

1. Question part 1/2 | 9702 Feb-March 2016 P2 V2 Q5

- 5 (a) (i) State what is meant by an *electric current*.

.....
 [1]

- (ii) Define electric *potential difference* (*p.d.*).

.....
 [1]

- (b) A power supply of electromotive force (e.m.f.) 8.7 V and negligible internal resistance is connected by two identical wires to three filament lamps, as shown in Fig. 5.1.

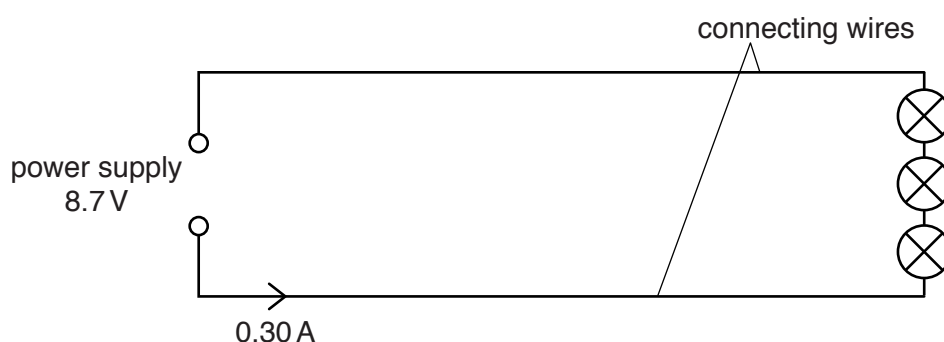


Fig. 5.1 (not to scale)

The power supply provides a current of 0.30 A to the circuit.
 The filament lamps are identical. The I - V characteristic for **one** of the lamps is shown in Fig. 5.2.

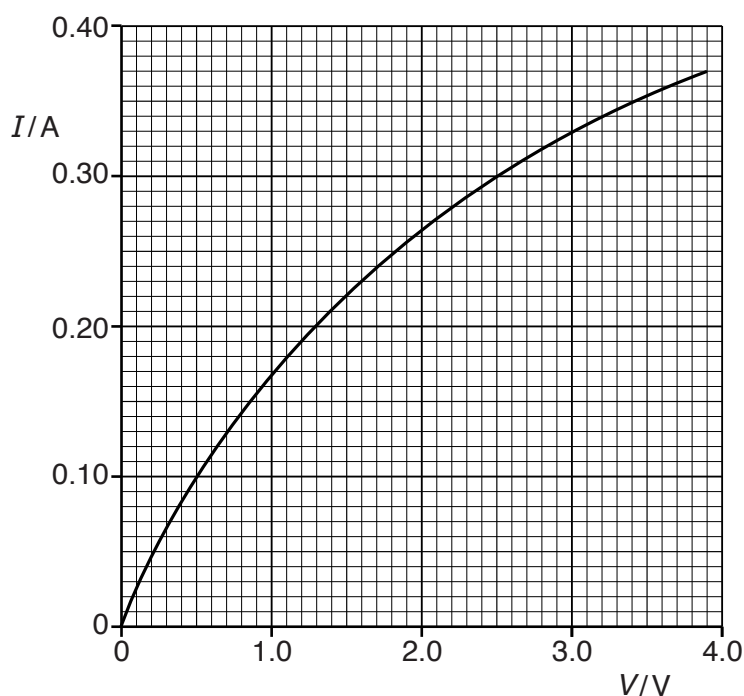


Fig. 5.2

- (i) Show that the resistance of each connecting wire is $2.0\,\Omega$.

[2]

- (ii) The resistivity of the metal of the connecting wires does not vary with temperature. On Fig. 5.2, sketch the I – V characteristic for **one** of the connecting wires.

[2]

- (iii) Calculate the power loss in one of the connecting wires.

power = ... W [2]

- (iv) Some data for the connecting wires are given below.

cross-sectional area = $0.40\,\text{mm}^2$

resistivity = $1.7 \times 10^{-8}\,\Omega\,\text{m}$

number density of free electrons = $8.5 \times 10^{28}\,\text{m}^{-3}$

Calculate

1. the length of one of the connecting wires,

length = ... m [2]

2. the drift speed of a free electron in the connecting wires.

drift speed = ... ms^{-1} [2]

[Total: 12]

- 6 (a) Define the *coulomb*.

.....[1]

- (b) A resistor X is connected to a cell as shown in Fig. 6.1.

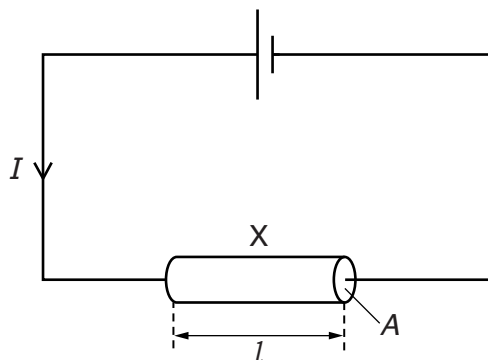


Fig. 6.1

The resistor is a wire of cross-sectional area A and length l . The current in the wire is I .

Show that the average drift speed v of the charge carriers in X is given by the equation

$$v = \frac{I}{nAe}$$

where e is the charge on a charge carrier and n is the number of charge carriers per unit volume in X.

[3]

- (c) A 12V battery with negligible internal resistance is connected to two resistors Y and Z, as shown in Fig. 6.2.

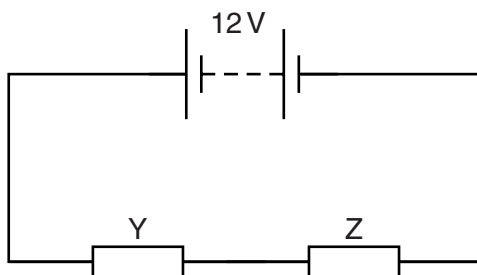


Fig. 6.2

The resistors are made from wires of the same material. The wire of Y has a diameter d and length l . The wire of Z has a diameter $2d$ and length $2l$.

(i) Determine the ratio

$$\frac{\text{average drift speed of the charge carriers in Y}}{\text{average drift speed of the charge carriers in Z}} .$$

ratio = ... [3]

(ii) Show that

$$\frac{\text{resistance of Y}}{\text{resistance of Z}} = 2.$$

[2]

(iii) Determine the potential difference across Y.

potential difference = ... V [2]

(iv) Determine the ratio

$$\frac{\text{power dissipated in Y}}{\text{power dissipated in Z}} .$$

ratio = ... [1]

[Total: 12]

- 6 Two parallel vertical metal plates are connected to a power supply, as shown in Fig. 6.1.

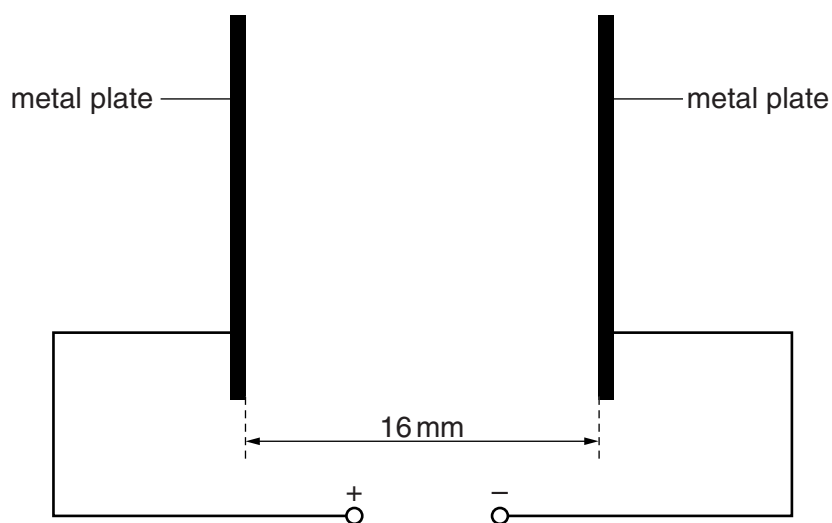


Fig. 6.1

The separation of the plates is 16 mm.

- (a) On Fig. 6.1, draw at least six field lines to represent the electric field between the plates. [1]
- (b) An α -particle travels in a vacuum between the two plates.

The electric field does work on the α -particle. The gain in kinetic energy of the α -particle is 15 keV.

Calculate the electric field strength between the plates.

electric field strength = ... V m^{-1} [4]

[Total: 5]

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- 7 (a) Electric current is a flow of charge carriers. The charge on the carriers is quantised. Explain what is meant by *quantised*.

.....[1]

- (b) A battery of electromotive force (e.m.f.) 9.0 V and internal resistance $0.25\ \Omega$ is connected in series with two identical resistors X and a resistor Y, as shown in Fig. 7.1.

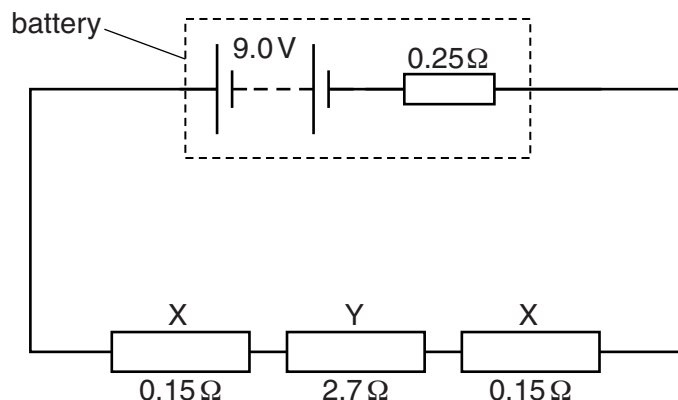


Fig. 7.1

The resistance of each resistor X is $0.15\ \Omega$ and the resistance of resistor Y is $2.7\ \Omega$.

- (i) Show that the current in the circuit is 2.8 A .

[3]

- (ii) Calculate the potential difference across the battery.

potential difference = ... V [2]

(c) Each resistor X connected in the circuit in (b) is made from a wire with a cross-sectional area of 2.5 mm^2 . The number of free electrons per unit volume in the wire is $8.5 \times 10^{29}\text{ m}^{-3}$.

(i) Calculate the average drift speed of the electrons in X.

drift speed = ... ms^{-1} [2]

(ii) The two resistors X are replaced by two resistors Z made of the same material and length but with half the diameter.

Describe and explain the difference between the average drift speed in Z and that in X.

.....
.....
.....
.....[2]

[Total: 10]

- 6 (a)** Define the *ohm*.

..... [1]

- (b)** A 15V battery with negligible internal resistance is connected to two resistors P and Q, as shown in Fig. 6.1.

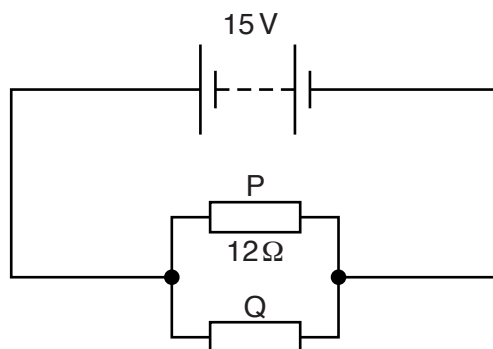


Fig. 6.1

The resistors are made of wires of the same material. The wire of P has diameter d and length $2l$. The wire of Q has diameter $2d$ and length l .

The resistance of P is 12Ω .

- (i)** Show that the resistance of Q is 1.5Ω .

[3]

- (ii)** Calculate the total power dissipated in the resistors P and Q.

power = ... W [3]

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(iii) Determine the ratio

$$\frac{\text{average drift speed of the charge carriers in P}}{\text{average drift speed of the charge carriers in Q}} .$$

ratio = ... [3]

[Total: 10]

2 (a) Define *electric field strength*.

.....
[1]

- (b)** A potential difference of 2.5 kV is applied across a pair of horizontal metal plates in a vacuum, as shown in Fig. 2.1.

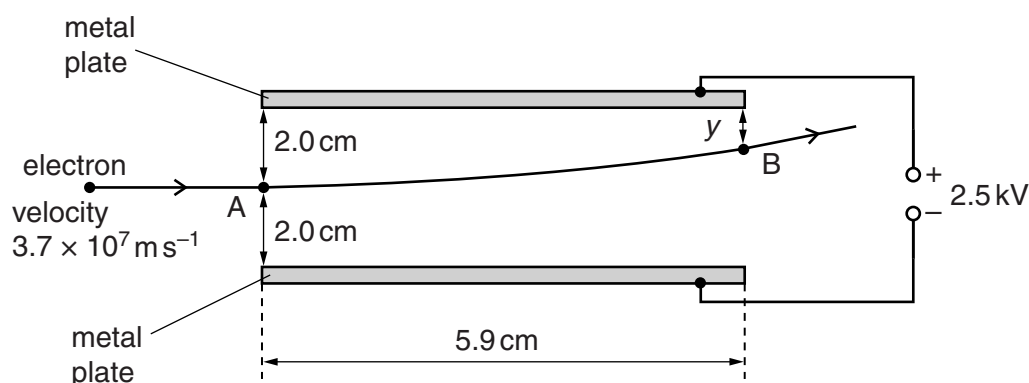


Fig. 2.1 (not to scale)

Each plate has a length of 5.9 cm. The separation of the plates is 4.0 cm. The arrangement produces a uniform electric field between the plates.

Assume the field does not extend beyond the edges of the plates.

An electron enters the field at point A with horizontal velocity $3.7 \times 10^7 \text{ m s}^{-1}$ along a line mid-way between the plates. The electron leaves the field at point B.

- (i)** Calculate the time taken for the electron to move from A to B.

time taken = ... s [1]

- (ii)** Calculate the magnitude of the electric field strength.

field strength = ... N C^{-1} [2]

- (iii)** Show that the acceleration of the electron in the field is $1.1 \times 10^{16} \text{ m s}^{-2}$.

- (iv) Use the acceleration given in (iii) and your answer in (i) to determine the vertical distance y between point B and the upper plate.

$y =$ cm [3]

- (v) Explain why the calculation in (iv) does not need to include the gravitational effects on the electron.

.....

.....[1]

- (vi) The electron enters the field at time $t = 0$.

On Fig. 2.2, sketch graphs to show the variation with time t of

1. the horizontal component v_x of the velocity of the electron,
2. the vertical component v_y of the velocity of the electron.

Numerical values are not required.

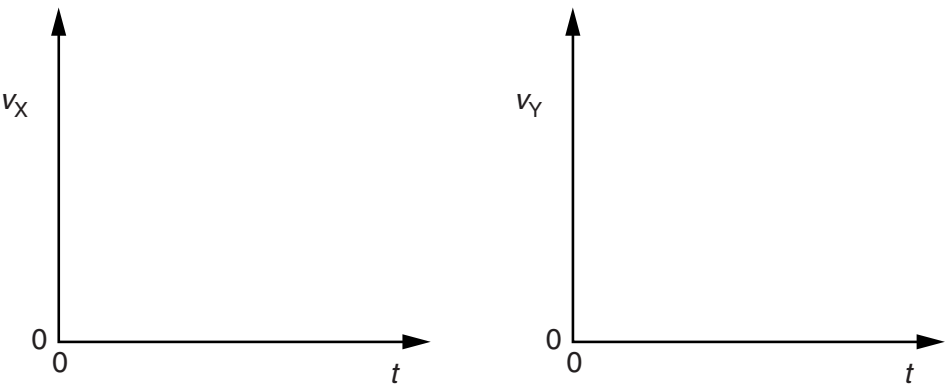


Fig. 2.2

[2]

[Total: 12]

- 6 (a) Define electric *potential difference* (*p.d.*).

.....
[1]

- (b) A battery of electromotive force (e.m.f.) 14V and negligible internal resistance is connected to a resistor network, as shown in Fig. 6.1.

