DPP – 01

CLASS – 12th

TOPIC – Electric Current and Basic Quantities

Q.1 It is found that 10^{20} electrons, each having a charge of 1.6×10^{-19} C, pass from a point X towards another point Y in 0.1 s. What is the current and its direction?

Q.2 What is conventional current?

Q.3 Define the term drift velocity of charge carriers in conductor and write its relationship with the current flowing through it.

Q.4 How does the drift velocity of electrons in a metallic conductor vary with increase in temperature?

Q.5 The potential difference across a given copper wire is increased. What happens to the drift velocity of the charge carriers?

Q.6 How many electrons pass through a lamp in 2 minutes, if the current is 300 mA? Given, charge on electron = 1.6×10^{-19} C.

Q.7 Calculate the average drift velocity of conduction electrons in a copper wire of cross-section 10^{-7} m^2 carrying a current of 1 A. Assume that each copper atom contributes one conduction electron. Given that density of copper = 9×10^3 kg m^{-3} and its atomic mass = 63.5.

Q.8 The number density of electrons in copper is 8.5×10^{28} m^{-3}. Find the current flowing through a copper wire of length 0.2m, area of cross-section 1 mm^2, when connected to a bettery of 3 V. Given that electron mobility = 4.5×10^{-6} m^2 V^{-1} s^{-1} and charge on electron = 1.6×10^{-19} C.

Q.9 A current of 1.8 A flows through a wire of area of cross-section 0.5mm^2. Find the current density in the wire. If the number density of electrons in the wire is 8.8×10^{28} m^{-3}, find the drift velocity of electrons.

Q.10 When a potential difference of 1.5 V is applied across a wire of length 0.2 m and area of cross-section 0.3 mm^2, a current of 2.4 A flows through the wire. If the number density of free electrons in the wire is $8.4 \times 10^{28}\ m^{-3}$, calculate the average relaxation time. Given that mass of electron = 9.1×10^{-31} kg and charge on electron = 1.6×10^{-19} C.

SOLUTION

(PHYSICS) **Electric Current and Basic Quantities**

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Sol.1 Here q = n e = $10^{20} \times 1.6 \times 10^{-19} = 16$ C]

$t = 0.1$ s

$$\therefore \quad I = \frac{q}{t}$$

$$= \frac{16}{0.1} = 160A$$

The direction of conventional current is from the point Y to X.

Sol.2 The current that flows from positive pole to negative pole of a cell in the external circuit is called conventional current.

Sol.3 The drift velocity is defined as the average velocity with which free electrons in a conductor get drifted under the influence of an external electric field applied across the conductor.

Sol.4 The drift velocity of electrons in a metallic conductor decrease with increase in tempreture of the conductor.

For details, refer to note of section 1.11.

Sol.5 we know, $\upsilon_d = \frac{eE}{m}\tau$

If l is length of the copper wire and V, the potential difference across it, then

$$\upsilon_d = \frac{e}{m}\left(\frac{V}{l}\right)\tau$$

Thus, $\upsilon_d \propto V$ i.e. if potential difference is increased, drift velocity of the electrons will increase.

Sol.6 Here, I = 300 mA = 300 m A = 300×10^{-3} A; e = 1.6×10^{-19} C;

t = 2 minutes = 120s

The charge passing through lamp in 2 minutes,

$$q = I \times t = 300 \times 10^{-3} \times 120 \text{ C}$$

Suppose that n electrons pass through lamp in 2 minutes. If e is charge on an electron, then

$q = ne$

or $$n = \frac{q}{e} = \frac{300 \times 10^{-3} \times 120}{1.6 \times 10^{-19}} = 2.25 \times 10^{20}$$

Sol.7 Here $A = 10^{-7}\ m^2$; I = 1 A

Now, 63.5 g of copper contains atoms equal to Avogadro number i.e. 6.02×10^{23}

Therefore, the number of atoms in 1 kg of copper

$$= \frac{6.02 \times 10^{23} \times 1{,}000}{63.5} \times 9 \times 10^{3} = 8.53 \times 10^{28}$$

As one copper atom contributes one conduction electron, the number density of electron in copper is equal to number of atoms in 1 m^3 of copper i.e.

$n = 8.53 \times 10^{28}$

Hence, the drift velocity of electrons,

$$\upsilon_d = \frac{1}{neA}$$

$$= \frac{1}{8.53 \times 10^{28} \times 1.6 \times 10^{-19} \times 10^{-7}}$$

$= 7.33 \times 10^{-4}\ m\ s^{-1}$

Sol.8 Here, V = 3 volt; $l = 0.2$; $A = 1\ mm^2 = 10^{-6}\ m^2$;

$n = 8.5 \times 10^{28}\ m^{-3}$; $\mu = 4.5 \times 10^{-6}\ m^2\ V^{-1}\ s^{-1}$

and $e = 1.6 \times 10^{-19}$ C

The electric field set up across the conductor,

$$E = \frac{V}{l} = \frac{3}{0.2} = 15\,V\,m^{-1}$$

Now, the current through the wire,

$I = n\ A\ \mu\ E\ e$

$= 8.5 \times 10^{28} \times 10^{-6} \times 4.5 \times 10^{-6} \times 15\ 1.6 \times 10^{-19}$

$= 0.92A$

Sol.9 Here, I = 1.8 ; $A = 0.5\ mm^2 = 0.5 \times 10^{6}\ m^2$

And $n = 8.8 \times 10^{28}\ m^{-3}$

Now, the current density,

$$j = \frac{1}{A} = \frac{1.8}{0.5 \times 10^{-6}} = 3.6 \times 10^{6}\ A\,m^{-2}$$

Also, $j = n\,\upsilon\,d\,e$

Or $$\upsilon_d = \frac{1}{ne} = \frac{3.6 \times 10^{6}}{8.8 \times 10^{28} \times 1.6 \times 10^{-19}}$$

$$= 2.56 \times 10^{-4}\ m\,s^{-1}$$

Sol.10 Here, $V = 1.5\ V$; $n = 8.4 \times 10^{28}\ m^{-3}$; $l = 0.2\ m$;

$A = 0.3\ mm^2 = 0.3 \times 10^{-6}\ m^2$, $I = 2.4\ A$;

$m = 9.1 \times 10^{-31}\ kg$ and $e = 1.6 \times 10^{-19}\ C$

The electric field set up across the conductor,

$$E = \frac{V}{l} = \frac{1.5}{0.2} = 7.5\ V\,m^{-1}$$

The current density in the wire,

$$j = \frac{1}{A} = \frac{2.4}{0.3 \times 10^{-6}} = 8 \times 10^{6}\ A\ m^{-2}$$

Now, $j = \dfrac{ne^2\tau}{m}E$

Therefore, the average relaxation time,

$$\tau = \frac{mj}{ne^2E} = \frac{9.1 \times 10^{-31} \times 8 \times 10^{6}}{8.4 \times 10^{28} \times\ 1.6 \times 10^{-19}\ ^{2} \times 7.5}$$

$$= 4.51 \times 10^{-16}\ s$$