Physics

Chapter 3-Current Electricity

1. The directed rate of flow of electric charge through any cross-section of a conductor is known as **electric current.**
If ΔQ charge flows in time Δt, then current at any time t is

$$I = \lim_{\Delta t \to 0} \frac{\Delta Q}{\Delta t} = \frac{dQ}{dt}$$

Also, $$I = \frac{q}{t} = \frac{ne}{t} \qquad [\because\ q = ne]$$

where, n = number of charged particles constitute the current

NOTE: Current is a scalar quantity.
I is in the direction of flow of positive charge and opposite to the direction of flow of negative charge.
SI unit of current is ampere and is represented by A.

$$1\text{ A} = \frac{1\text{ coulomb (C)}}{1\text{ second (s)}} = 1\text{C / s}$$

2. The current density at a point in a conductor is the ratio of the current at that point in the conductor to the area of cross-section of the conductor at that point provided the area is held normal to the direction of flow of current.

Current density, $j = \dfrac{\Delta I}{\Delta A}$ or $dI = \hat{\mathbf{j}} \cdot d\mathbf{A}$ or $I = \int \hat{\mathbf{j}} \cdot d\mathbf{A} = \int jdA \cos\theta$

NOTE: Current density is a vector quantity.
3. Flow of Electric Charge in Metallic Conductors Among the solids, all metals are good conductors of electricity. The cause of conductance is free electrons.
In Case of a Solid Conductor (i.e. Cu, Fe, Ag, etc) atoms are tightly bound to each other. There are large number of free electrons in them.
In Case of a Liquid Conductor Like electrolytic solution, there are positive and negative charged ions which can move on applying electric field.
4. Drift Velocity It is defined as the average velocity with which the free electrons move towards the positive end of a conductor under the influence of an external electric field applied.

$$\Rightarrow \qquad \mathbf{v}_d = \frac{e\mathbf{E}}{m}\tau$$

where, τ = relaxation time, $\mathbf{E}$ = electric field, m = mass, e = electron

NOTE The drift velocity of electron is of the order of 10^{-4}ms^{-1}.

5. Electric current in terms of drift velocity

$$I = nea\,v_d$$

where, n = number density of free electrons, e = electronic charge
a = cross-sectional area and v_d = drift velocity of an electron

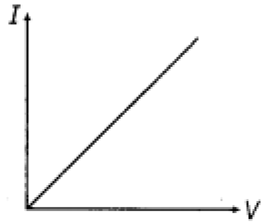
6. Current density at any point of conductor,
$j = nev_d$
where, j is a vector quantity.
7. Mobility The ratio of drift velocity of electrons and the applied electric field is known as mobility.

$$\Rightarrow \qquad \mu = \frac{v_d}{E} = \frac{q\tau}{m}$$

SI unit is $[m^2 s^{-1} V^{-1}]$.

8. Ohm's Law At constant temperature, the potential difference V across the ends of a given metallic wire (conductor) in an circuit (electric) is directly proportional to the current flowing through it.

$V \propto I$



The variation of current w.r.t. applied potential difference is shown with the help of following graph.

V = IR

where, R = resistance of conductor

No effect of V and I on R because as V increase, I increase but R remains the same.

9. Resistance of a Conductor Mathematically, it is the ratio of potential difference applied across the ends of conductor to the current flowing through it.

=> R = V/I

SI unit is ohm (Ω).

Resistance can also be written as,

R =ρ L/A

where, L = length of the conductor, A = area of cross-section and ρ = constant, known as resistivity of the material. It depends upon nature of the material.

10. Relationship between resistivity and relaxation time

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

where, τ = relaxation time

Specific resistance or resistivity (ρ) depends on the material of conductor, not on the length and cross-sectional area (A) i.e. geometry of conductor.

11. $\because \qquad R = \rho \frac{l}{A}$

For a given conductor, ρ = constant and stretching/compression of conductor is done, then

$$\frac{\Delta R}{R} \times 100 = \frac{\Delta l}{l} \times 100 - \frac{\Delta A}{A} \times 100$$

At constant volume of conductor, if length increases, area decreases and *vice-versa*.

Here, $\frac{\Delta R}{R} \times 100$ = percentage change in resistance.

12. Temperature Coefficient of resistance is given by

$$\alpha = \frac{R_2 - R_1}{R_1 (t_2 - t_1)}$$

13. Conductivity It is defined as the reciprocal of resistivity of a conductor.

It is expressed as, σ = 1/ρ

SI unit is mho per metre (Ω-1/ m).

14. Superconductivity The resistivity of certain metal or alloy drops to zero when they are cooled below a certain temperature is called superconductivity. It was observed by Prof. Kamerlingh in 1911.

15. Relationship between current density (j), electric field (E)and conductivity (σ) is
$j = \sigma E$

16. Some Important Units

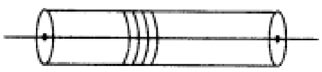
(*i*) Resistance	Ohm (Ω)
(*ii*) Resistivity	Ohm-metre (Ω-m)
(*iii*) Conductance $\left(\frac{1}{R}\right)$	Mho or Ω^{-1} or Siemen (S)
(*iv*) Current density	A/m^2

17. If a conductor is stretched or compresses to n times of original length, then
$l' = nl \Rightarrow R' = n^2R$
where, R' = new resistance and R = original resistance.

18. Colour Code of Resistance The colour code on carbon resistor remains in the form of coaxial rings.

The first band represents the first significant figure, second band represents second significant figure and third band represents multiplier (i.e. power of ten). The fourth band represents tolerance.

Black	Brown	Red	Orange	Yellow		Green	Blue		Violet	Grey	White
B	B	R	O	Y	of	Great	Britain	had	Very	Good	Wife
0	1	2	3	4		5	6		7	8	9



Carbon resistor

Tolerance Unit

Gold	5%
Silver	10%
No colour	20%

19. Combinations of Resistance There are two types of resistance combinations.

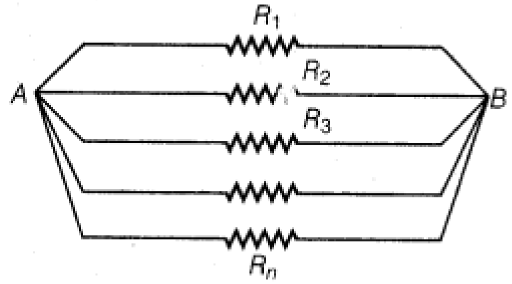
(i) Series Combination In this combination, different resistances are connected end to end. Equivalent resistance can be obtained as the formula,

$$R_{eq} = R_1 + R_2 + \ldots + R_n$$

NOTE: The total resistance in the series combination is more than the greatest resistance in the circuit.

(ii) Parallel Combination In this combination, first end of all the resistances are connected to one point and last end of all the resistances are connected to other point. Equivalent resistance can be obtained by the formula

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots \frac{1}{R_n}$$



NOTE: The total resistance in parallel combination is less than the least resistance of the circuit.

20. If n identical resistors each of resistance r are connected in

(i) series combination, $R_{eq} = nr$

(ii) parallel combination, $R_{eq} = r/n$