Charge, Currents & circuits

Name & Set

Charge on an electron, $e = -1.6 \times 10^{-19}$ C
Avogadro's constant $N_A = 6.02 \times 10^{23}$ per mole

1 How many electrons per second are passing through a wire if the current is 1.00 mA, given that the charge carried by each electron is 1.6×10^{-19} C? Does the cross-section of the wire make a difference to your answer?

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_____ [2]

2 The drift speed of electrons in a particular wire of cross-sectional area 4.0 mm^2 is 0.50 mms^{-1}. There are 1.0×10^{29} electrons in each cubic metre of wire. The length of the wire is 12 mm.

(a) How long will it take all the electrons to drift through one end face?

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_____ [2]

(b) How many electrons are there within this wire?

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_____ [2]

(c) What is the total charge transferred by the electrons?

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(d) By considering the rate at which charge leaves the wire calculate the magnitude of the current.

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_____ [2]

3 When a current of 4.0 A flows through a piece of wire that has a cross-sectional area of 2.0×10^{-6} m^2, the average drift velocity of the electrons is 2.5×10^{-4} ms^{-1}. Use these values to calculate the number of free electrons per unit volume of the material.

[2]

4 It is generally accepted that the maximum safe current density for any wire made of copper is 1.0×10^7 Am^{-1}. If there are 1.0×10^{29} free electrons per cubic metre of copper, calculate the mean drift velocity of these electrons when the current reaches this density.

[2]

5 Calculate the mean drift velocity of the electrons when the current through a wire of cross-sectional area 1 mm^2 is 1 A. Take the number density, n, of the free electrons to be 5×10^{28} m^{-3}

[2]

6 Copper has a density of 8.9×10^3 kgm^{-3} and a relative atomic mass of 64. A particular copper wire has a cross-sectional area of 0.10 mm^3 and carries a current of 2.0 A. Calculate

(a) the number density of copper atoms

[2]

(b) the number density, n, of conduction electrons (assume that each atom contributes *one* free electron)

[2]

(c) the drift speed of an electron for this current.

[2]

7 The resistivity of aluminium at room temperature is 3.2×10^{-8} Ωm. Assuming that it has 5×10^{28} free electrons per cubic metre, calculate the drift velocity of the electrons if a potential gradient of 1 Vm^{-1} were applied a wire made from aluminium.

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_____ [2]

8 Copper contains 10^{29} free electrons per cubic meter and its resistivity is 1.72×10^{-8} Ωm. A potential difference of 10 mV is set up between two points 10 cm apart on a uniform wire. Calculate the average drift velocity with which the electrons will move through the wire.

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_____ [2]

9 Explain how and why the resistance of a good conductor (i.e. a material that obeys Ohm's law) is affected by a change in its temperature. Explain also why the resistance of a semiconductor drops when its temperature is increased.

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_____ [2]

10 Show that the drift velocity, *v*, in *any* conductor is proportional to the electric field, *E*, applied to it.

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_____ [2]

Answers: CURRENT & DRIFT VELOCITY

1 6.25×10^{15}

2 (a) 24 secs (b) 4.8×10^{21} (c) 768 C (d) 32 A

3 $n = 5 \times 10^{28}$ m^{-3}

4 $v = 6.25 \times 10^{-4}$ ms^{-1}

5 1.25×10^{-4} ms^{-1}

6 (a) & (b) 8.4×10^{28} m^{-3} (c) 1.5 mm s^{-1}

7 3.9 mm s^{-1}

8 3.63×10^{-4} ms^{-1}