# Direct Current

1) What will be the conductivity of sodium metal having electron density $2.5 \times 10^{28}\ m^{-3}$ & relaxation time $3 \times 10^{-19}$ sec?

=> Sol^n,

$n = 2.5 \times 10^{28}\ m^{-3}$

$\tau = 3 \times 10^{-14}$ sec

$\sigma = ?$

we know,

$$\rho = \frac{m_e}{ne^2\tau}$$

$$\frac{1}{\sigma} = \frac{m_e}{ne^2\tau}$$

$$\sigma = \frac{ne^2\tau}{m_e}$$

$$\sigma = \frac{2.5 \times 10^{28} \times (1.6 \times 10^{-19})^2 \times 3 \times 10^{-14}}{9.1 \times 10^{-31}}$$

$\therefore \sigma = 2.1 \times 10^{7}$ mho/m.

2) The current density in a cylindrical wire of radius R = 2mm & uniform CSA is given by $J = 2 \times 10^5\ Am^2$. What is the current through the outer portion of the wire between radial distance R/2 & R?

=> Sol^n

$R = 2mm = 2 \times 10^{-3} m$

$J = 2 \times 10^5\ Am^2$

$r = \frac{R}{2} = 10^{-3} m$

We know,

$$J = \frac{I}{A}$$

$$I = J \cdot A$$

$$I = 2\times10^5 \times \pi (R^2 - r^2)$$

$$I = 2\times10^5 \times \pi \times \left( (2\times10^{-3})^2 - (10^{-3})^2 \right)$$

$$I = 1.884\,A$$

3) Calculate the (a) mean free time and (b) mean free path betn collision for the conduction electron in copper having electron density $8.4\times10^{22}$ $cm^{-3}$ & resistivity $1.7\times10^{-8}\ \Omega m$. [change of $e^-$ is $1.6\times10^{-19}$ C, mass of electron is $9.1\times10^{-31}$ kg, ~~1.6×10^-19 C, mass~~ of electron is $1.6\times10^6$ m/s] effective speed of

⇒ soln,

$$n = 8.4\times10^{22}/cm^2 = 8.4\times10^{28}/m^3$$

$$\rho = 1.7\times10^{-8}\ \Omega m.$$

(a) mean free time

$$\tau = \frac{m_e}{ne^2\rho}$$

$$= \frac{9.1\times10^{-31}}{8.4\times10^{28}\times(1.6\times10^{-19})^2\times1.7\times10^{-8}}$$

$$= 2.48\times10^{-14}\ sec$$

(b) mean free path

$$\lambda = \tau \times \text{effective speed of } e^-$$

$$= 2.48\times10^{-14}\times1.6\times10^6$$

$$= 3.98\times10^{-8}\ m$$

Q) A copper wire of CSA $3 \times 10^{-6} m^2$ carries a steady current of 60 A, assumming one $e^-$ per atom. Calculate (i) free $e^-$ identity & (ii) average drift velocity.

density of Cu = $8.9 \times 10^3$ kg/m3
mass of Cu = 64
Avagadro's no. : $6.02 \times 10^{23}$ /mole

=> Soln,

$A = 3 \times 10^{-6} m^2$
$I = 60 A$
$d = 8.9 \times 10^3$ kg/m3
$M = 64$ gm $= 64 \times 10^{-3}$ kg
$N_A = 6.02 \times 10^{23}$ /mole.
$n = ?$
$v_d = ?$

we know

$$n = \frac{N_A d}{m}$$

$$= \frac{6.02 \times 10^{23} \times 8.9 \times 10^3}{64 \times 10^{-3}}$$

$$= 8.37 \times 10^{28} /m^3.$$

&

$$I = v_d e n A$$

$$v_d = I/enA$$

$$v_d = \frac{60}{1.6 \times 10^{-19} \times 8.37 \times 10^{28} \times 3 \times 10^{-6}}$$

$$v_d = 1.49 \times 10^{-3} m/s.$$

5. Two conductors are made of the same material & have the same length. conductor A is a solid wire of diameter 1mm & B is a hollow tude of outer diameter 2mm & inner diameter 1mm. What is the resistance ratio $R_A/R_B$ measured betn their ends?

