CHAPTER

3

Electricity

Electricity is an important source of energy in the modern times. Electricity is used in our homes, in industry and in transport. For example, electricity is used in our homes for lighting, operating fans, coolers, computers and heating purposes. In industry, electricity is used to run various types of machines and in transport sector electricity is being used to run electric trains.

3.1 ELECTRIC CURRENT

When two charged bodies at different electric potentials are connected by a metal wire, an electric current will flow from the body at higher potential to the one at lower potential, till they both acquire the same potential.

A metal (or conductor) contains larger number of free electrons. The free electrons in the conductor are responsible for electric conduction. When electric field is applied across the conductor these free electrons aligned and drifted towards the field direction. The electron or charge flow in unit time is called current. In the simple words the electric current is defined as the rate of charge flow per unit time.

It is noticeable that conventionally the direction of current is taken to the direction of opposite to electron† flow

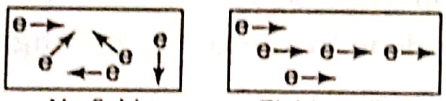

Fig. 3.1

$$\text{Current } i = \frac{\text{charge } q}{\text{time } t}$$

The CGS unit of current is statampere.

$$1 \text{ statampere} = \frac{1 \text{ state coulomb}}{1 \text{ second}}$$

The SI unit of electric current is ampere

$$1 \text{ ampere} = 3 \times 10^9 \text{ statampere.}$$

If $q = 1$ coulomb, $t = 1$ sec,

then 1 ampere = 1 coulomb/sec.

We know that 1 electron carries 1.6×10^{-19} C of charge.

† Only electron is responsible for electricity because electron is very light compared to proton. Protons are tightly bound to nucleus while electron can be easily escape from its orbit. The conventional direction of electric current is from positive terminal of a cell (or battery) to the negative terminal, through the outer circuit.

$$= \frac{1}{1.6 \times 10^{-19}} \text{ electron should flow.}$$

$$1\text{ C} = 6.25 \times 10^{18} \text{ electrons.}$$

$$1 \text{ ampere} = 6.25 \times 10^{18} \text{ electrons per second}$$

Electric current is a scalar quantity. However we represent current in a wire by an arrow but it does not mean that current is a vector quantity.

Example. 1. In a metallic wire, 10^{19} electrons drift across a cross section per second. What is the resulting current flow?

Solution. Charge on one electron = 1.6×10^{-19} C

Total charge move across per second

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

$$\text{Current. } i = \frac{q}{t}$$

$$= 1.6 \text{ A}$$

3.2 E.M.F OF A CELL

In order to maintain the continuous flow of charge (electric current) in an electric circuit, work has to be done. This work is done by a cell.

A cell is a device that is able to store electrical energy in the form of chemical energy and convert that energy into electricity.

The energy given by the cell in the flow of unit charge in the whole circuit is called the electromotive force (e.m.f) of the cell. The e.m.f. is a characteristic of a cell which depends upon the nature of the plates and the electrolyte used in the cell.

If the energy given the work done by the cell in flowing a charge of q coulomb is W joule, then e.m.f. E of the cell is

$$E = \frac{W}{q} \text{ J/C}$$

This unit is also called volt.

The direction of the current inside the cell is from the negative (lower potential) to positive (higher potential) electrodes. In the outer circuit the direction of current (positive charge) is from the positive electrode to the negative electrode

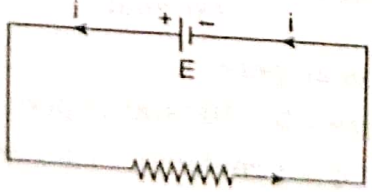

Fig. 3.2

3.3 OHM'S LAW

It is a relation given by Ohm in 1826 to correlate the potential difference applied at the both ends of the metallic conductor (Fig. 3.3a) to the current flowing in that conductor. The law says: the ratio of the potential difference at the ends of the conductor and the current flowing across it remains constant, if its physical state doesn't change (as temperature, pressure etc.)

Now according to Ohm's law,

$$\text{Voltage} \propto \text{current}$$

$$V \propto i$$

$$V = Ri$$

Then
$$R = \frac{V}{i} \quad ...(3.1)$$

R is the proportionality constant and called electric resistance of the conductor medium†. Electric resistance or simply called resistance is the opposition produced in the way of current in any conductor.