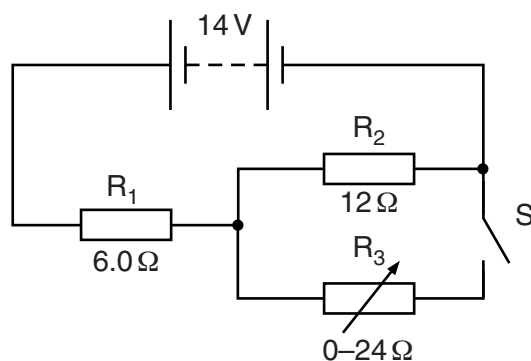


Fig. 6.1

R_1 and R_2 are fixed resistors of resistances $6.0\,\Omega$ and $12\,\Omega$ respectively. R_3 is a variable resistor.

Switch S is **closed**.

- (i) Calculate the current in the battery when the resistance of R_3 is set

1. at zero,

current = ... A [2]

2. at $24\,\Omega$.

current = ... A [2]

- (ii) Use your answers in (b)(i) to calculate the change in the total power produced by the battery when the resistance of R_3 is changed from zero to $24\,\Omega$.

change in power = ... W [2]

- (c) Switch S in Fig. 6.1 is now **opened**.

Resistors R_1 and R_2 are made from metal wires. Some data for these resistors are shown in Fig. 6.2.

	R_1	R_2
cross-sectional area of wire	A	$1.8A$
number of free electrons per unit volume in metal	n	$0.50n$

Fig. 6.2

Determine the ratio

$$\frac{\text{average drift speed of free electrons in } R_1}{\text{average drift speed of free electrons in } R_2}.$$

ratio = ... [2]

[Total: 9]

- 2 (a) Define *electric field strength*.

.....
[1]

- (b) A potential difference of 2.5 kV is applied across a pair of horizontal metal plates in a vacuum, as shown in Fig. 2.1.

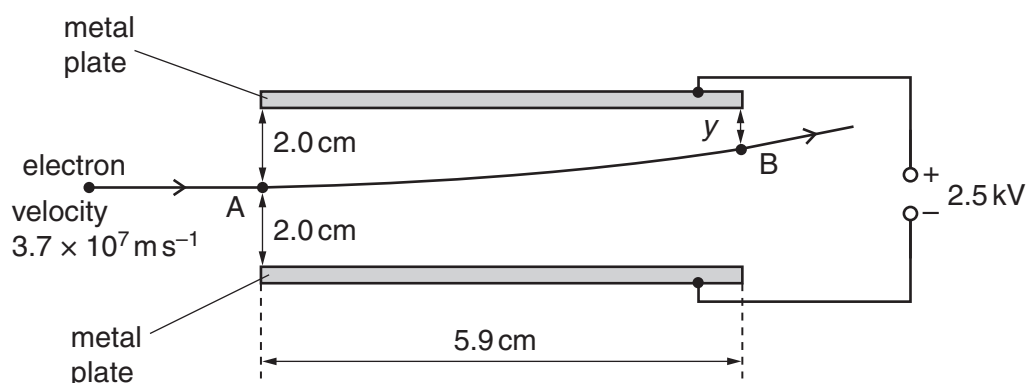


Fig. 2.1 (not to scale)

Each plate has a length of 5.9 cm. The separation of the plates is 4.0 cm. The arrangement produces a uniform electric field between the plates. Assume the field does not extend beyond the edges of the plates.

An electron enters the field at point A with horizontal velocity $3.7 \times 10^7 \text{ m s}^{-1}$ along a line mid-way between the plates. The electron leaves the field at point B.

- (i) Calculate the time taken for the electron to move from A to B.

time taken = ... s [1]

- (ii) Calculate the magnitude of the electric field strength.

field strength = ... N C^{-1} [2]

- (iii) Show that the acceleration of the electron in the field is $1.1 \times 10^{16} \text{ m s}^{-2}$.

- (iv) Use the acceleration given in (iii) and your answer in (i) to determine the vertical distance y between point B and the upper plate.

$y = \dots\dots\dots \text{ cm [3]}$

- (v) Explain why the calculation in (iv) does not need to include the gravitational effects on the electron.

.....
.....[1]

- (vi) The electron enters the field at time $t = 0$.

On Fig. 2.2, sketch graphs to show the variation with time t of

- 1. the horizontal component v_x of the velocity of the electron,
- 2. the vertical component v_y of the velocity of the electron.

Numerical values are not required.

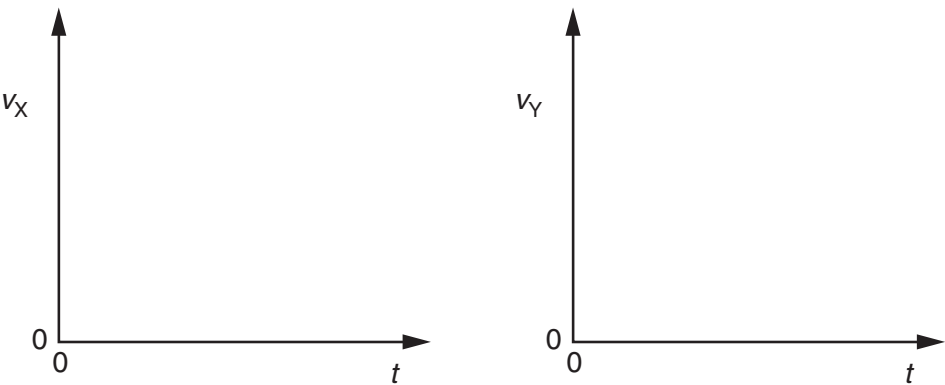


Fig. 2.2

[2]

[Total: 12]

- 5 An electron is travelling in a straight line through a vacuum with a constant speed of $1.5 \times 10^7 \text{ m s}^{-1}$. The electron enters a uniform electric field at point A, as shown in Fig. 5.1.

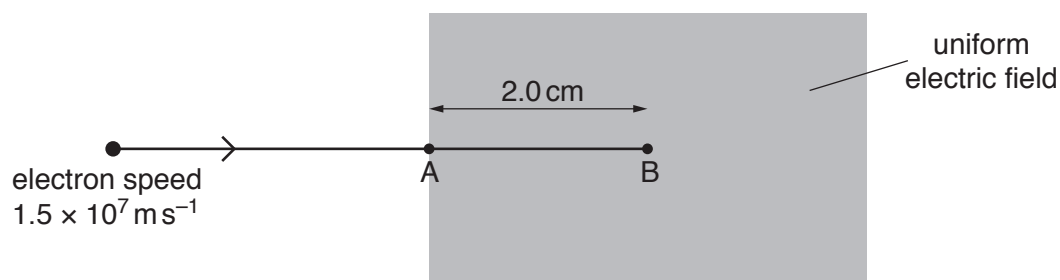


Fig. 5.1

The electron continues to move in the same direction until it is brought to rest by the electric field at point B. Distance AB is 2.0 cm.

- (a) State the direction of the electric field.

.....[1]

- (b) Calculate the magnitude of the deceleration of the electron in the field.

deceleration = ... m s^{-2} [2]

- (c) Calculate the electric field strength.

electric field strength = ... V m^{-1} [3]

(d) The electron is at point A at time $t = 0$.

On Fig. 5.2, sketch the variation with time t of the velocity v of the electron until it reaches point B. Numerical values of v and t do not need to be shown.

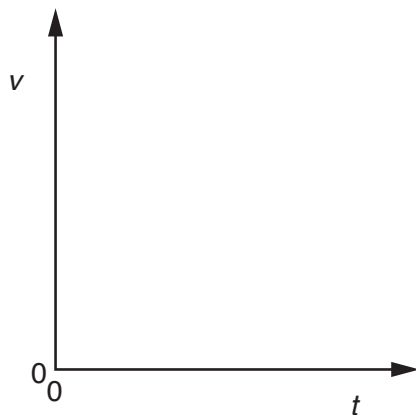


Fig. 5.2

[1]

[Total: 7]

- 6 (a)** Three resistors of resistances R_1 , R_2 and R_3 are connected as shown in Fig. 6.1.

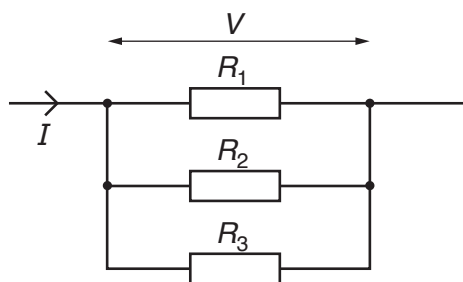


Fig. 6.1

The total current in the combination of resistors is I and the potential difference across the combination is V .

Show that the total resistance R of the combination is given by the equation

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}.$$

[2]

- (b)** A battery of electromotive force (e.m.f.) 6.0 V and internal resistance r is connected to a resistor of resistance 12Ω and a variable resistor X , as shown in Fig. 6.2.

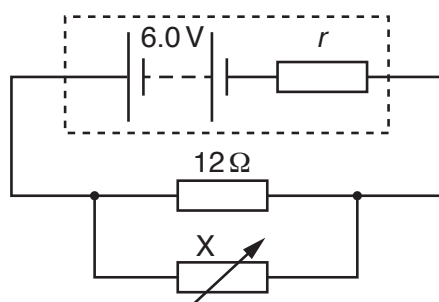


Fig. 6.2

- (i)** By considering energy, explain why the potential difference across the battery's terminals is less than the e.m.f. of the battery.

.....

.....

.....

.....[2]

- (ii) A charge of 2.5 kC passes through the battery.

Calculate

1. the total energy transformed by the battery,

energy = ...J [2]

2. the number of electrons that pass through the battery.

number = ...[1]

- (iii) The combined resistance of the two resistors connected in parallel is $4.8\ \Omega$.

Calculate the resistance of X.

resistance of X = ... Ω [1]

- (iv) Use your answer in (b)(iii) to determine the ratio

$$\frac{\text{power dissipated in X}}{\text{power dissipated in } 12\ \Omega \text{ resistor}}.$$

ratio = ...[2]

- (v) The resistance of X is now decreased. Explain why the power produced by the battery is increased.

.....
.....
.....[1]

[Total: 11]

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3 (a) Define *electric field strength*.

.....
.....[1]

(b) An electron is accelerated from point A to point B by a uniform electric field, as illustrated in Fig. 3.1.

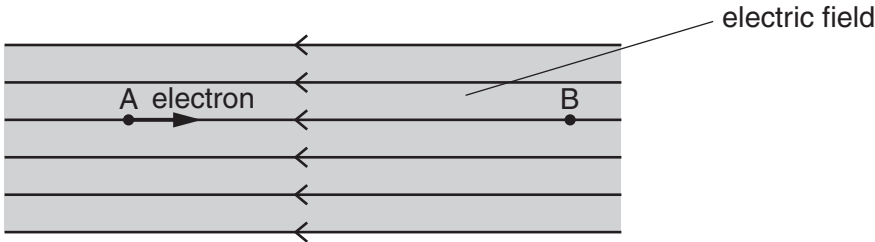


Fig. 3.1

The distance between A and B is 12 mm. The velocity of the electron at A is 2.5 km s^{-1} and at B is 18 Mm s^{-1} .

Calculate

(i) the acceleration of the electron,

acceleration = ... m s^{-2} [2]

(ii) the change in kinetic energy of the electron,

change in kinetic energy = ...J [3]

(iii) the electric field strength.

electric field strength = ... V m^{-1} [3]

(c) An α -particle moves from A to B in the electric field in (b).

Describe and explain how the change in the kinetic energy of the α -particle compares with that of the electron. Numerical values are not required.

.....

.....

.....

.....

.....[3]

[Total: 12]

6 (a) Describe the I - V characteristic of

(i) a metallic conductor at constant temperature,

.....
[1]

(ii) a semiconductor diode.

.....

[2]

(b) Two identical filament lamps are connected in series and then in parallel to a battery of electromotive force (e.m.f.) 12 V and negligible internal resistance, as shown in Fig. 6.1a and Fig. 6.1b.

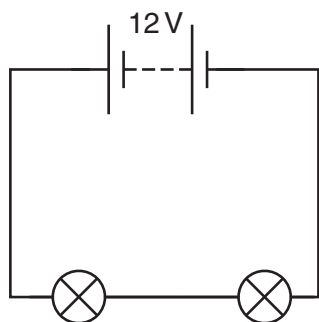


Fig. 6.1a

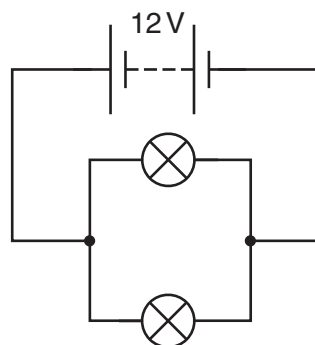


Fig. 6.1b

The I - V characteristic of each lamp is shown in Fig. 6.2.

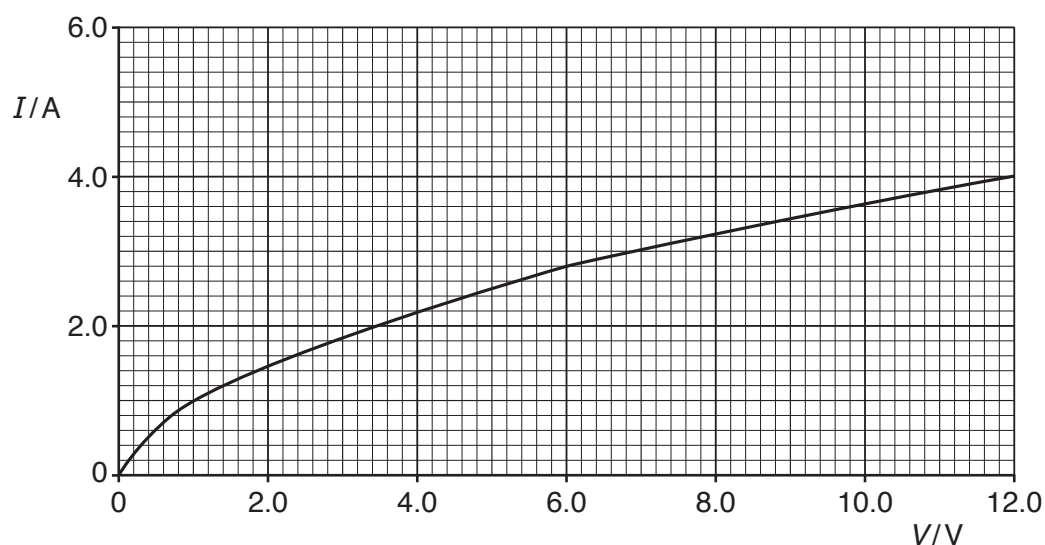


Fig. 6.2

(i) Use the information shown in Fig. 6.2 to determine the current through the battery in

1. the circuit of Fig. 6.1a,

current = ...A

2. the circuit of Fig. 6.1b.

current = ...A
[3]

(ii) Calculate the total resistance in

1. the circuit of Fig. 6.1a,

resistance = ... Ω

2. the circuit of Fig. 6.1b.

resistance = ... Ω
[3]

(iii) Calculate the ratio

$\frac{\text{power dissipated in a lamp in the circuit of Fig. 6.1a}}{\text{power dissipated in a lamp in the circuit of Fig. 6.1b}}$

ratio = ...[2]

[Total: 11]

6 (a) Define *electric field strength*.

.....
[1]

(b) Two parallel metal plates in a vacuum are separated by a distance of 15 mm, as shown in Fig. 6.1.

