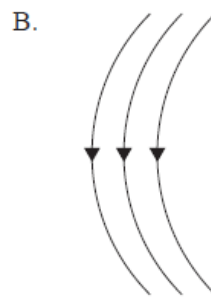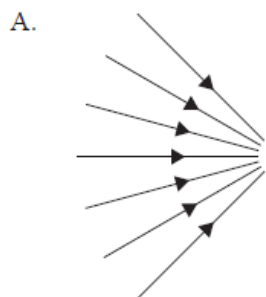
This question is about motion in a magnetic field.

An electron, that has been accelerated from rest by a potential difference of 250 V, enters a region of magnetic field of strength 0.12 T that is directed into the plane of the page.
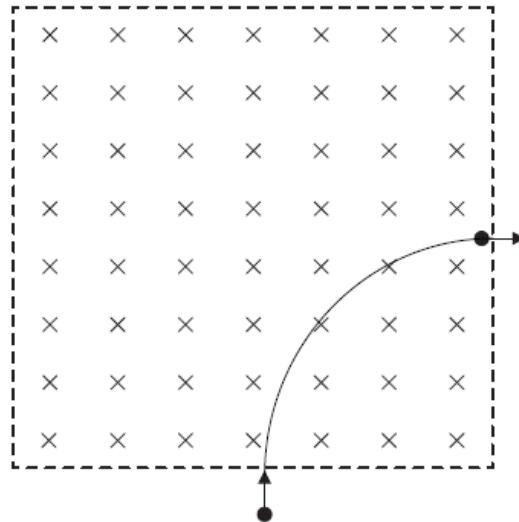


38a. The electron's path while in the region of magnetic field is a quarter circle. Show that the    *[4 marks]*

(i) speed of the electron after acceleration is $9.4\times10^6 ms^{-1}$.

(ii) radius of the path is $4.5\times10^{-4}$m.

38b. The diagram below shows the momentum of the electron as it enters and leaves the region of magnetic field.    *[3 marks]*
The magnitude of the initial momentum and of the final momentum is $8.6\times10^{-24}$Ns.
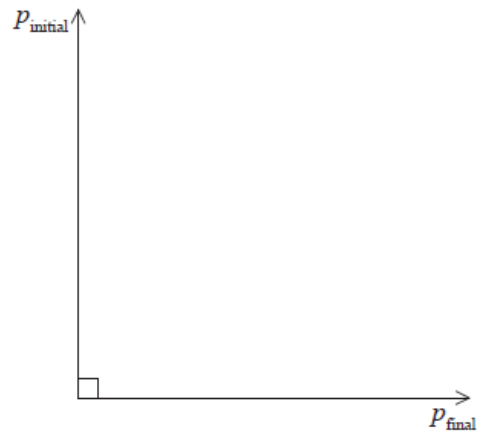


(i) On the diagram above, draw an arrow to indicate the vector representing the change in the momentum of the electron.

(ii) Show that the magnitude of the change in the momentum of the electron is $1.2\times10^{-23}$Ns.

(iii) The time the electron spends in the region of magnetic field is $7.5\times10^{-11}$s. Estimate the magnitude of the average force on the electron.

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This question is in **two** parts. **Part 1** is about electric circuits. **Part 2** is about the energy balance of the Earth.
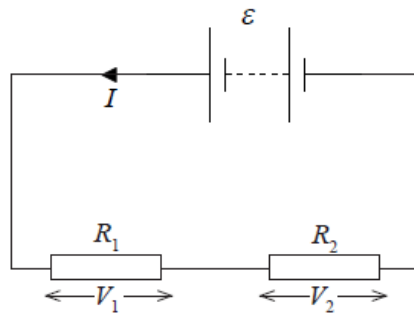
**Part 1** Electric circuits

39a. Define    *[2 marks]*

(i) *electromotive force* (emf ) of a battery.

(ii) *electrical resistance* of a conductor.

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39b. A battery of emf $\varepsilon$ and negligible internal resistance is connected in series to two resistors. The current in the circuit is $I$.  [3 marks]
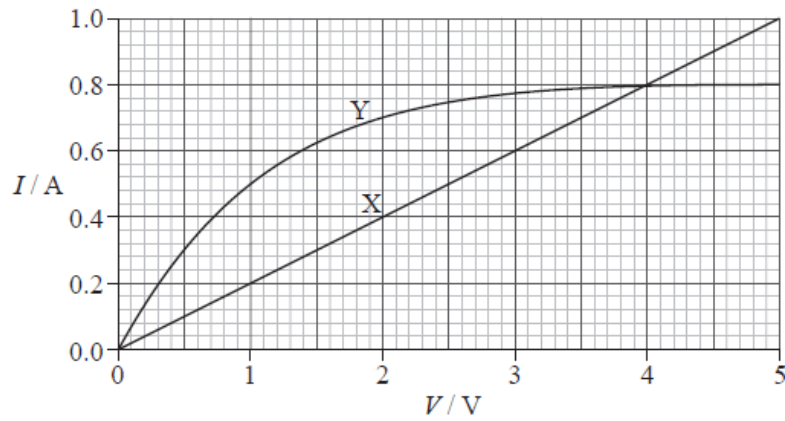


(i) State an equation giving the total power delivered by the battery.

(ii) The potential difference across resistor $R_1$ is $V_1$ and that across resistor $R_2$ is $V_2$. Using the law of the conservation of energy, deduce the equation below.
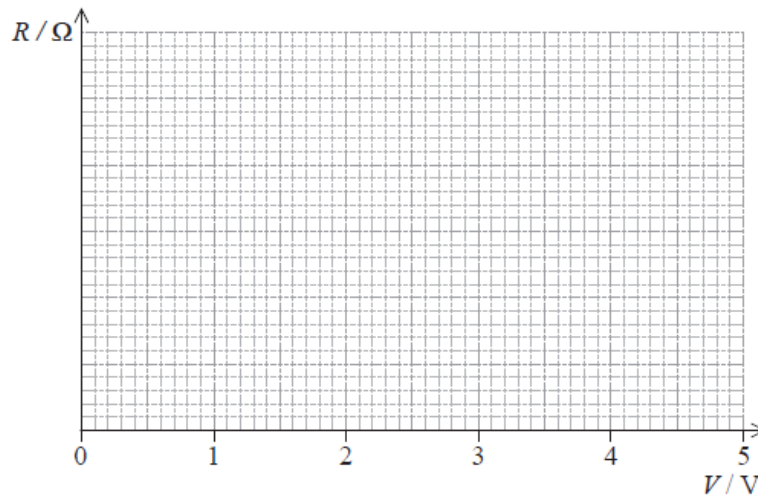
$$\varepsilon = V_1 + V_2$$

39c. The graph shows the *I-V* characteristics of two conductors, X and Y. [3 marks]

On the axes below, sketch graphs to show the variation with potential difference *V* of the resistance of conductor X (label this graph X) and conductor Y (label this graph Y). You do not need to put any numbers on the vertical axis.

39d. The conductors in (c) are connected in series to a battery of emf $\varepsilon$ and negligible internal resistance. [4 marks]
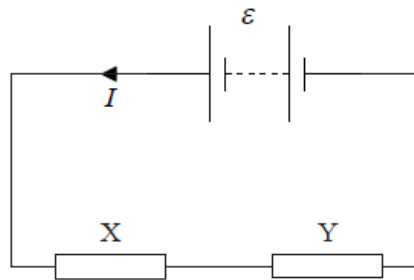
The power dissipated in each of the two resistors is the same.

Using the graph given in (c),

(i) determine the emf of the battery.

(ii) calculate the total power dissipated in the circuit.