9. Electricity

9.1 Electric current

Paper 2

Question Paper

1 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 3.3×10^4 A for a time of 2.6×10^{-5} s.

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

charge = ... C [2]

2 A metal wire in a circuit has a length of 1.8 m and a cross-sectional area of 1.5×10^{-6} 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 172 C 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 8.5×10^{28} m^{-3}.

[1]

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

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

3 **(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:

(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]

4 **(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.

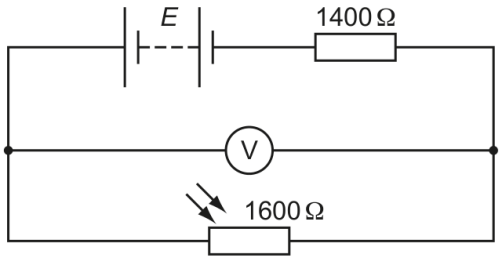


Fig. 6.1

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

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

number of free electrons = ... [2]

5 **(c)** A battery of electromotive force (e.m.f.) 9.0 V and internal resistance *r* is connected to two resistors P and Q, as shown in Fig. 6.2.

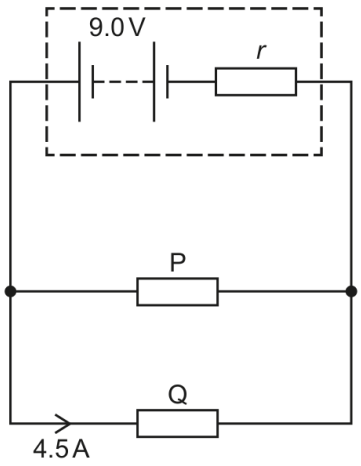


Fig. 6.2

A total charge of 650 C moves through resistor P in a time interval of 540 s. During this time resistor P dissipates 4800 J of energy. The current in resistor Q is 4.5 A. Assume that the e.m.f. of the battery remains constant.

Calculate:

(i) the current in resistor P

current = ...A [2]

6 **(b)** A battery has electromotive force (e.m.f.) 4.0 V and internal resistance 0.35 Ω. The battery is connected to a uniform resistance wire XY and a fixed resistor of resistance *R*, as shown in Fig. 5.1.

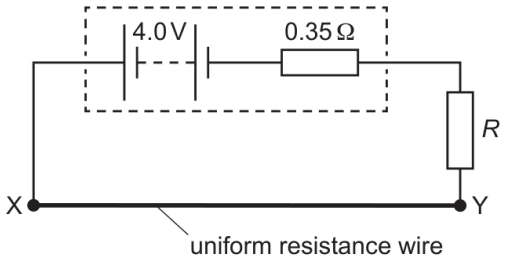


Fig. 5.1

Wire XY has resistance 0.90 Ω. The potential difference across wire XY is 1.8 V.

Calculate:

(ii) the number of free electrons that pass a point in the battery in a time of 45 s

number = ... [2]

7 **(c)** A radioactive source produces a beam of α-particles in a vacuum. The average current produced by the beam is 6.9×10^{-9} A.

Calculate the average number of α-particles passing a fixed point in the beam in a time of 1.0 minute.

number = ... [3]

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

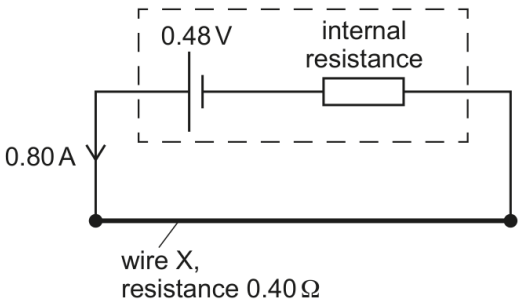


Fig. 6.1

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

Wire X has length 3.0 m, cross-sectional area 1.3×10^{-7} m^2 and resistance 0.40 Ω.

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

charge = ... C [2]

(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 = ... m^{-3} [1]

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

average drift speed = ... m s^{-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.

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..... [3]

9 **(a)** Metal wire is used to connect a power supply to a lamp. The wire has a total resistance of 3.4 Ω and the metal has a resistivity of 2.6×10^{-8} Ωm. The total length of the wire is 59 m.

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

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.

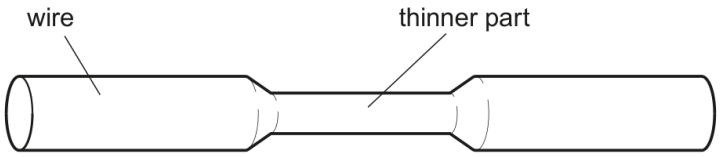


Fig. 5.1

(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.

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..... [2]

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

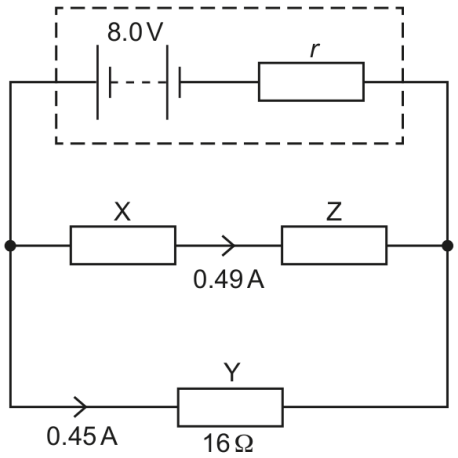


Fig. 6.2

Resistor Y has a resistance of 16 Ω. The current in resistor X is 0.49 A and the current in resistor Y is 0.45 A.