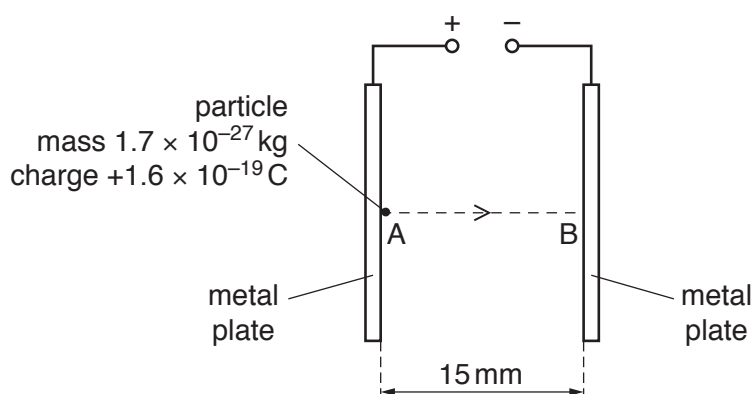


Fig. 6.1

A uniform electric field is produced between the plates by applying a potential difference between them.

A particle of mass $1.7 \times 10^{-27} \text{ kg}$ and charge $+1.6 \times 10^{-19} \text{ C}$ is initially at rest at point A on one plate. The particle is moved by the electric field to point B on the other plate. The particle reaches point B with kinetic energy $2.4 \times 10^{-16} \text{ J}$.

(i) Calculate the speed of the particle at point B.

speed = ... ms^{-1} [2]

(ii) State the work done by the electric field to move the particle from A to B.

work done = ... J [1]

- (iii) Use your answer in (ii) to determine the force on the particle.

force = ... N [2]

- (iv) Determine the potential difference between the plates.

potential difference = ... V [3]

- (v) On Fig. 6.2, sketch a graph to show the variation of the kinetic energy of the particle with the distance x from point A along the line AB.
Numerical values for the kinetic energy are not required.

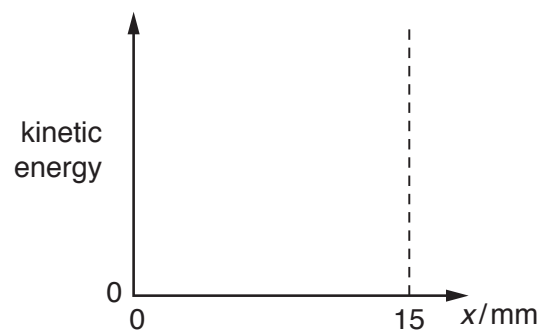


Fig. 6.2

[1]

[Total: 10]

- 7
- (a) Define the *ohm*.

.....[1]

(b) Wires are used to connect a battery of negligible internal resistance to a lamp, as shown in Fig. 7.1.

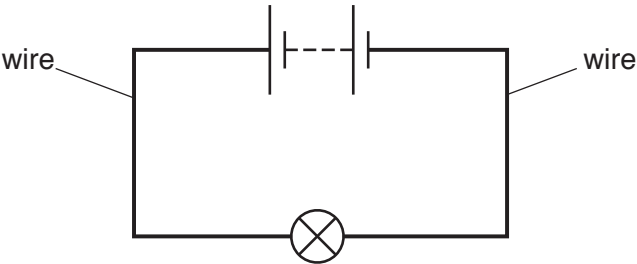


Fig. 7.1

The lamp is at its normal operating temperature. Some data for the filament wire of the lamp and for the connecting wires of the circuit are shown in Fig. 7.2.

	filament wire	connecting wires
diameter	d	$14d$
total length	L	$7.0L$
resistivity of metal (at normal operating temperature)	ρ	0.028ρ

Fig. 7.2

- (i) Show that

$$\frac{\text{resistance of filament wire}}{\text{total resistance of connecting wires}} = 1000.$$

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(ii) Use the information in (i) to explain qualitatively why the power dissipated in the filament wire of the lamp is greater than the total power dissipated in the connecting wires.

.....
.....
.....[1]

(iii) The lamp is rated as 12V, 6.0W. Use the information in (i) to determine the total resistance of the connecting wires.

total resistance of connecting wires = ... Ω [3]

(iv) The diameter of the connecting wires is decreased. The total length of the connecting wires and the resistivity of the metal of the connecting wires remain the same.

State and explain the change, if any, that occurs to the resistance of the filament wire of the lamp.

.....
.....
.....
.....
.....[3]

[Total: 10]

- 5 (a) Define the *coulomb*.

.....[1]

- (b) Two vertical metal plates in a vacuum have a separation of 4.0 cm. A potential difference of $2.0 \times 10^2 \text{ V}$ is applied between the plates. Fig. 5.1 shows a side view of this arrangement.

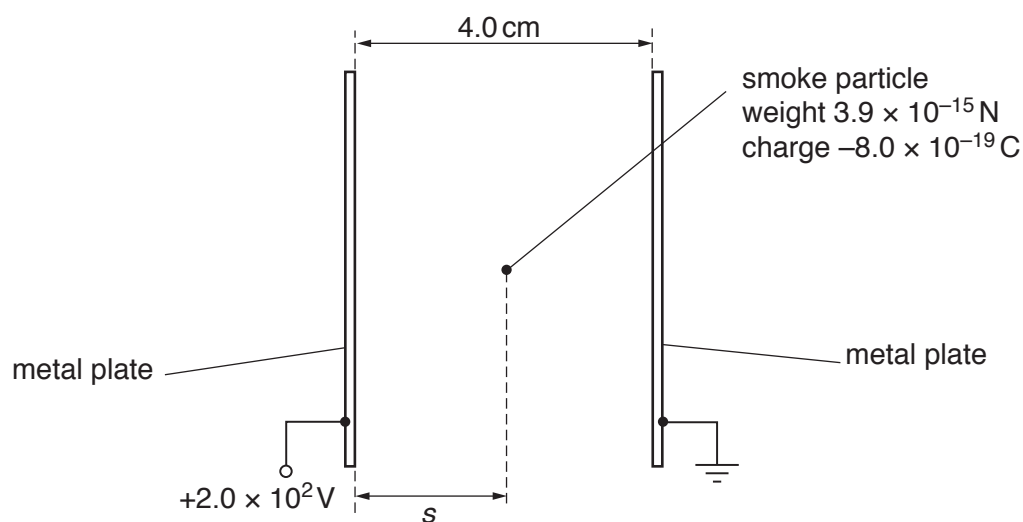


Fig. 5.1

A smoke particle is in the uniform electric field between the plates. The particle has weight $3.9 \times 10^{-15} \text{ N}$ and charge $-8.0 \times 10^{-19} \text{ C}$.

- (i) Show that the electric force acting on the particle is $4.0 \times 10^{-15} \text{ N}$.

[2]

- (ii) On Fig. 5.1, draw labelled arrows to show the directions of the two forces acting on the smoke particle. [1]

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(iii) The resultant force acting on the particle is F .

Determine

1. the magnitude of F ,

magnitude = ... N

2. the angle of F to the horizontal.

angle = ...
[3]

(c) The electric field in (b) is switched on at time $t = 0$ when the particle is at a horizontal displacement $s = 2.0\text{ cm}$ from the left-hand plate. At time $t = 0$ the horizontal velocity of the particle is zero. The particle is then moved by the electric field until it hits a plate at time $t = T$.

On Fig. 5.2, sketch the variation with time t of the horizontal displacement s of the particle from the left-hand plate.

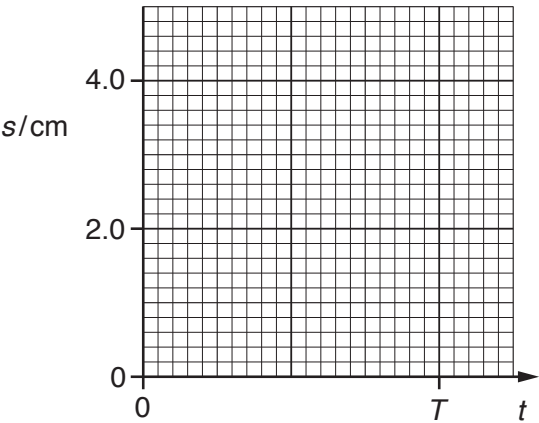


Fig. 5.2

[2]

[Total: 9]

- 6 (a) State what is meant by an *electric current*.

.....[1]

- (b) A metal wire has length L and cross-sectional area A , as shown in Fig. 6.1.

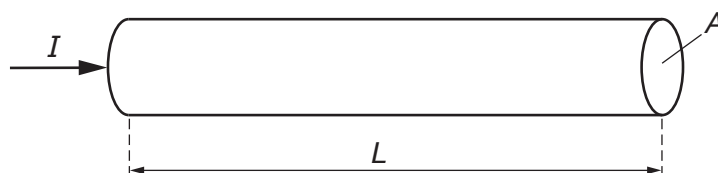


Fig. 6.1

I is the current in the wire,
 n is the number of free electrons per unit volume in the wire,
 v is the average drift speed of a free electron and
 e is the charge on an electron.

- (i) State, in terms of A , e , L and n , an expression for the total charge of the free electrons in the wire.

.....[1]

- (ii) Use your answer in (i) to show that the current I is given by the equation

$$I = nAve.$$

[2]

- (c) A metal wire in a circuit is damaged. The resistivity of the metal is unchanged but the cross-sectional area of the wire is reduced over a length of 3.0 mm, as shown in Fig. 6.2.

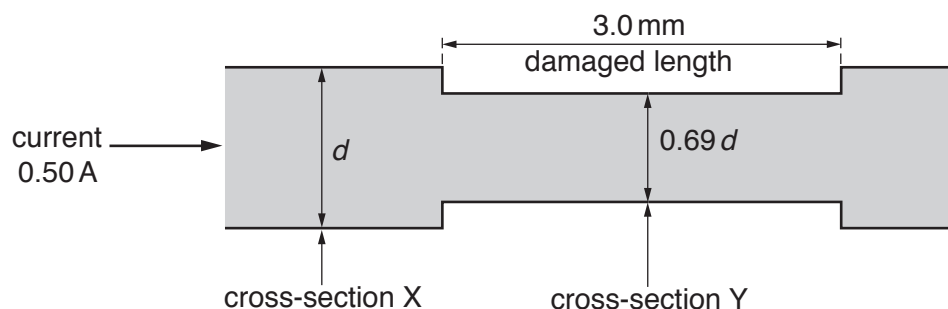


Fig. 6.2

The wire has diameter d at cross-section X and diameter $0.69d$ at cross-section Y.
 The current in the wire is 0.50 A.

(i) Determine the ratio

$$\frac{\text{average drift speed of free electrons at cross-section Y}}{\text{average drift speed of free electrons at cross-section X}}.$$

ratio = ...[2]

(ii) The main part of the wire with cross-section X has a resistance per unit length of $1.7 \times 10^{-2} \Omega \text{ m}^{-1}$.

For the damaged length of the wire, calculate

1. the resistance per unit length,

resistance per unit length = ... $\Omega \text{ m}^{-1}$ [2]

2. the power dissipated.

power = ... W [2]

(iii) The diameter of the damaged length of the wire is further decreased. Assume that the current in the wire remains constant.

State and explain qualitatively the change, if any, to the power dissipated in the damaged length of the wire.

.....
.....
.....[2]

5 (a) Define *electric field strength*.

.....
.....[1]

(b) Two parallel metal plates in a vacuum are separated by 0.045 m. A potential difference *V* is applied between the plates, as shown in Fig. 5.1.

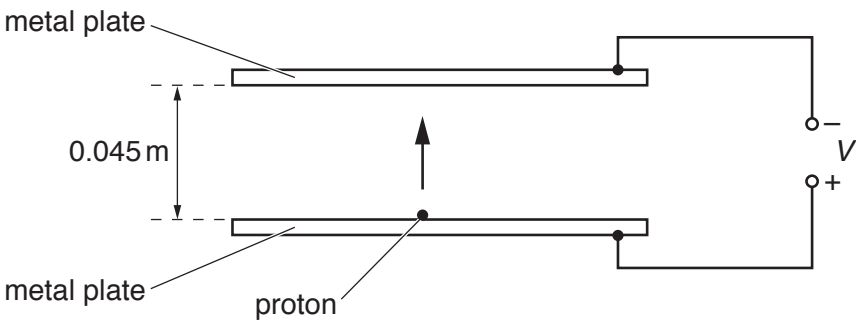


Fig. 5.1

A proton is initially at rest on the surface of the positive plate. The proton in the uniform electric field takes a time of $1.5 \times 10^{-7}\text{ s}$ to reach the negative plate.

(i) Show that the acceleration of the proton is $4.0 \times 10^{12}\text{ ms}^{-2}$.

[2]

(ii) Calculate the electric force on the proton.

force = ... N [1]

(iii) Use your answer in **(ii)** to determine

1. the electric field strength,

field strength = ... NC^{-1} [2]

2. the potential difference V between the plates.

$V =$ V [2]

(c) An α particle is now accelerated between the two metal plates in **(b)** by the electric field.

Calculate the ratio

$$\frac{\text{acceleration of } \alpha \text{ particle}}{\text{acceleration of proton}} .$$

ratio = ... [2]

[Total: 10]

6 A filament lamp is rated as 30 W, 120 V. A potential difference of 120 V is applied across the lamp.

(a) For the filament wire of the lamp, calculate

(i) the current,

current = ... A [2]

(ii) the number of electrons passing a point in 3.0 hours.

number = ... [2]

(b) Show that the resistance of the filament wire is $480\ \Omega$.

[2]

(c) The filament wire has an uncoiled length of 580 mm and is made of metal. The metal has resistivity $6.1 \times 10^{-7}\ \Omega\text{ m}$ at the operating temperature of the lamp.

Calculate the diameter of the wire.

diameter = ... m [3]

(d) The potential difference across the lamp is now reduced. State and explain the effect, if any, on the resistance of the filament wire.

.....

..... [1]

[Total: 10]

6 A wire X has a constant resistance per unit length of $3.0\,\Omega\,\text{m}^{-1}$ and a diameter of $0.48\,\text{mm}$.

(a) Calculate the resistivity of the metal of wire X.

resistivity = ... $\Omega\,\text{m}$ [3]

(b) The wire X is connected into the circuit shown in Fig. 6.1.

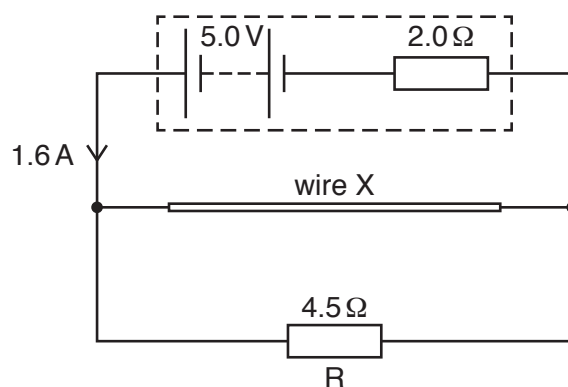


Fig. 6.1

The battery has an electromotive force (e.m.f.) of $5.0\,\text{V}$ and an internal resistance of $2.0\,\Omega$. The wire X and a resistor R of resistance $4.5\,\Omega$ are connected in parallel. The current in the battery is $1.6\,\text{A}$.

(i) Calculate the potential difference across resistor R.

potential difference = ... V [1]

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(ii) Determine, for wire X,

1. its resistance,

resistance = ... Ω [3]

2. its length.

length = ... m [1]

[Total: 8]

Please turn over for Question 7.

5 (a) State what is meant by an *electric field*.

.....
..... [1]

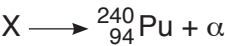
(b) A particle of mass m and charge q is in a uniform electric field of strength E . The particle has acceleration a due to the field.

Show that

$$a = \frac{Eq}{m}.$$

[2]

(c) A stationary nucleus X decays by emitting an α -particle to form a nucleus of plutonium, $^{240}_{94}\text{Pu}$, as shown.



