ELECTRIC CURRENT

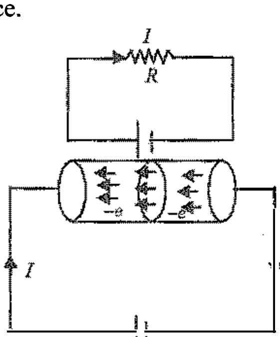
- Rate of flow of electric charge through a conductor is called electric current. It is measured as the amount of electric charge passing through any cross-section of conductor in unit time.
  (i) If an electric current flowing through a conductor is steady, then it is measured as

  $$I=\frac{q}{t}=\frac{Ne}{t}$$

  where q is the electric charge and N is the number of free electrons passing through a cross-section of a conductor in time t.
  (ii) If an electric current flowing through a conductor is not steady, then it is measured as

  $$I=\frac{dq}{dt}$$

- Electric current through a conductor always flow from the region of higher potential to the region of lower potential or from positive to negative terminal of a source.



- SI unit of electric current is 'Ampere' denoted by 'A', where
  $1A = 1\ C\ s^{-1}$
- Thus electric current through a conductor is said to be one ampere, if one coulomb of charge flows through its at any cross-section in one second.

Movement of Free Electrons in a Conductor

- At any temperature, electrons in a metal move randomly in all directions like ideal gas particles. When an electric field is applied, each electron experiences an acceleration of (eE/m) opposite to field direction. But the acceleration is momentary, because electrons loose the gained velocity due to collisions with vibrating atoms or ions or other free electrons. The average velocity of the electrons gained against electric field is then called drift velocity.

DRIFT VELOCITY

- It is defined as the average velocity with which free electrons get drifted towards the positive end of the conductor under the influence of an external electric field.
- Drift velocity of electrons is given by

  $$\vec{v}_d=-\frac{e\vec{E}}{m}\tau$$

  where e is the charge on electron, m is the mass, $\vec{E}$ is the electric field applied and τ is the time of relaxation. –ve sign shows that drift velocity of electrons is in a direction opposite to the direction of external electric field.
- Drift velocity depends on electric field as $v_d \propto E$. So greater the electric field, larger will be the drift velocity.

Relationship between Electric Current and Drift Velocity

$$I = nAev_d$$

where n is the number density of electrons or number of electrons per unit volume of the conductor and A is the area of cross-section of the conductor.

Relationship between Current Density and Drift Velocity

$$J = nev_d$$

where symbols have their usual meaning.

Illustration 1

The number density of conduction electrons in a copper conductor estimated is $8.5 \times 10^{28}\ m^{-3}$. How long does an electron take to drift from one end of a wire 3.0 m long to its other end? The area of cross-section of the wire is $2.0 \times 10^{-6} m^2$ and it is carrying a current of 3.0 A.

Soln.: We can first calculate drift velocity of the electrons from the given data

$I = Anev_d$

$3 = 2 \times 10^{-6} \times 8.5 \times 10^{28} \times 1.6 \times 10^{-19}\ v_d$

$v_d = 0.11 \times 10^{-3}\ m\ s^{-1}$

now time taken by an electron to drift a length of 3 m with drift speed

$$t=\frac{l}{v_d}=\frac{3}{0.11\times10^{-3}}=27.27\times10^{3}\ \text{sec}.$$