⇒ Soln,

For conductor A;

$$\text{Area } (A_A) = \frac{\pi d^2}{4} = \frac{\pi (1)^2}{4} = 0.785 \text{ mm}^2$$

For conductor B;

$$\text{Area } (A_B) = \pi\left(\frac{d_o^2}{4} - \frac{d_i^2}{4}\right) = \pi\left(\frac{2^2}{4} - \frac{1^2}{4}\right)$$

$$= 2.356 \text{ mm}^2$$

we know,

$$\text{Resistance } (R) = \frac{\rho l}{A}$$

Since the two conductor are made of same material & have the same length; $R \propto 1/A$

ie,

$R_A \propto 1/0.785$ — (i) & $R_B \propto 1/2.356$ — (ii)

Dividing (i) by (ii)

$$\frac{R_A}{R_B} = \frac{1}{0.785} \times \frac{2.356}{1}$$

$$\therefore \frac{R_A}{R_B} = \frac{3.001}{1} \approx 3:1$$ Ans

6) What is the average time betn collision of free electrons in a copper wire?

At. wt = 63 g/mol.
density = 9 gm/cc
$\rho$ = $1.7 \times 10^{-4}$ Ωm
$N_A$ = $6.02 \times 10^{23}$ $mol^{-1}$

=> Soln,

At wt. (m) = 63 g/mol = $63 \times 10^{-3}$ kg/mol
density (d) = 9 gm/cc = $9 \times 10^{3}$ kg/m³
$\rho$ = $1.7 \times 10^{-4}$ Ωm
$N_A$ = $6.02 \times 10^{23}$ $mol^{-1}$
$\tau$ = ?

We have,

$$\rho = \frac{m_e}{ne^2\tau}$$

$$\tau = \frac{m}{ne^2\rho}$$

now,

$$n = \frac{d \cdot N_A}{m}$$

$$= \frac{9\times10^{3} \times 6.02 \times 10^{23}}{63 \times 10^{-3}}$$

$$= 8.6 \times 10^{23} / m^2$$

Then,

$$\tau = \frac{9.1 \times 10^{-31}}{8.6 \times 10^{28} \times (1.6 \times 10^{-19})^2 \times 1.7 \times 10^{-4}}$$

$$= 2.43 \times 10^{-8} \text{ sec.}$$ #

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Q.7) A current of $1.2 \times 10^{-10}$ A exist in a copper wire (At. wt = 63 g/mol., density = 9 gm/cc) where diameter is 2.5 mm & resistivity is $1.7 \times 10^{-8}$ Ωm. Assuming current to be uniform, calculate

(a) Current density (J)

(b) Electrical conductivity (σ)

(c) mobility of election.

→ Soln,

Current (I) = $1.2 \times 10^{-10}$ A

At. wt = 63 g/mol

density (d) = 9 gm/cc

radius (r) = $\frac{d}{2} = \frac{2.5}{2} = 1.25 \times 10^{-3}$ m.

$\rho = 1.7 \times 10^{-3}$ Ωm

we know,

$$n = \frac{N_A}{m/d}$$

$$= \frac{d N_A}{m}$$

$$= \frac{9 \times 6.023 \times 10^{23}}{63}$$

$$= 8.60 \times 10^{22} /cc$$

$$= 8.6 \times 10^{28} /m^3$$

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Now,

(A) $J = \frac{I}{A} = \frac{1.2\times10^{-10}}{\pi\times r^2} = \frac{1.2\times10^{-10}}{\pi\times(1.25\times10^{-3})^2}$

$J = 2.44\times10^{-5}\ A/m^2$

(b) Electrical conductivity $(\sigma) = \frac{1}{\rho}$

$= \frac{1}{1.7\times10^{-8}\ \Omega m}$

$= 5.8\times10^{7}/\Omega m$

(c) mobility of electron $(\mu) = \frac{\sigma}{ne}$

$= \frac{5.8\times10^{7}}{8.6\times10^{28}\times1.6\times10^{-19}}$

$= 4.27\times10^{-3}\ m^2V^{-1}s^{-1}$ //