(i) Determine the number of protons and the number of neutrons in nucleus X.

number of protons = ...
number of neutrons = ...
[2]

(ii) The total mass of the plutonium nucleus and the α -particle is less than that of nucleus X. Explain this difference in mass.

.....
.....
.....
..... [2]

- (iii) The plutonium nucleus and the α -particle are both accelerated by the same uniform electric field.

Use the expression in (b) to determine the ratio

$$\frac{\text{acceleration of the } \alpha\text{-particle}}{\text{acceleration of the plutonium nucleus}} .$$

ratio = ... [2]

[Total: 9]

6 (a) Define the *volt*.

.....
[1]

(b) A battery of electromotive force (e.m.f.) 7.0 V and negligible internal resistance is connected in series with three components, as shown in Fig. 6.1.

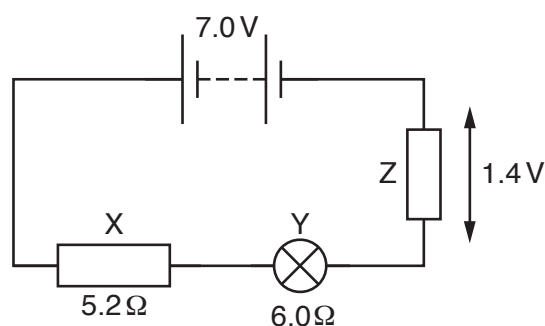


Fig. 6.1

Resistor X has a resistance of $5.2\ \Omega$. The resistance of the filament wire of lamp Y is $6.0\ \Omega$. The potential difference across resistor Z is 1.4 V .

(i) Calculate the current in the circuit.

current = ... A [2]

(ii) Determine the resistance of resistor Z.

resistance = ... Ω [1]

(iii) Calculate the percentage efficiency with which the battery supplies power to the lamp.

efficiency = ... % [3]

- (iv) The filament wire of the lamp is made of metal of resistivity $3.7 \times 10^{-7} \Omega \text{ m}$ at its operating temperature in the circuit.

Determine, for the filament wire, the value of α where

$$\alpha = \frac{\text{cross-sectional area}}{\text{length}} .$$

$\alpha = \dots\dots\dots \text{ m [2]}$

[Total: 9]

- 7 (a) The current I in a metal wire is given by the expression

$$I = Anve.$$

State what is meant by the symbols A and n .

A :

n : [2]

- (b) The diameter of a wire XY varies linearly with distance along the wire as shown in Fig. 7.1.

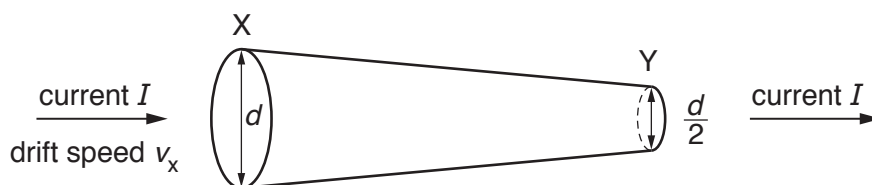


Fig. 7.1

There is a current I in the wire. At end X of the wire, the diameter is d and the average drift speed of the free electrons is v_x . At end Y of the wire, the diameter is $\frac{d}{2}$.

On Fig. 7.2, sketch a graph to show the variation of the average drift speed with position along the wire between X and Y.

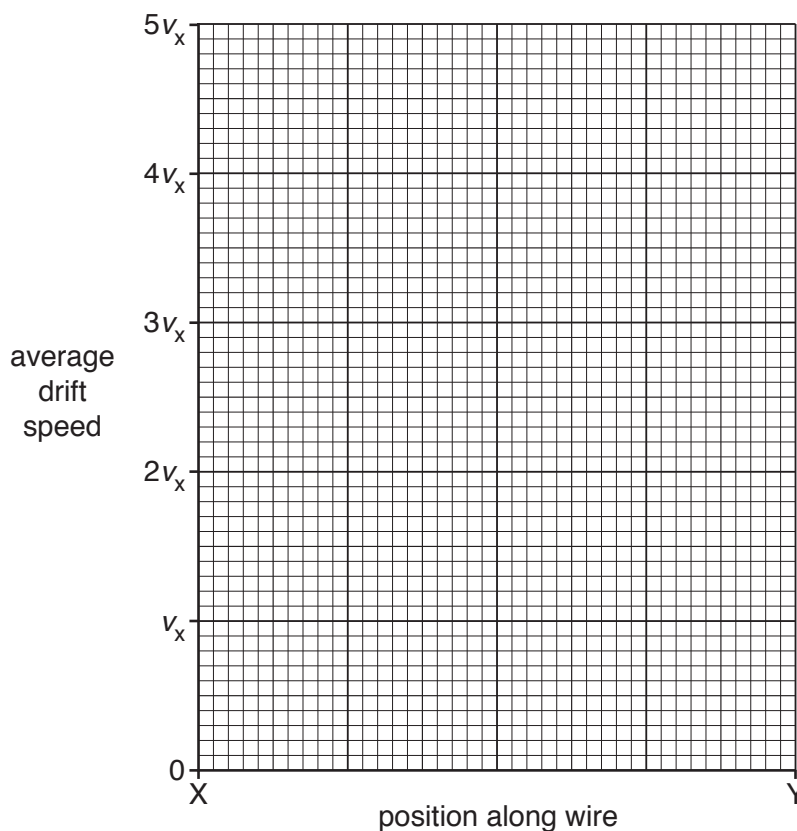


Fig. 7.2

[2]

[Total: 4]

- 5** A particle of mass m and charge q is in a uniform electric field of strength E . The particle has acceleration a due to the field.

(a) Show that

$$\frac{q}{m} = \frac{a}{E}.$$

[2]

- (b)** The particle has a charge of $4e$ where e is the elementary charge. The electric field strength is $3.5 \times 10^4 \text{ V m}^{-1}$. The acceleration of the particle is $1.5 \times 10^{12} \text{ m s}^{-2}$.

Use the expression in **(a)** to show that the mass of the particle is 9.0 u .

[2]

- (c)** The particle is a nucleus. State the number of protons and the number of neutrons in the nucleus.

number of protons = ...

number of neutrons = ...

[1]

- (d)** A second nucleus that is an isotope of the nucleus in **(c)** is in the same uniform electric field.

State and explain whether the electric field produces, for the two nuclei, the same magnitudes of

(i) force,

.....

.....[1]

(ii) acceleration.

.....

.....[1]

[Total: 7]

6 (a) Define the *coulomb*.

.....
.....[1]

(b) An electric current is a flow of charge carriers.

In the following list, underline the possible charges for a charge carrier.

$8.0 \times 10^{-19}\text{C}$ $4.0 \times 10^{-19}\text{C}$ $1.6 \times 10^{-19}\text{C}$ $1.6 \times 10^{-20}\text{C}$ [1]

(c) The diameter of a wire ST varies linearly with distance along the wire as shown in Fig. 6.1.

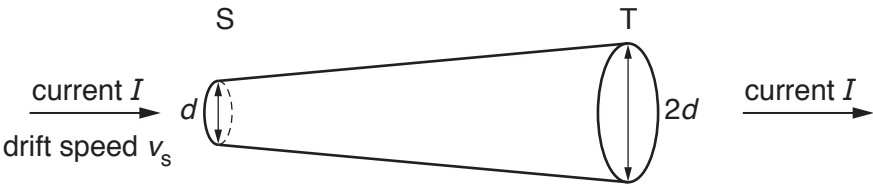


Fig. 6.1

There is a current I in the wire. At end S of the wire, the diameter is d and the average drift speed of the free electrons is v_s . At end T of the wire, the diameter is $2d$.

On Fig. 6.2, sketch a graph to show the variation of the average drift speed with position along the wire between S and T.

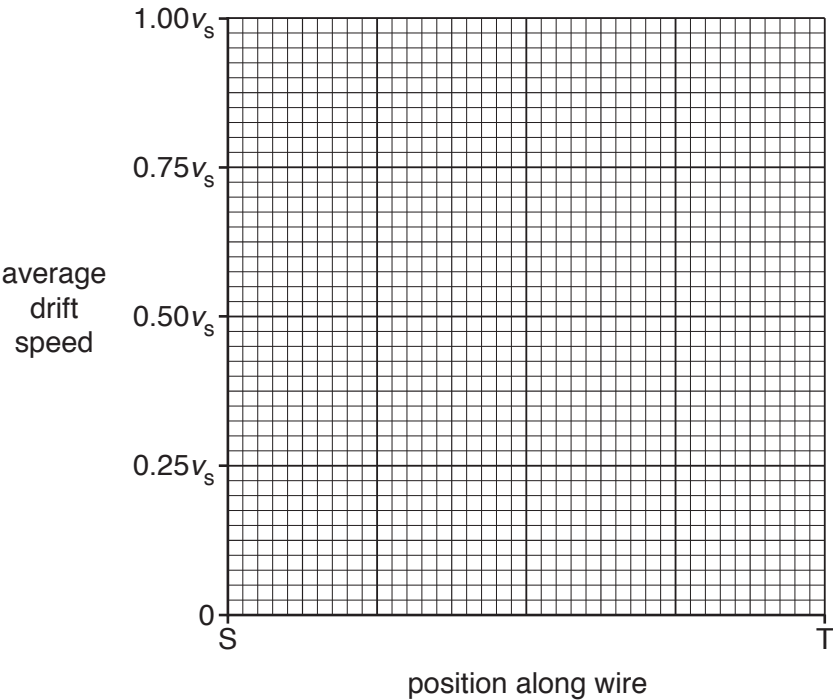


Fig. 6.2

[2]

[Total: 4]

4 (a) Define *electric field strength*.

.....
.....[1]

(b) Two very small metal spheres X and Y are connected by an insulating rod of length 72 mm. A side view of this arrangement is shown in Fig. 4.1.

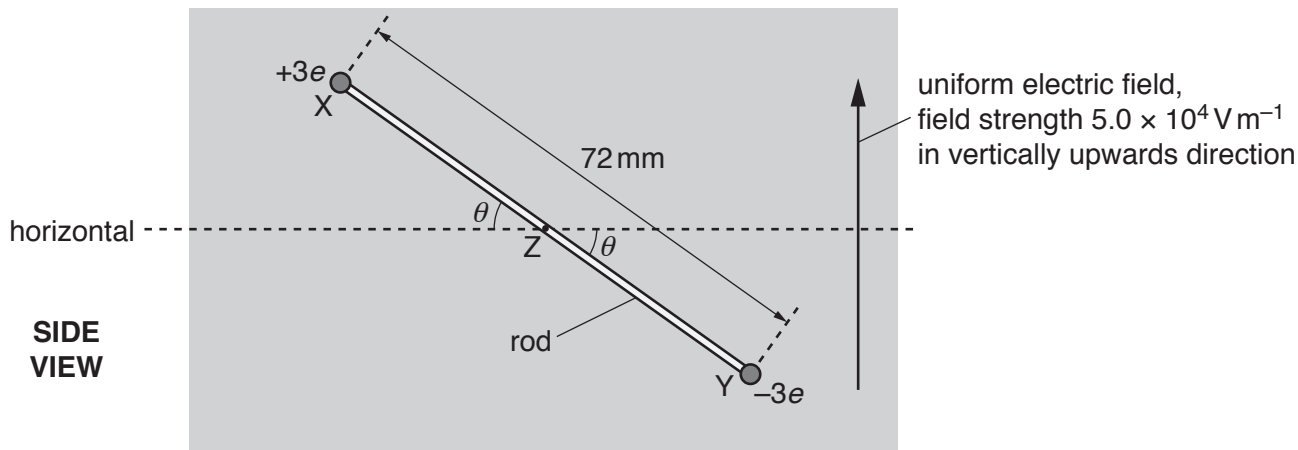


Fig. 4.1 (not to scale)

Sphere X has a charge of $+3e$ and sphere Y has a charge of $-3e$, where e is the elementary charge. The rod is held at its mid point Z at an angle θ to the horizontal. The rod and spheres have negligible mass and are in a uniform electric field. The electric field strength is $5.0 \times 10^4 \text{ V m}^{-1}$. The direction of this field is vertically upwards.

(i) The electric field is produced by applying a potential difference of 4.0 kV between two charged parallel metal plates.

1. Calculate the separation between the plates.

separation = ... m [2]

2. Describe the arrangement of the two plates. Include in your answer a statement of the sign of the charge on each plate. You may draw on Fig. 4.1.

.....

.....

.....

.....[2]

(ii) Determine the magnitude and direction of the force on sphere Y.

magnitude = ... N

direction [2]

(iii) The electric forces acting on the two spheres form a couple. This couple acts on the rod with a torque of $6.2 \times 10^{-16} \text{ N m}$.

Calculate the angle θ of the rod to the horizontal.

$\theta =$ $^{\circ}$ [2]

[Total: 9]

6 (a) State what is meant by a *field line (line of force)* in an electric field.

.....
.....[1]

(b) An electric field has two different regions X and Y. The field strength in X is less than that in Y. Describe a difference between the pattern of field lines (lines of force) in X and in Y.

.....
.....[1]

(c) A particle P has a mass of 0.15 u and a charge of $-1e$, where e is the elementary charge.

(i) Particle P and an α -particle are in the same uniform electric field. Calculate the ratio

$$\frac{\text{magnitude of acceleration of particle P}}{\text{magnitude of acceleration of } \alpha\text{-particle}} .$$

ratio = ... [3]

(ii) Particle P is a hadron composed of only two quarks. One of them is a down (d) quark.

By considering charge, determine a possible type (flavour) of the other quark.
Explain your working.

.....
.....[3]

[Total: 8]

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1 (a) (i) Define *resistance*.

.....
.....[1]

(ii) A potential difference of 0.60 V is applied across a resistor of resistance 4.0 GΩ.

Calculate the current, in pA, in the resistor.

current = ... pA [2]

(b) The energy E transferred when charge Q moves through an electrical component is given by the equation

$$E = QV$$

where V is the potential difference across the component.

Use the equation to determine the SI base units of potential difference.

SI base units [3]

[Total: 6]

- 4 Two vertical metal plates in a vacuum are separated by a distance of 0.12 m. Fig. 4.1 shows a side view of this arrangement.

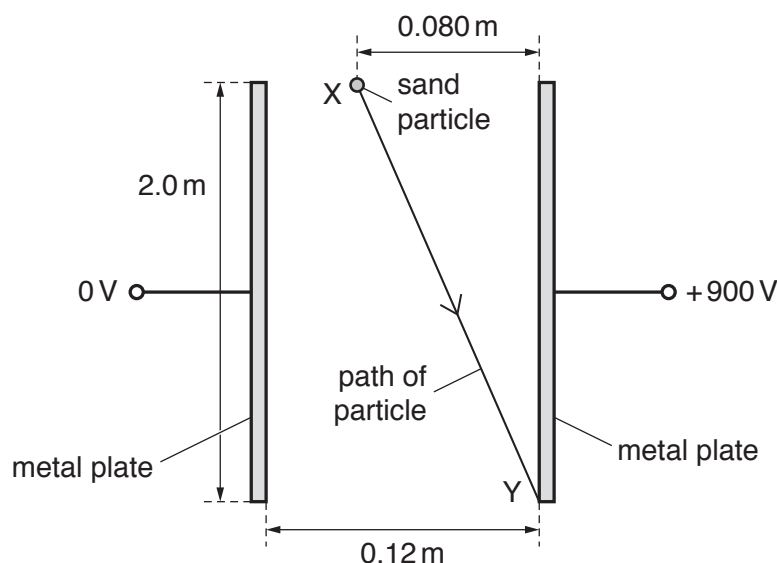


Fig. 4.1 (not to scale)

Each plate has a length of 2.0 m. The potential difference between the plates is 900 V. The electric field between the plates is uniform.