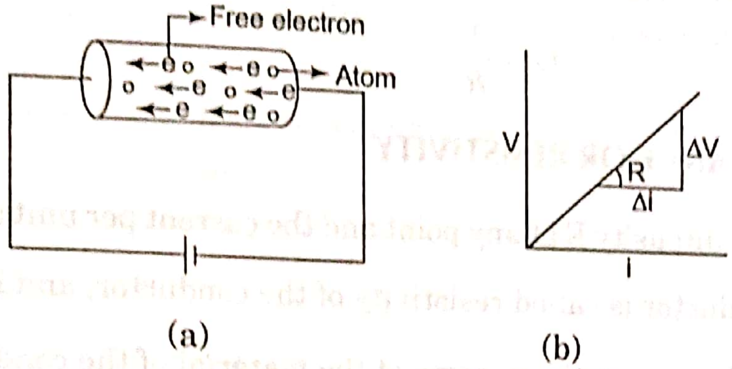

Fig. 3.3

The graph (Fig 3. 3b) between i and V comes out to be a straight line. It's slope gives the resistance R of the metallic conductor.

3.4 RESISTANCE (*Resist the flow of free electrons*)

We know that electric current is a flow of electrons through a conductor. When the electrons move from one part of the conductor to the other part, they collide with other atoms and ions present in the body of the conductor. Due to these collisions, there is some obstruction or opposition to the flow of electron current through the conductor (Fig. 3.3a). The property of a conductor due to which it opposes the current flow through it is called resistance.

If the potential difference between the ends of a conductors is V. and the current in the conductor is l, then the electric resistance of the conductor is

$$R = \frac{V}{i}$$

The unit of resistance (S.I.) is ohm (Ω)

$$1 \text{ ohm} = \frac{1V}{1A}$$

or
$$1 = 1V/A = 1\ VA^{-1}$$

On increasing the temperature of a metal (conductor) the velocity of molecules increases. It increases the collisions between the free electrons and atoms. Hence opposition is increased in the current flow. Thus on increasing the temperature the resistance of a conductor increases. In other words, with rise in temperature the electric conductance of a conductor decreases.

† **The medium through which moving charge is called conductor. This may be metal, liquid (electrolyte) or a gas.**

If the resistance of a conductor at 0° C is R_0 at t° C it is R_t then the value of R_t is given by.

$$R_t = R_0(1 + \alpha t)$$

where α is a constant and called the temperature coefficient of resistence of the conductor.

For most of the cases the value of α is nearly $\frac{1}{237}$ per° C, hence the equation will be

$$R_t = R_0\left(1 + \frac{t}{237}\right) = R_0\left(\frac{273 + t}{273}\right)$$

Conductance : The reciprocal of the resistance is called electric conductance, simply called conductance and its unit is mho or ohm^{-1} (Ω^{-1}) or siemen (s). It is denoted by G.

$$G = \frac{1}{R}$$

3.5 SPECIFIC RESISTANCE OR RESISTIVITY

The ratio of electric field intensity E at any point and the current per unit area j (current density) at that point in the conductor is called resistivity of the conductor, and is given by, $\rho = \frac{E}{d}$

Resistivity† is the characteristic property of the material of the conductor.

Suppose the length of the conductor is l, its area is A. The voltage across the conductor is V. The electric field at any point in the wire is given by

$$E = \frac{V}{l}$$

and
$$j = \frac{i}{A}$$

∴
$$\text{Resistivity } \rho = \frac{V/l}{i/A}$$

or
$$\rho = \frac{VA}{il}$$

∴
$$\rho = R\frac{A}{l} \qquad ...(3.2) \left[\because \frac{V}{i} = R\right]$$

The unit of resistivity is ohm-metre.

If l = 1m, A = 1m^2, then

$$\rho = R \times \frac{1}{1} = R \text{ ohm-metre}$$

Conductivity : Conductivity of material is its ability to conduct electric current. It is the reciprocal of resistivity. It is denoted by σ,

where,
$$\sigma = \frac{1}{\rho}$$

† **Resistivity does not depends upon the shape, size of conductor. It remains same for a conductor (at a constant temperature), while resistance depends upon the shape, size of the conductor.**