Charge and Current Questions – OCR A Level Physics

Praneel Physics

1. Define electric current and state its SI unit. **(P)**

Working and Answer:

Current is the rate of flow of electric charge.

$$I = \frac{Q}{t}$$

Unit: Ampere (A)

2. State the elementary charge and its value. **(P)**

Working and Answer:

The elementary charge is the charge on a single proton or electron.

$$e = 1.60 \times 10^{-19} \text{ C}$$

3. Calculate the charge that flows through a wire carrying 2 A for 3 minutes. **(P)**

Working and Answer:

$$Q = It = 2 \times (3 \times 60) = 360 \text{ C}$$

4. What is the direction of conventional current? **(P)**

Working and Answer:

Conventional current flows from the positive terminal to the negative terminal of a power supply.
Answer: From positive to negative.

5. Calculate the number of electrons that flow when 0.8 C of charge passes. **(P)**

Working and Answer:

$$n = \frac{Q}{e} = \frac{0.8}{1.6 \times 10^{-19}} = 5 \times 10^{18}$$

Answer: 5×10^{18} electrons

6. Define mean drift velocity and give the formula. **(PP)**

Working and Answer:

Mean drift velocity is the average velocity of charge carriers in a conductor.

$$I = nAve$$

where n is number density, A cross-sectional area, v drift velocity, e elementary charge.

7. A copper wire has cross-sectional area $1.5 \times 10^{-6}\,\text{m}^2$, carries 3 A. If number density is 8.5×10^{28} electrons/m^3, calculate mean drift velocity. **(PP)**

Working and Answer:

$$v = \frac{I}{nAe} = \frac{3}{8.5 \times 10^{28} \times 1.5 \times 10^{-6} \times 1.6 \times 10^{-19}} \approx 1.47 \times 10^{-4}\ \text{m/s}$$

8. State the condition required for a material to be a conductor. **(PP)**

Working and Answer:

It must have free or delocalised charge carriers (typically electrons) that can move under an electric field.
Answer: Presence of mobile charge carriers.

9. A 0.5 A current flows for 20 seconds. How many electrons have passed a point in the wire? **(PP)**

Working and Answer:

$$Q = It = 0.5 \times 20 = 10 \text{ C}$$

$$n = \frac{Q}{e} = \frac{10}{1.6 \times 10^{-19}} = 6.25 \times 10^{19} \text{ electrons}$$

10. What causes resistance in a metal conductor at the atomic level? **(PP)**

Working and Answer:

Collisions between free electrons and lattice ions, which scatter electrons and reduce their average drift speed.
Answer: Lattice scattering of charge carriers.

11. Copper has $n = 8.5 \times 10^{28}\,\mathrm{m}^{-3}$. A wire of diameter 0.8 mm carries 1.5 A. Find drift velocity. **(PPP)**

Working and Answer:

$$A = \pi r^2 = \pi(0.4 \times 10^{-3})^2 = 5.0265 \times 10^{-7}\ \mathrm{m}^2$$

$$v = \frac{I}{nAe} = \frac{1.5}{8.5 \times 10^{28} \times 5.03 \times 10^{-7} \times 1.6 \times 10^{-19}} \approx 2.2 \times 10^{-4}\ \mathrm{m/s}$$

12. Explain why the current in a metal wire is not due to the movement of positive charges. **(PPP)**

Working and Answer:

In metals, only electrons (negative charge carriers) are free to move. Positive ions are fixed in the lattice.
Answer: Current is due to negatively charged electrons.

13. A 5 m long wire carries 2 A with $n = 1 \times 10^{29}\,\mathrm{m}^{-3}$, area $1 \times 10^{-6}\ \mathrm{m}^2$. Find how long it takes an electron to travel the length. **(PPP)**

Working and Answer:

$$v = \frac{I}{nAe} = \frac{2}{1 \times 10^{29} \times 1 \times 10^{-6} \times 1.6 \times 10^{-19}} = 1.25 \times 10^{-4}\ \mathrm{m/s}$$

$$t = \frac{d}{v} = \frac{5}{1.25 \times 10^{-4}} = 40000\ \mathrm{s}$$

14. Describe how current varies with cross-sectional area of the wire, all else constant. **(PPP)**

Working and Answer:

From $I = nAve$, if n, v, e constant, then current is directly proportional to cross-sectional area.
Answer: Increasing area increases current.

15. A 3 mm^2 wire carries 4 A. If the number density is doubled, what happens to drift velocity? **(PPP)**

Working and Answer:

Since $v = \frac{I}{nAe}$, doubling n halves v.
Answer: Drift velocity is halved.

16. Derive the relationship between current and drift velocity using dimensional reasoning. **(PPPP)**

Working and Answer:

$$\text{Current } I = \text{charge per second} = nAve$$

n: carriers/m^3, A: m^2, v: m/s, e: C
Units: $(\text{m}^{-3}) \cdot \text{m}^2 \cdot \text{m/s} \cdot \text{C} = \text{C/s} = \text{A}$

17. A gold wire with area 0.5 mm^2, $n = 5.9 \times 10^{28}\,\text{m}^{-3}$, carries 0.3 A. Find drift velocity. **(PPPP)**

Working and Answer:

$$A = 0.5 \times 10^{-6}\ \text{m}^2$$

$$v = \frac{I}{nAe} = \frac{0.3}{5.9 \times 10^{28} \times 0.5 \times 10^{-6} \times 1.6 \times 10^{-19}} \approx 6.37 \times 10^{-5}\ \text{m/s}$$

18. A 0.75 mm diameter wire carries 2.5 A. If $v = 1.1 \times 10^{-4}\,\text{m/s}$, estimate number density n. **(PPPP)**

Working and Answer:

$$A = \pi(0.375 \times 10^{-3})^2 = 4.42 \times 10^{-7}\ \text{m}^2$$

$$n = \frac{I}{Ave} = \frac{2.5}{4.42 \times 10^{-7} \times 1.1 \times 10^{-4} \times 1.6 \times 10^{-19}} \approx 3.2 \times 10^{28}\,\text{m}^{-3}$$

19. A 1.2 mm^2 aluminium wire with $n = 6.0 \times 10^{28}$ carries 4.8 A. Calculate the time taken for an electron to move 1 cm. **(PPPPP)**

Working and Answer:

$$A = 1.2{\times}10^{-6}\ \text{m}^2, \quad v = \frac{4.8}{6.0 \times 10^{28} \times 1.2 \times 10^{-6} \times 1.6 \times 10^{-19}} = 4.17{\times}10^{-4}\ \text{m/s}$$

$$t = \frac{0.01}{4.17 \times 10^{-4}} \approx 24\ \text{s}$$

20. Copper and aluminium wires carry the same current. Copper has higher number density. Which has higher drift velocity? Justify. **(PPPPP)**

Working and Answer:

From $v = \frac{I}{nAe}$, for same I, A, and e, drift velocity v is inversely proportional to n.

Answer: Aluminium has higher drift velocity due to lower n.