A negatively charged sand particle is released from rest at point X, which is a horizontal distance of 0.080 m from the top of the positively charged plate. The particle then travels in a straight line and collides with the positively charged plate at its lowest point Y, as illustrated in Fig. 4.1.

- (a) Describe the pattern of the field lines (lines of force) between the plates.

.....

[2]

- (b) State the names of the **two** forces acting on the particle as it moves from X to Y.

.....[1]

- (c) By considering the vertical motion of the sand particle, show that the time taken for the particle to move from X to Y is 0.64 s.

- (d)** Calculate the horizontal component of the acceleration of the particle.

horizontal component of acceleration = ... ms^{-2} [2]

- (e) (i)** Calculate the magnitude of the electric field strength.

electric field strength = ... NC^{-1} [2]

- (ii)** The sand particle has mass m and charge q . Use your answers in **(d)** and **(e)(i)** to determine the ratio $\frac{q}{m}$.

ratio = ... C kg^{-1} [2]

- (f)** Another particle has a smaller magnitude of the ratio $\frac{q}{m}$ than the sand particle. This particle is also released from point X.

For the movement of this particle, state the effect, if any, of the decreased magnitude of the ratio on:

- (i)** the vertical component of the acceleration

.....[1]

- (ii)** the horizontal component of the acceleration.

.....[1]

[Total: 13]

6 (a) Define the *ohm*.

.....[1]

(b) A battery of electromotive force (e.m.f.) E and internal resistance 1.5Ω is connected to a network of resistors, as shown in Fig. 6.1.

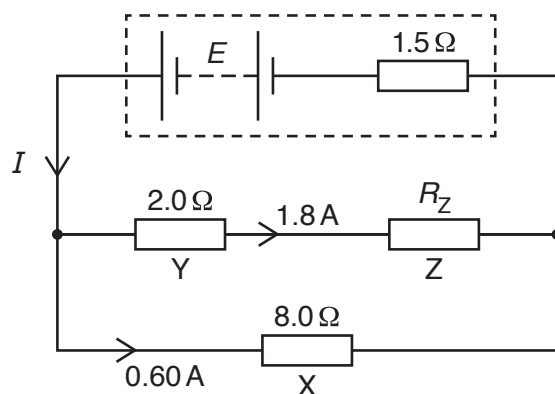


Fig. 6.1

Resistor X has a resistance of 8.0Ω . Resistor Y has a resistance of 2.0Ω . Resistor Z has a resistance of R_Z . The current in X is 0.60A and the current in Y is 1.8A .

(i) Calculate:

1. the current I in the battery

$I = \dots\dots\dots \text{A}$ [1]

2. resistance R_Z

$R_Z = \dots\dots\dots \Omega$ [2]

3. e.m.f. E .

$E = \dots\dots\dots \text{V}$ [2]

- (ii) Resistors X and Y are each made of wire. The two wires have the same length and are made of the same metal.

Determine the ratio:

1.
$$\frac{\text{cross-sectional area of wire X}}{\text{cross-sectional area of wire Y}}$$

ratio = ... [2]

2.
$$\frac{\text{average drift speed of free electrons in X}}{\text{average drift speed of free electrons in Y}}$$

ratio = ... [2]

[Total: 10]

Please turn over for Question 7.

6 (a) Define *electric potential difference* (*p.d.*).

.....
..... [1]

(b) The variation with potential difference V of the current I in a semiconductor diode is shown in Fig. 6.1.

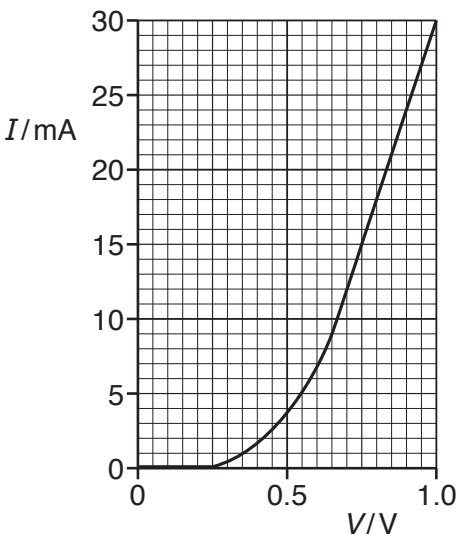


Fig. 6.1

Use Fig. 6.1 to describe qualitatively the variation of the resistance of the diode as V increases from 0 to 1.0 V.

.....
.....
.....
..... [2]

- (c) The diode in (b) is part of the circuit shown in Fig. 6.2.

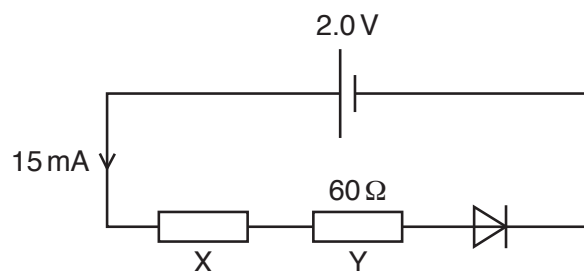


Fig. 6.2

The cell of electromotive force (e.m.f.) 2.0 V and negligible internal resistance is connected in series with the diode and resistors X and Y. The resistance of Y is $60\ \Omega$. The current in the cell is 15 mA.

- (i) Use Fig. 6.1 to determine the resistance of the diode.

resistance = ... Ω [3]

- (ii) Calculate:

1. the resistance of X

resistance = ... Ω [3]

2. the ratio

$$\frac{\text{power dissipated in resistor Y}}{\text{total power produced by the cell}}$$

ratio = ... [2]

[Total: 11]

3 (a) State the property of an object that experiences a force when the object is placed in:

(i) a gravitational field

..... [1]

(ii) an electric field.

..... [1]

(b) A potential difference of $1.2 \times 10^3 \text{ V}$ is applied between a pair of horizontal metal plates in a vacuum, as shown in Fig. 3.1.

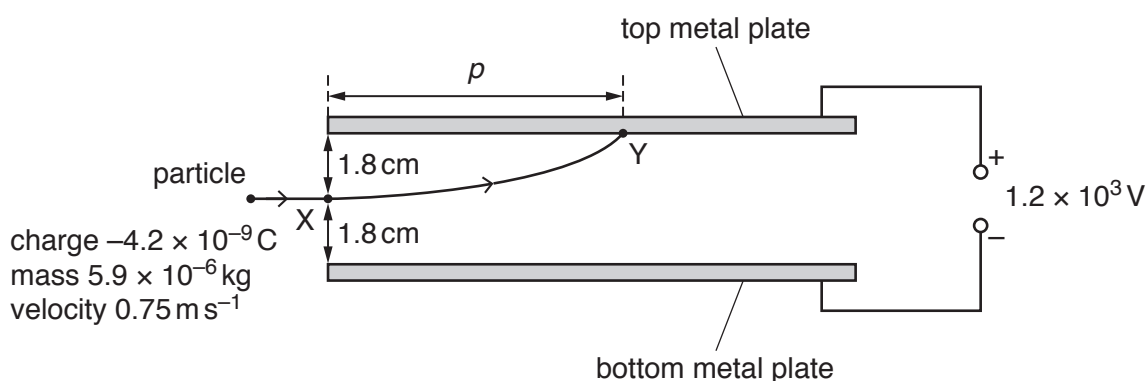


Fig. 3.1 (not to scale)

The separation of the plates is 3.6 cm. The electric field between the plates is uniform.

A particle of mass $5.9 \times 10^{-6} \text{ kg}$ and charge $-4.2 \times 10^{-9} \text{ C}$ enters the field at point X with a horizontal velocity of 0.75 m s^{-1} along a line midway between the two plates.

The particle is deflected by the field and hits the top plate at point Y.

(i) Calculate the magnitude of the electric force acting on the particle in the field.

electric force = ... N [3]

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- (ii) By considering the resultant vertical force acting on the particle, show that the acceleration of the particle in the electric and gravitational fields is 14 m s^{-2} .

[4]

- (iii) Determine:

1. the time taken for the particle to move from X to Y

time taken = ... s [2]

2. the distance p of point Y from the left-hand edge of the top plate.

$p = \dots\dots\dots \text{m}$ [1]

[Total: 12]

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- 5 (a) Define the *ohm*.

.....

 [1]

- (b) A wire has a resistance of $1.8\ \Omega$. The wire has a uniform cross-sectional area of $0.38\ \text{mm}^2$ and is made of metal of resistivity $9.6 \times 10^{-7}\ \Omega\text{m}$.

Calculate the length of the wire.

length = ... m [3]

- (c) A resistor X of resistance $1.8\ \Omega$ is connected to a resistor Y of resistance $0.60\ \Omega$ and a battery P, as shown in Fig. 5.1.

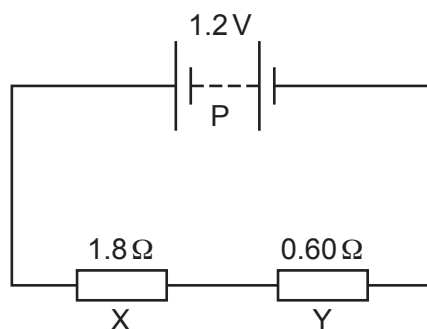


Fig. 5.1

The battery P has an electromotive force (e.m.f.) of 1.2V and negligible internal resistance.

- (i) Explain, in terms of energy, why the potential difference (p.d.) across resistor X is less than the e.m.f. of the battery.

.....

 [1]

- (ii) Calculate the potential difference across resistor X.

potential difference = ... V [2]

- (d) Another battery Q of e.m.f. 1.2 V and negligible internal resistance is now connected into the circuit of Fig. 5.1 to produce the new circuit shown in Fig. 5.2.

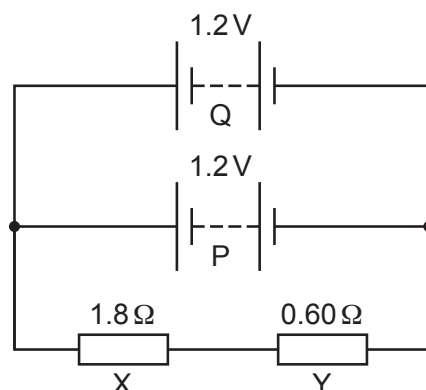


Fig. 5.2

State whether the addition of battery Q causes the current to decrease, increase or remain the same in:

(i) resistor X [1]

(ii) battery P. [1]

- (e) The circuit shown in Fig. 5.2 is modified to produce the new circuit shown in Fig. 5.3.

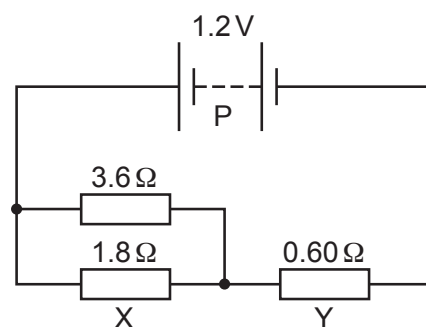


Fig. 5.3

Calculate:

- (i) the total resistance of the two resistors connected in parallel

resistance = ... Ω [1]

- (ii) the current in resistor Y.

current = ... A [2]

[Total: 12]

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- 6** A uniform electric field is produced between two parallel metal plates. The electric field strength is $1.4 \times 10^4 \text{ NC}^{-1}$. The potential difference between the plates is 350 V.

(a) Calculate the separation of the plates.

separation = ... m [2]

- (b)** A nucleus of mass $8.3 \times 10^{-27} \text{ kg}$ is now placed in the electric field. The electric force acting on the nucleus is $6.7 \times 10^{-15} \text{ N}$.

(i) Calculate the charge on the nucleus in terms of e , where e is the elementary charge.

charge = ... e [3]

(ii) Calculate the mass, in u , of the nucleus.

mass = ... u [1]

(iii) Use your answers in **(b)(i)** and **(b)(ii)** to determine the number of neutrons in the nucleus.

number = ... [1]

[Total: 7]

34. Question part 1/2 | 9702 May-June 2020 P2 V1 Q5

- 5 (a)** Metal wire is used to connect a power supply to a lamp. The wire has a total resistance of $3.4\ \Omega$ and the metal has a resistivity of $2.6 \times 10^{-8}\ \Omega\text{m}$. The total length of the wire is 59 m.

(i) Show that the wire has a cross-sectional area of $4.5 \times 10^{-7}\ \text{m}^2$.

[2]

- (ii)** The potential difference across the total length of wire is 1.8 V.

Calculate the current in the wire.

current = ... A [1]

- (iii)** The number density of the free electrons in the wire is $6.1 \times 10^{28}\ \text{m}^{-3}$.

Calculate the average drift speed of the free electrons in the wire.

average drift speed = ... m s^{-1} [2]

- (b)** A different wire carries a current. This wire has a part that is thinner than the rest of the wire, as shown in Fig. 5.1.

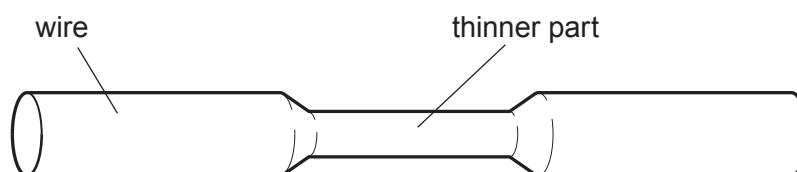


Fig. 5.1

- (i) State and explain qualitatively how the average drift speed of the free electrons in the thinner part compares with that in the rest of the wire.

.....

 [2]

- (ii) State and explain whether the power dissipated in the thinner part is the same, less or more than the power dissipated in an equal length of the rest of the wire.

.....

 [2]

- (c) Three resistors have resistances of $180\ \Omega$, $90\ \Omega$ and $30\ \Omega$.

- (i) Sketch a diagram showing how **two** of these three resistors may be connected together to give a combined resistance of $60\ \Omega$ between the terminals shown. Ensure you label the values of the resistances in your diagram.



[1]

- (ii) A potential divider circuit is produced by connecting the three resistors to a battery of electromotive force (e.m.f.) 12 V and negligible internal resistance. The potential divider circuit provides an output potential difference V_{OUT} of 8.0 V . Fig. 5.2 shows the circuit diagram.

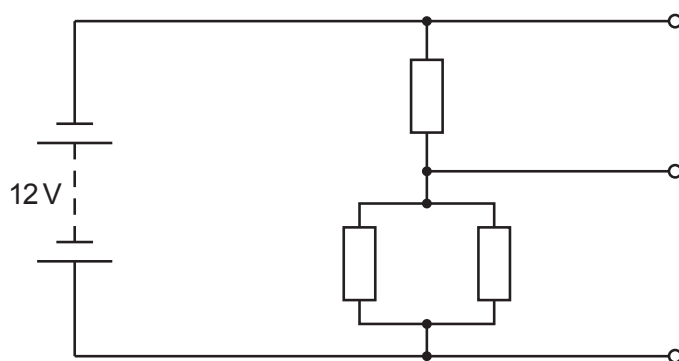


Fig. 5.2

On Fig. 5.2, label the resistances of all three resistors and the potential difference V_{OUT} .

[2]

[Total: 12]

- 5 (a) Define the *volt*.

.....
 [1]

- (b) Fig. 5.1 shows a network of three resistors.

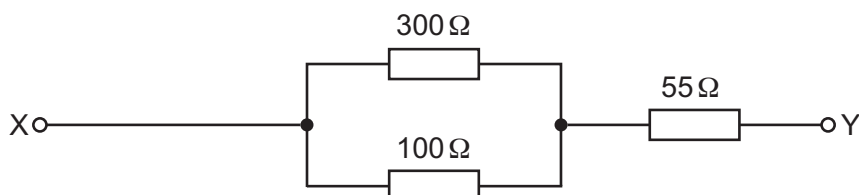


Fig. 5.1

Calculate:

- (i) the combined resistance of the two resistors connected in parallel

combined resistance = ... Ω [1]

- (ii) the total resistance between terminals X and Y.

total resistance = ... Ω [1]

- (c) The network in (b) is connected to a power supply so that there is a potential difference between terminals X and Y. The power dissipated in the resistor of resistance 55 Ω is 0.20 W.