(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 2.1×10^{-4} m s^{-1}.

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

v = ... m s^{-1} [2]

11 (a) A spherical oil drop has a radius of 1.2×10^{-6} m. The density of the oil is 940 kg m^{-3}.

(ii) The oil drop is charged. Explain why it is impossible for the magnitude of the charge to be 8.0×10^{-20} C.

.....

.....[1]

12 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. 6.1.

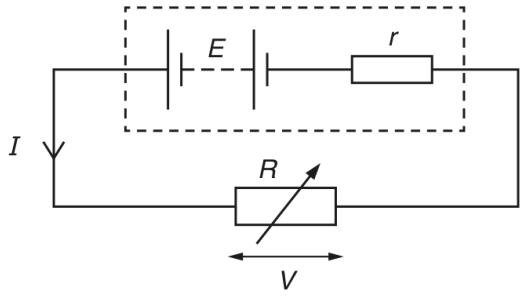


Fig. 6.1

The current in the circuit is I and the potential difference across the variable resistor is V.

(c) The resistance R of the variable resistor is varied. The variation with I of V is shown in Fig. 6.2.

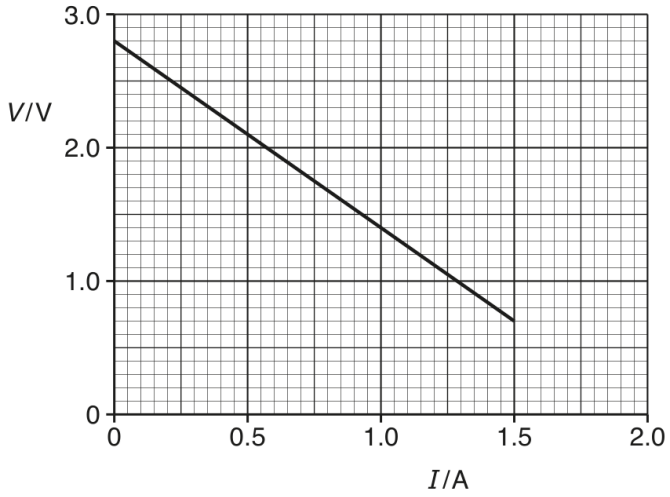


Fig. 6.2

(d) The battery stores 9.2 kJ of energy. The variable resistor is adjusted so that $V = 2.1$ V. Use Fig. 6.2 to:

(ii) calculate the number of conduction electrons moving through the battery in a time of 1.0 s

number = ... [1]

13 (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.

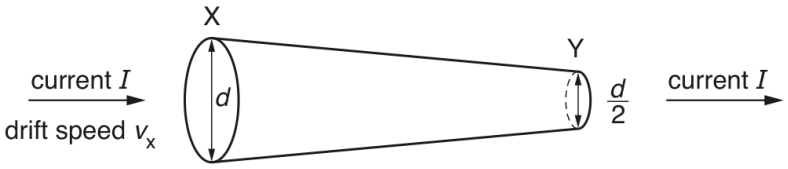


Fig. 7.1

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.

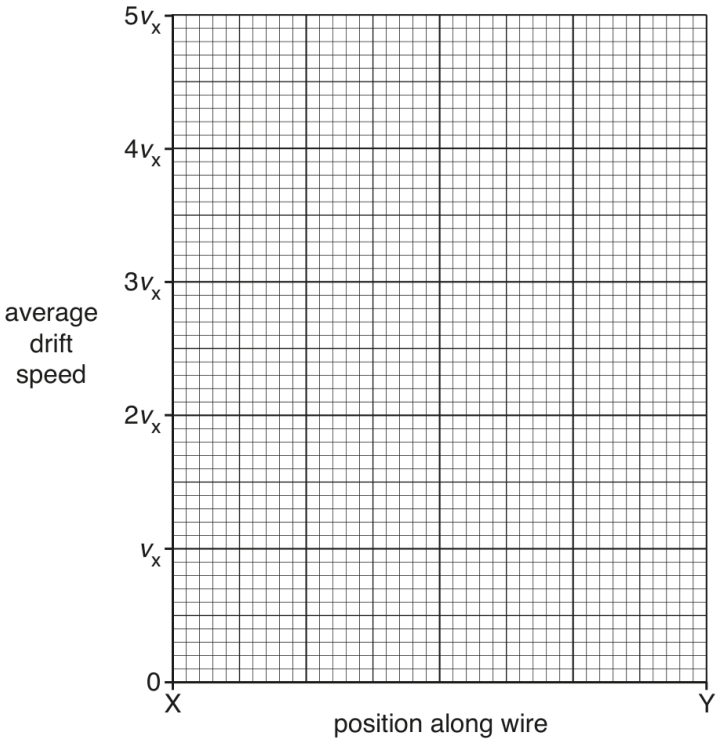


Fig. 7.2

[2]