- (i) Calculate the current in the resistor of resistance:

1. 55 Ω

current = ... A

2. 300 Ω.

current = ... A
 [3]

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(ii) Calculate the potential difference between X and Y.

potential difference = ... V [1]

[Total: 7]

- 6** The current I in a metal wire is given by the expression

$$I = Anve$$

where v is the average drift speed of the free electrons in the wire and e is the elementary charge.

- (a)** State what is meant by the symbols A and n .

A :

n : [2]

- (b)** Use the above expression to determine the SI base units of e .
Show your working.

base units [2]

- (c)** Two lamps P and Q are connected in series to a battery, as shown in Fig. 6.1.

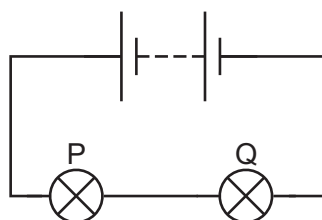


Fig. 6.1

The radius of the filament wire of lamp P is twice the radius of the filament wire of lamp Q. The filament wires are made of metals with the same value of n .

Calculate the ratio

$$\frac{\text{average drift speed of free electrons in filament wire of P}}{\text{average drift speed of free electrons in filament wire of Q}}.$$

ratio = ... [2]

[Total: 6]

7 (a) Define the *ohm*.

.....
..... [1]

(b) A uniform wire has resistance $3.2\,\Omega$. The wire has length $2.5\,\text{m}$ and is made from metal of resistivity $460\,\text{n}\Omega\,\text{m}$.

Calculate the cross-sectional area of the wire.

cross-sectional area = ... m^2 [3]

(c) A cell of electromotive force (e.m.f.) E and internal resistance r is connected to a variable resistor of resistance R , as shown in Fig. 7.1.

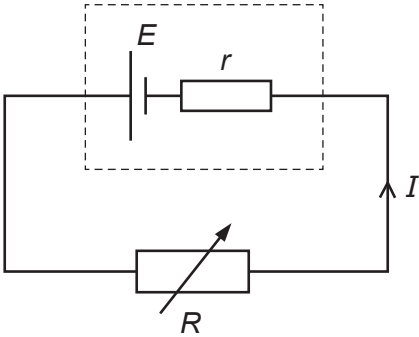


Fig. 7.1

The current in the circuit is I .

(i) State, in terms of energy, why the potential difference across the variable resistor is less than the e.m.f. of the cell.

.....
..... [1]

- (ii) State an expression for E in terms of I , R and r .

$$E = \dots\dots\dots [1]$$

- (iii) The resistance R of the variable resistor is changed so that it is equal to r .

Determine an expression, in terms of only E and r , for the power P dissipated in the variable resistor.

$$P = \dots\dots\dots [2]$$

[Total: 8]

- 6 (a) A network of three resistors of resistances R_1 , R_2 and R_3 is shown in Fig. 6.1.

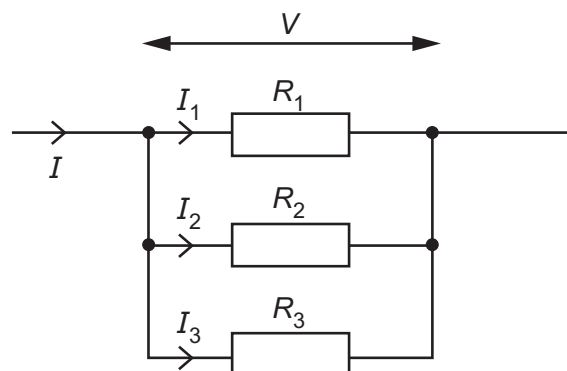


Fig. 6.1

The individual currents in the resistors are I_1 , I_2 and I_3 . The total current in the combination of resistors is I and the potential difference across the combination is V .

Show that the combined resistance R of the network is given by

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}.$$

[2]

- (b) A battery of electromotive force (e.m.f.) 8.0V and internal resistance r is connected to three resistors X, Y and Z, as shown in Fig. 6.2.

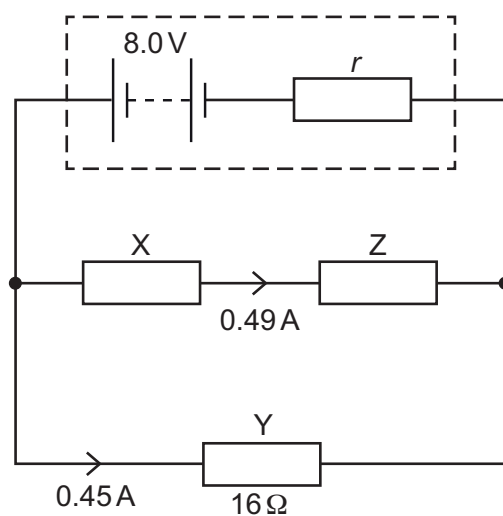


Fig. 6.2

Resistor Y has a resistance of $16\,\Omega$. The current in resistor X is 0.49A and the current in resistor Y is 0.45A .

Calculate:

- (i) the current in the battery

current = ... A [1]

- (ii) the internal resistance r of the battery.

$r = \dots\dots\dots \Omega$ [2]

- (c) Resistors X and Y in Fig. 6.2 are made from wires of the same material and cross-sectional area. The average drift speed of the free electrons in X is $2.1 \times 10^{-4}\text{ms}^{-1}$.

Calculate the average drift speed v of the free electrons in Y.

$v = \dots\dots\dots \text{ms}^{-1}$ [2]

- (d) Resistor Z in Fig. 6.2 is replaced by a new resistor of smaller resistance.

State and explain the effect, if any, on the terminal potential difference of the battery.

.....
.....
..... [2]

[Total: 9]

5 (a) Define the *ohm*.

.....
 [1]

(b) A wire is made of metal of resistivity ρ . The length L of the wire is gradually increased. Assume that the volume V of the wire remains constant as its length is increased.

Show that the resistance R of the extending wire is proportional to L^2 .

[2]

(c) A battery of electromotive force (e.m.f.) E and internal resistance r is connected to a variable resistor of resistance R , as shown in Fig. 5.1.

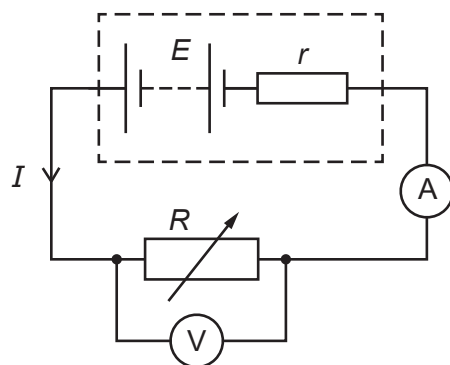


Fig. 5.1

An ammeter measures the current I in the circuit. A voltmeter measures the potential difference V across the variable resistor.

The resistance R is now varied to change the values of I and V .

The variation with I of V is shown in Fig. 5.2.

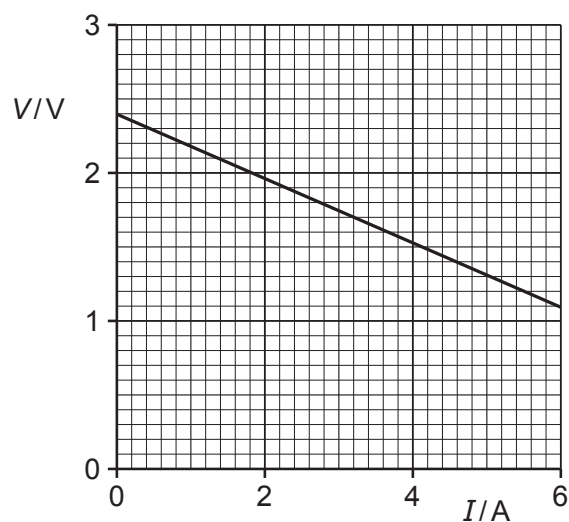


Fig. 5.2

- (i) Use Fig. 5.2 to state the e.m.f. E of the battery.

$E = \dots\dots\dots$ V [1]

- (ii) Use Fig. 5.2 to determine the power dissipated in the variable resistor when there is a current of 5.0A.

power = $\dots\dots\dots$ W [3]

- (iii) State what is represented by the value of the gradient of the graph.

$\dots\dots\dots$ [1]

[Total: 8]

- 2 A charged oil drop is in a vacuum between two horizontal metal plates. A uniform electric field is produced between the plates by applying a potential difference of 1340 V across them, as shown in Fig. 2.1.

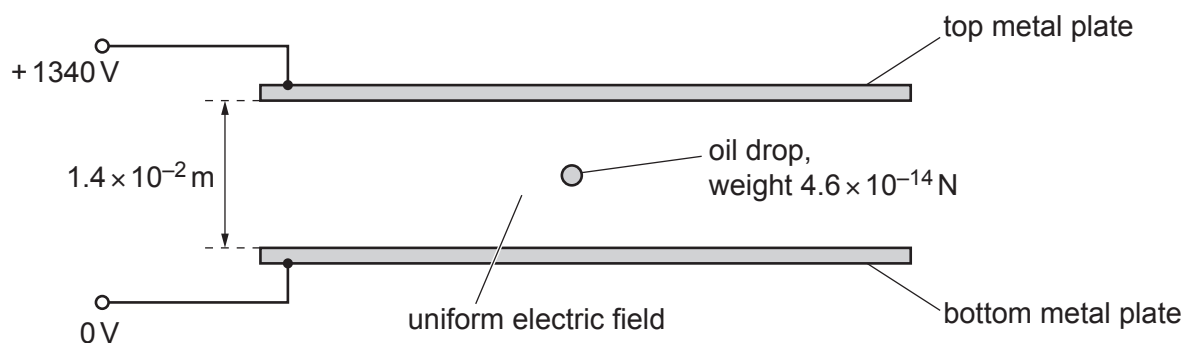


Fig. 2.1

The separation of the plates is $1.4 \times 10^{-2} \text{ m}$.

The oil drop of weight $4.6 \times 10^{-14} \text{ N}$ remains stationary at a point mid-way between the plates.

- (a) (i) Calculate the magnitude of the electric field strength.

electric field strength = ... N C^{-1} [2]

- (ii) Determine the magnitude and the sign of the charge on the oil drop.

magnitude of charge = ... C

sign of charge [3]

- (b) The electric potentials of the plates are instantaneously reversed so that the top plate is at a potential of 0 V and the bottom plate is at a potential of +1340 V. This change causes the oil drop to start moving downwards.

- (i) Compare the new pattern of the electric field lines between the plates with the original pattern.

.....
 [2]

- (ii) Determine the magnitude of the resultant force acting on the oil drop.

resultant force = ... N [1]

- (iii) Show that the magnitude of the acceleration of the oil drop is 20 m s^{-2} .

[2]

- (iv) Assume that the radius of the oil drop is negligible.

Use the information in **(b)(iii)** to calculate the time taken for the oil drop to move to the bottom metal plate from its initial position mid-way between the plates.

time = ... s [2]

- (c) The oil drop in **(b)** starts to move at time $t = 0$. The distance of the oil drop from the bottom plate is x .

On Fig. 2.2, sketch the variation with time t of distance x for the movement of the drop from its initial position until it hits the surface of the bottom plate. Numerical values of t are not required.

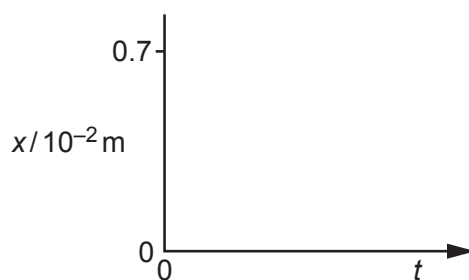


Fig. 2.2

[2]

[Total: 14]

41. Question part 1/2 | 9702 Oct-Nov 2021 P2 V2 Q6

- 6** A cell of electromotive force (e.m.f.) 0.48 V is connected to a metal wire X, as shown in Fig. 6.1.

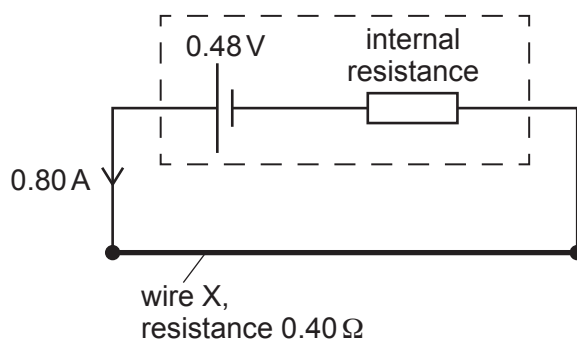


Fig. 6.1

The cell has internal resistance. The current in the cell is 0.80 A .

Wire X has length 3.0 m , cross-sectional area $1.3 \times 10^{-7}\text{ m}^2$ and resistance $0.40\ \Omega$.

- (a)** Calculate the charge passing through the cell in a time of 7.5 minutes .

charge = ... C [2]

- (b)** Calculate the percentage efficiency with which the cell supplies power to wire X.

efficiency = ... % [3]

41. Question part 2/2 | 9702 Oct-Nov 2021 P2 V2 Q6

(c) There are 3.2×10^{22} free (conduction) electrons contained in the volume of wire X.

For wire X, calculate:

(i) the number density n of the free electrons

$n = \dots\dots\dots \text{m}^{-3}$ [1]

(ii) the average drift speed of the free electrons.

average drift speed = $\dots\dots\dots \text{ms}^{-1}$ [2]

(d) A wire Y has the same cross-sectional area as wire X and is made of the same metal. Wire Y is longer than wire X.

Wire X in the circuit is now replaced by wire Y. Assume that wire Y has the same temperature as wire X.

State and explain whether the average drift speed of the free electrons in wire Y is greater than, the same as, or less than that in wire X.

.....
.....
.....
.....
.....
..... [3]

[Total: 11]

42. Question part 1/2 | 9702 Oct-Nov 2021 P2 V3 Q4

- 4 An α -particle moves in a straight line through a vacuum with a constant speed of $4.1 \times 10^6 \text{ m s}^{-1}$. The α -particle enters a uniform electric field at point A, as shown in Fig. 4.1.

**Fig. 4.1**

The α -particle continues to move in the same straight line until it is brought to rest at point B by the electric field. The deceleration of the α -particle by the electric field is $2.7 \times 10^{14} \text{ m s}^{-2}$.

- (a) State the direction of the electric field.

..... [1]

- (b) Calculate the distance AB.

distance = ... m [2]

- (c) Calculate the electric field strength.

electric field strength = ... V m^{-1} [3]

- (d) The α -particle is at point A at time $t = 0$.

On Fig. 4.2, sketch the variation with time t of the momentum of the α -particle as it travels from point A to point B. Numerical values are not required.

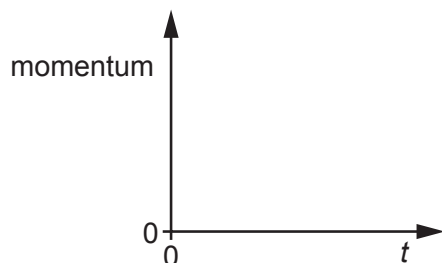


Fig. 4.2

[1]

- (e) State the name of the quantity that is represented by the gradient of the graph in (d).

..... [1]

- (f) A β^- particle now enters the electric field along the same initial path as the α -particle and with the same initial speed of $4.1 \times 10^6 \text{ m s}^{-1}$.

- (i) Calculate the kinetic energy, in J, of the β^- particle at point A.

kinetic energy = ... J [3]

- (ii) State and explain the differences between the electric force on the β^- particle in the electric field and the electric force on the α -particle in the electric field.

.....

 [3]

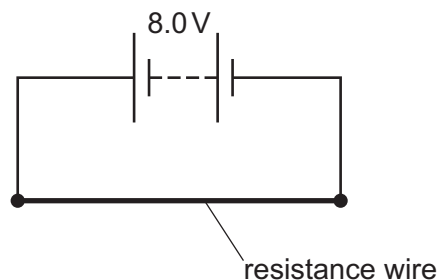
- (iii) The β^- particle is produced by the decay of a nucleus. State the name of another lepton that is produced at the same time as the β^- particle.

..... [1]

[Total: 15]

43. Question part 1/3 | 9702 Feb-March 2022 P2 V2 Q6

- 6** The ends of a metal resistance wire are connected to a battery of electromotive force (e.m.f.) 8.0 V and negligible internal resistance, as shown in Fig. 6.1.

**Fig. 6.1**

The power dissipated by the resistance wire is 36 W.

(a) Calculate:

- (i)** the current in the resistance wire

current = ... A [2]

- (ii)** the number of free electrons that pass through the resistance wire in a time of 50 s

number = ... [2]

- (iii)** the resistance of the wire.

resistance = ... Ω [2]

- (b) The metal of the resistance wire in the circuit has a resistivity of $1.4 \times 10^{-6} \Omega \text{m}$. The cross-sectional area of the wire is 0.25mm^2 .

Determine the length of the wire.

length = ...m [2]

- (c) The circuit shown in Fig. 6.1 is modified by replacing the original resistance wire with a second resistance wire. The second wire has a greater diameter than the original wire. There are no other differences between the second wire and the original wire.

By reference to resistance, state and explain whether the power dissipated by the second wire is more than, less than or the same as the power dissipated by the original wire.

.....
.....
.....
..... [2]

- (d) The circuit shown in Fig. 6.1 is modified by connecting a second battery, of e.m.f. 8.0V and negligible internal resistance, in parallel with the original battery and the original resistance wire, as shown in Fig. 6.2.

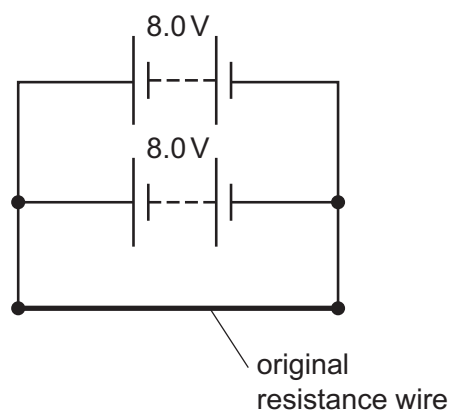


Fig. 6.2

By reference to the current in the resistance wire, state and explain whether the addition of the second battery causes the power in the original resistance wire to decrease, increase or stay the same.

.....

.....

.....

..... [2]

[Total: 12]

44. Question part 1/2 | 9702 May-June 2022 P2 V3 Q6

6 (a) (i) On Fig. 6.1, sketch the I – V characteristic of a filament lamp.

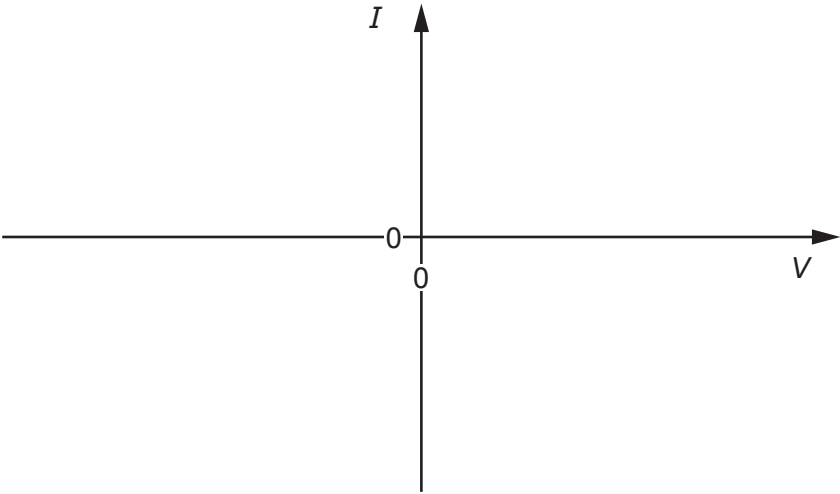


Fig. 6.1

[2]

(ii) Explain the shape of the line in (a)(i).

.....

.....

.....

..... [3]

(b) A conducting wire has length 5.8 m and cross-sectional area $3.4 \times 10^{-8} \text{ m}^2$. The resistivity of the metal of the wire is $5.6 \times 10^{-8} \Omega \text{ m}$.

Calculate the resistance of the wire.

resistance = ... Ω [2]

44. Question part 2/2 | 9702 May-June 2022 P2 V3 Q6

- (c) A resistor of resistance R is placed in a circuit with a cell of negligible internal resistance, two switches S_1 and S_2 , a second resistor of resistance $2R$ and three ammeters X, Y and Z. The circuit is shown in Fig. 6.2.

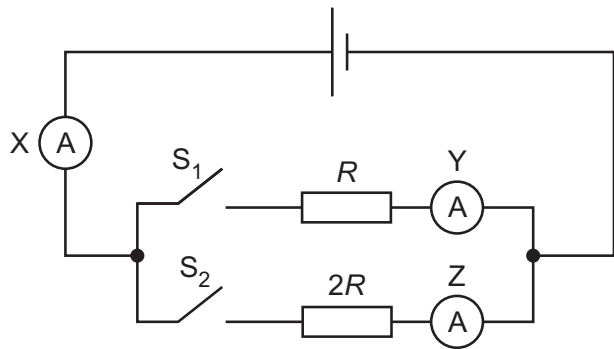


Fig. 6.2

The reading on X is 1.0A when S_1 is open and S_2 is closed.

Complete Table 6.1.

Table 6.1

position of switches		ammeter readings		
S_1	S_2	reading on X/A	reading on Y/A	reading on Z/A
open	open	0	0	0
open	closed	1.0		
closed	open			
closed	closed			

[4]

[Total: 11]

9702 Physics Paper 2 - Electricity

Topical questions | 56 questions

45. Question | 9702 May-June 2023 P2 V1 Q6

- 6** A metal wire in a circuit has a length of 1.8m and a cross-sectional area of $1.5 \times 10^{-6} \text{ m}^2$.
The total number of free electrons (charge carriers) in the wire is 2.3×10^{23} .

There is a current in the wire so that a charge of 172C moves past a fixed point in the wire in a time of 2.5 minutes.

- (a)** Show that the number density of the free electrons in the wire is $8.5 \times 10^{28} \text{ m}^{-3}$.

[1]

- (b)** Calculate the average drift speed of the free electrons.

average drift speed = ... ms^{-1} [3]

[Total: 4]

- 6 (a) The current in a filament lamp decreases.

State and explain how the resistance of the lamp changes.

.....
..... [1]

- (b) A cylindrical wire has length L and resistance R . The **total** number of free electrons (charge carriers) contained in the volume of the wire is N . Each free electron has charge e . The potential difference between the ends of the wire is V .

Determine expressions, in terms of some or all of the symbols e , L , N , R and V for:

- (i) the current in the wire

current = ... [1]

- (ii) the average drift speed of the free electrons

average drift speed = ... [2]

- (iii) the average time taken for a free electron to move along the full length of the wire.

time taken = ... [1]

[Total: 5]

47. Question part 1/2 | 9702 May-June 2023 P2 V3 Q5

- 5** A student sets up a circuit with a battery, an ammeter, a heater and a light-dependent resistor (LDR) all in series.

The battery has negligible internal resistance.

A voltmeter is connected across (in parallel with) the heater.

- (a)** On Fig. 5.1, complete the circuit diagram of this arrangement.

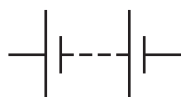


Fig. 5.1

[3]

- (b)** The heater is a wire made of metal of resistivity $1.1 \times 10^{-6} \Omega \text{ m}$. The wire has length 2.0 m and cross-sectional area $3.8 \times 10^{-7} \text{ m}^2$.

The reading on the voltmeter is 4.8 V.

Calculate:

- (i)** the resistance of the heater

resistance = ... Ω [2]

- (ii)** the reading on the ammeter.

reading on ammeter = ... A [1]

- (c) The heater is replaced by a new wire. The new wire is made of the same metal as the wire in (b) and has the same length but a larger diameter.

The resistance of the LDR remains constant.

- (i) State and explain whether the new wire has a resistance that is greater than, less than or the same as that of the wire in (b).

.....

.....

..... [2]

- (ii) State and explain whether the new reading on the voltmeter is greater than, less than or equal to 4.8 V.

.....

.....

..... [2]

[Total: 10]

- 6 (a)** A metal wire has a resistance per unit length of $0.92\,\Omega\text{m}^{-1}$. The wire has a uniform cross-sectional area of $5.3 \times 10^{-7}\text{m}^2$.

Calculate the resistivity of the metal of the wire.

resistivity = ... Ωm [2]

- (b)** A battery of electromotive force (e.m.f.) E and negligible internal resistance is connected in series with a fixed resistor and a light-dependent resistor (LDR), as shown in Fig. 6.1.

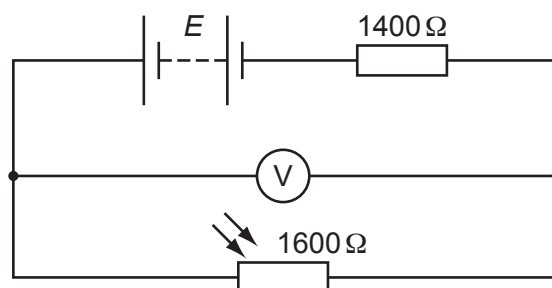


Fig. 6.1

The resistance of the fixed resistor is $1400\,\Omega$. The intensity of the light illuminating the LDR causes it to have a resistance of $1600\,\Omega$. A voltmeter connected across the LDR reads 6.4 V .

- (i)** Show that the current in the LDR is $4.0 \times 10^{-3}\text{ A}$.

[1]

- (ii)** Calculate the number of free electrons passing through the LDR in a time of 3.2 minutes.

number of free electrons = ... [2]

(iii) Calculate the e.m.f. E .

$E = \dots\dots\dots \text{ V [2]}$

(iv) Determine the ratio

$$\frac{\text{power dissipated in LDR}}{\text{power dissipated in fixed resistor}}.$$

$\text{ratio} = \dots\dots\dots \text{ [2]}$

(c) The environmental conditions change causing a decrease in the resistance of the LDR in (b). The temperature of the environment does not change.

State whether there is a decrease, increase or no change to:

(i) the intensity of the light illuminating the LDR
..... [1]

(ii) the current in the battery
..... [1]

(iii) the reading of the voltmeter.
..... [1]

[Total: 12]

- 7 (a) State Ohm's law.

.....

 [2]

- (b) A battery of electromotive force (e.m.f.) 6.2V and negligible internal resistance is connected in a circuit to a uniform resistance wire, a voltmeter, a fixed resistor and a switch, as shown in Fig. 7.1.

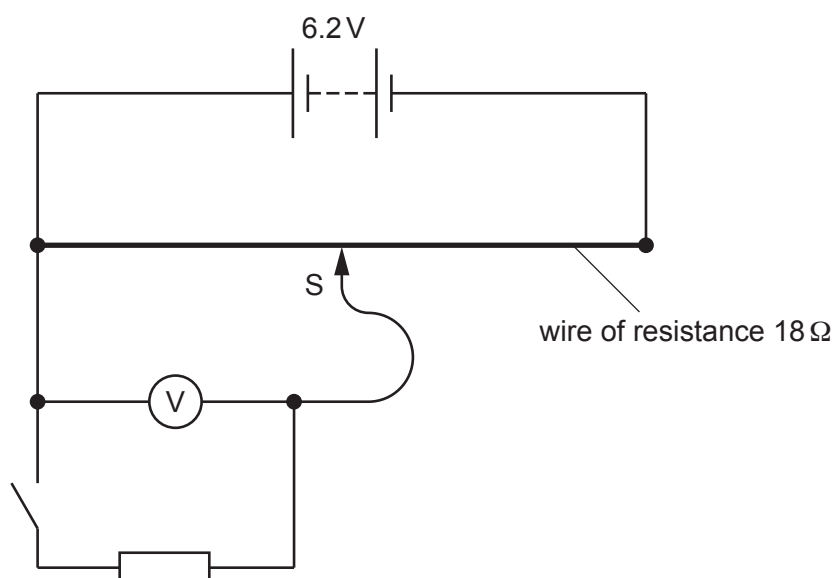


Fig. 7.1

The resistance wire has resistance 18Ω , length 0.94 m and cross-sectional area $7.2 \times 10^{-8}\text{ m}^2$. The slider S is positioned half-way along the length of the wire.

- (i) Calculate the resistivity ρ of the material of the resistance wire.

$\rho = \dots\dots\dots \Omega\text{ m}$ [2]

- (ii) The switch is open.
 State the reading on the voltmeter.

voltmeter reading = $\dots\dots\dots \text{ V}$ [1]

(iii) The switch is now closed.

State whether there is an increase, decrease or no change to:

- the current in the battery
.....
- the voltmeter reading.
.....

[2]

(iv) The switch remains closed. The slider S is moved along the resistance wire so that the voltmeter reading is 3.1 V.

On Fig. 7.1, draw a cross (×) on the resistance wire to show a possible new position of the slider. [1]

(c) The circuit in (b) is altered by changing the battery for one of a different e.m.f. The switch is open.

A student records the following data for the resistance wire:

current in the wire	0.93A
mean drift speed of charge carriers	$1.3 \times 10^{-3} \text{ m s}^{-1}$
number density of charge carriers	$9.0 \times 10^{28} \text{ m}^{-3}$.

(i) Determine the charge q of a charge carrier in the wire suggested by this data.

$q = \text{..... C}$ [2]

(ii) With reference to the value of q , explain why the data recorded by the student cannot be correct.

.....
..... [1]

[Total: 11]

BLANK PAGE

- 3** Lightning occurs when charge builds up in the atmosphere, creating a potential difference between the ground and the atmosphere.

During a lightning strike there is an average current of $3.3 \times 10^4 \text{ A}$ for a time of $2.6 \times 10^{-5} \text{ s}$.

- (a)** Calculate the charge transferred during the lightning strike.

charge = ... C [2]

- (b)** The potential difference between the ground and the atmosphere is $3.0 \times 10^7 \text{ V}$.

Calculate the average power, in GW, transferred during the lightning strike.

power = ... GW [2]

- (c)** A lightning rod is attached to a tall building to conduct charge safely to the ground. The lightning rod is modelled as a uniform cylindrical copper cable of total length 95 m that runs from the ground to the top of the building, as shown in Fig. 3.1.

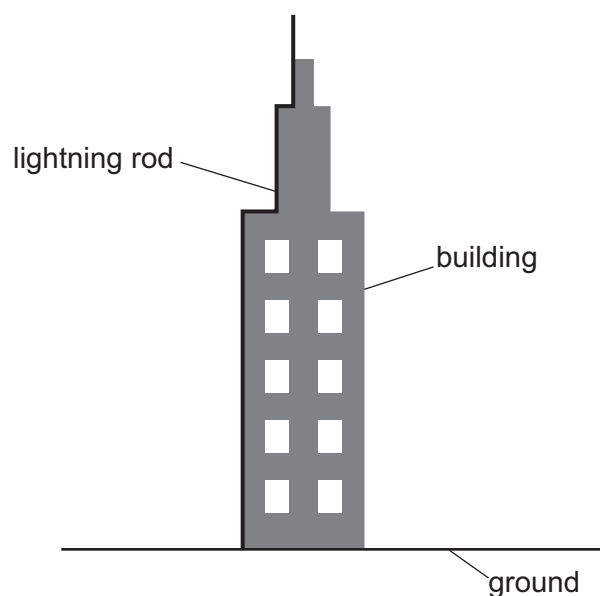


Fig. 3.1



- (i) The resistance of the lightning rod is $9.6\,\Omega$.
The resistivity of copper is $1.7 \times 10^{-8}\,\Omega\text{ m}$.

Determine the radius of the lightning rod.

radius = ... m [3]

- (ii) The radius of the copper lightning rod is doubled with no change to its length.

State the effect of this change on the resistance of the lightning rod.

..... [1]

- (d) A section of the lightning rod of length 0.12 m is removed for testing. A tensile stress of $1.9 \times 10^6\text{ Pa}$ is applied, as shown in Fig. 3.2.

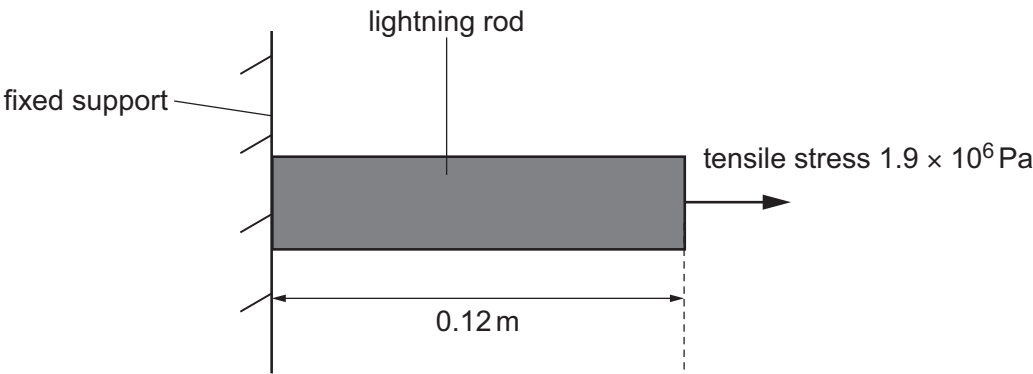


Fig. 3.2 (not to scale)

The section of the rod obeys Hooke’s law. The Young modulus of copper is $1.3 \times 10^{11}\text{ Pa}$.

Calculate the extension of the section.

extension = ... m [3]

51. Question part 1/2 | 9702 Oct-Nov 2024 P2 V2 Q5

5 (a) Define electric potential difference (p.d.).

.....
..... [1]

(b) A power supply, three resistors and a component X are connected in the circuit shown in Fig. 5.1.

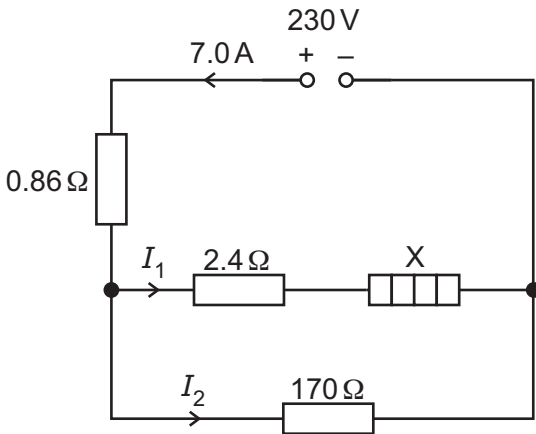


Fig. 5.1

The power supply has an electromotive force (e.m.f.) of 230 V and negligible internal resistance. The current in the power supply is 7.0 A.

(i) Identify component X.

..... [1]

(ii) Show that the p.d. across the resistor of resistance 0.86 Ω is 6.0 V.

[1]

(iii) Determine the current I_1 .

$I_1 =$ A [2]

51. Question part 2/2 | 9702 Oct-Nov 2024 P2 V2 Q5



(iv) Calculate the p.d. across component X.

p.d. = ... V [2]

(v) Calculate the power dissipated in component X.

power = ... W [2]

(vi) The purpose of the circuit is to provide power to component X.

Determine the percentage efficiency of the circuit.

efficiency = ... % [2]

(vii) The resistor of resistance $170\,\Omega$ is removed, leaving an open circuit in the lower branch of the circuit. There is no change to the resistance of component X.

State whether the current in the power supply increases, decreases or remains the same.

..... [1]

[Total: 12]

6 (a) Define resistance.

.....
..... [1]

(b) A cylindrical metal wire of length 2.4 m and cross-sectional area $8.0 \times 10^{-6} \text{ m}^2$ has a resistance of $0.33 \, \Omega$. There is a current in the wire of 4.7 A.

(i) Determine the resistivity of the metal from which the wire is made.

resistivity = ... $\Omega \text{ m}$ [2]

(ii) Calculate the charge that passes through the wire in a time of 5.0 minutes.

charge = ... C [2]

(iii) The free electrons (charge carriers) in the wire have an average drift speed of 0.16 mm s^{-1} .

Determine the number density of charge carriers in the metal.

number density = ... m^{-3} [2]



- (c) The wire in (b) may be considered to be a fixed resistor. It is connected in series with a thermistor to a battery that has negligible internal resistance.
- (i) Use circuit symbols to complete Fig. 6.1 to show the circuit diagram of this arrangement.

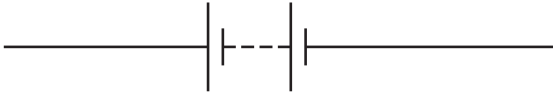


Fig. 6.1

[1]

- (ii) Explain, without calculation, how the power dissipated in the wire changes as the temperature of the thermistor is increased.

.....

.....

.....

..... [2]

[Total: 10]

53. Question part 1/3 | 9702 Feb-March 2025 P2 V2 Q6

- 6 A cylindrical copper wire P of length 0.24 m is shown in Fig. 6.1.

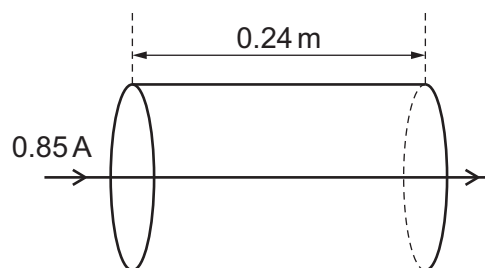


Fig. 6.1 (not to scale)

The current in the wire is 0.85 A.

The resistance of the wire is 3.3 mΩ.

The **total** number of charge carriers N in the wire is 2.6×10^{22} .

The resistivity of copper is $1.8 \times 10^{-8} \Omega \text{ m}$.

- (a) Calculate the potential difference between the two ends of the wire.

potential difference = ... V [2]

- (b) (i) Show that the cross-sectional area of the wire is $1.3 \times 10^{-6} \text{ m}^2$.

[2]

- (ii) Show that the number density of charge carriers in the wire is $8.3 \times 10^{28} \text{ m}^{-3}$.

[1]

- (iii) Calculate the average drift speed of the charge carriers (electrons) in the wire.

average drift speed = ... ms^{-1} [2]

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(c) A different copper wire Q has the same volume as wire P, but non-uniform radius, as shown in Fig. 6.2.

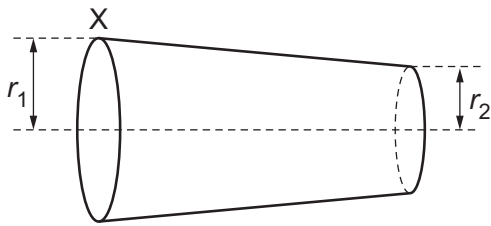


Fig. 6.2 (not to scale)

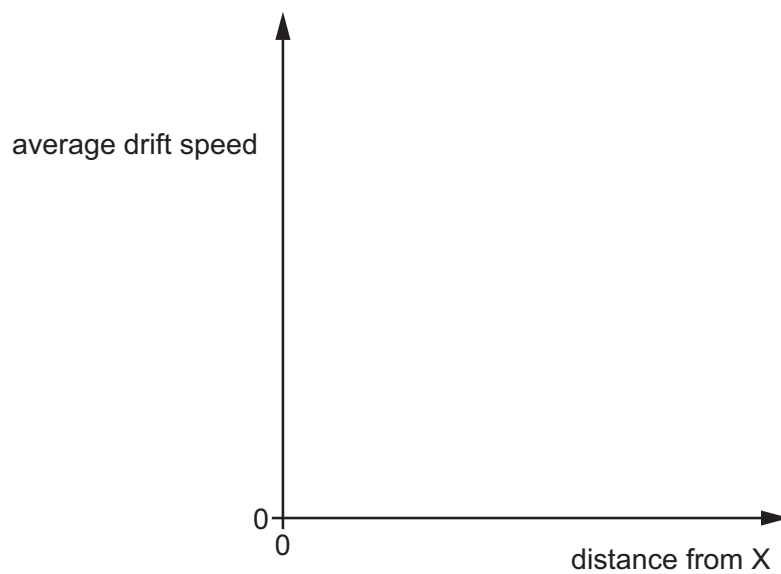
The radius r_1 at end X of wire Q is the same as the radius of wire P. Radius r_2 is less than r_1 .

- (i) State and explain how the resistance of wire Q compares with the resistance of wire P.
-
-
-
-
-
-
- [4]

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- (ii) On Fig. 6.3, sketch a graph of the variation of the average drift speed of the charge carriers with distance from end X of wire Q.

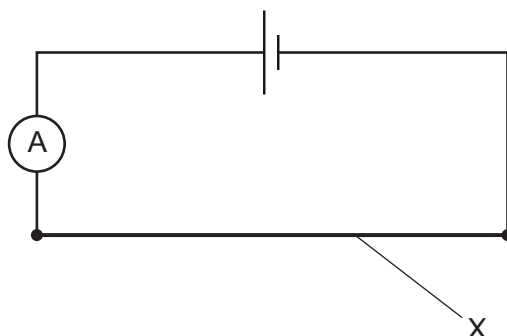
**Fig. 6.3**

[2]

[Total: 13]

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- 6 A nichrome wire X of length 45 cm and cross-sectional area $4.7 \times 10^{-7} \text{ m}^2$ is connected into the circuit shown in Fig. 6.1.

**Fig. 6.1**

The resistance of X is 1.1Ω . The cell has electromotive force (e.m.f.) 1.3 V and negligible internal resistance.

- (a) (i) Calculate the current in X.

current = ...A [1]

- (ii) The number density of charge carriers (electrons) in nichrome is $8.5 \times 10^{28} \text{ m}^{-3}$.

Calculate the average drift speed of the charge carriers in X.

average drift speed = ... ms^{-1} [2]

- (iii) Calculate the resistivity of the nichrome.

resistivity = ... $\Omega \text{ m}$ [3]

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(b) Wire Y is identical to wire X. Wire Y is added to the circuit in parallel with wire X, as shown in Fig. 6.2.

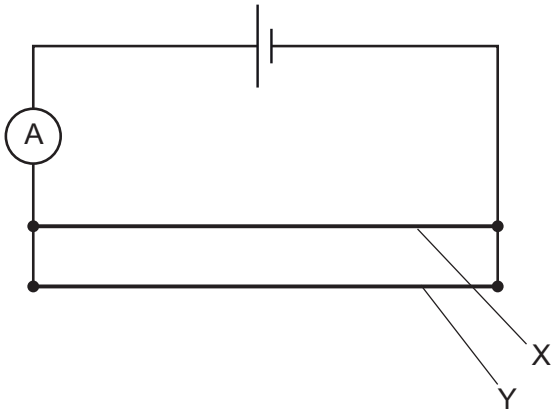


Fig. 6.2

State and explain the effect, if any, of this change on:

(i) the reading on the ammeter

.....

.....

..... [2]

(ii) the average drift speed of the charge carriers in X.

.....

..... [1]

[Total: 9]

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- 5 (a) (i) State and explain the effect, if any, on the resistance of a filament wire in a lamp as the current in the wire decreases.

.....
 [1]

- (ii) On Fig. 5.1, sketch the I – V characteristic of a filament lamp.

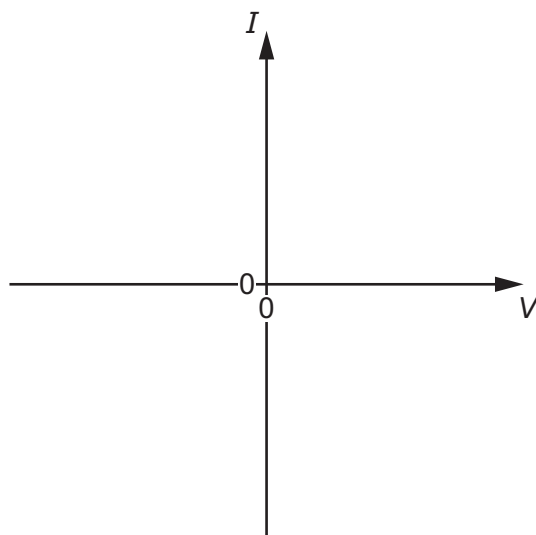


Fig. 5.1

[2]

- (b) A battery of electromotive force (e.m.f.) E and negligible internal resistance is connected in parallel with two filament lamps A and B, as shown in Fig. 5.2.

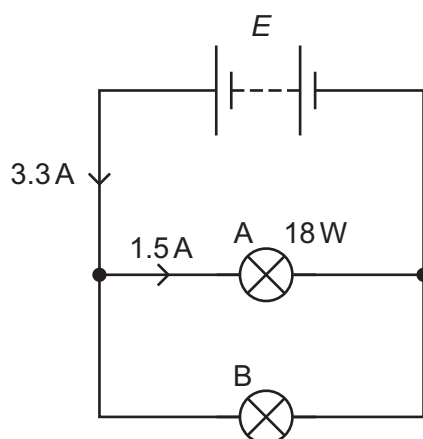


Fig. 5.2

The current in the battery is 3.3 A and the current in lamp A is 1.5 A. The power dissipated in lamp A is 18 W.

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- (i) Calculate the e.m.f. E of the battery.

$E = \dots\dots\dots$ V [2]

- (ii) The filament wire of lamp B has a cross-sectional area of $1.4 \times 10^{-9} \text{ m}^2$. The number of free (conduction) electrons per unit volume in the metal of the filament wire is $3.4 \times 10^{28} \text{ m}^{-3}$.

Calculate the average drift speed of the free electrons in the filament wire of lamp B.

average drift speed = $\dots\dots\dots$ ms^{-1} [3]

[Total: 8]

56. Question part 1/2 | 9702 Oct-Nov 2025 P2 V4 Q5

5 A student uses a circuit containing an ammeter, a voltmeter and a cell to take measurements to determine the resistance of a length of nichrome wire.

(a) (i) Define resistance.

.....
..... [1]

(ii) Draw a circuit diagram to show how the components should be connected. Use the symbol for a resistor to represent the nichrome wire.

[2]

(b) The student also measures the length and the diameter of the wire. Table 5.1 shows the measurements recorded for each quantity.

Table 5.1

quantity	measurement
length	$(0.864 \pm 0.001)\text{m}$
diameter	$(0.496 \pm 0.002)\text{mm}$
voltmeter reading	$(1.38 \pm 0.02)\text{V}$
ammeter reading	$(0.276 \pm 0.001)\text{A}$

(i) Show that the resistance of the wire is $5.00\,\Omega$.

[1]

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(ii) Calculate, to three significant figures, the resistivity ρ of the nichrome.

$\rho = \dots\dots\dots \Omega\text{m}$ [3]

(iii) Calculate the percentage uncertainty in ρ .

percentage uncertainty = $\dots\dots\dots\%$ [2]

(iv) Determine the absolute uncertainty in ρ .

absolute uncertainty = $\dots\dots\dots \Omega\text{m}$ [1]

[Total: 10]