11. Current Electricity

Electric Current (I)

It is the rate of flow of electric charge flowing though any section of wire.

Ohm's Law

Electric current flowing through a conductor is directly proportional to the potential difference across the two ends of the conductor; physical quantities such as temperature, mechanical strain, etc. remaining constant.

$V = RI$

Where, R is a constant for a given conductor

Electrical resistance:

R=ρlA

Where, *r* is the specific resistance or electrical resistivity of the material

Conductance and Electrical conductivity:

Conductance G=Aρl

Electrical conductivity (*s*) is defined as the reciprocal of resistivity.

σ=1ρ

The other form of Ohm's law is

J= σE

J = current density

E = electric field applied

Motion of electrons due to thermal energy

Free electrons are in continuous random motion. They undergo change in direction at each collision and the thermal velocities are randomly distributed in all directions.

Average thermal velocity,u=u1+u2+u3+........+unn is zero … (1)

Drift velocity

- vd→ is defined as the velocity with which the free electrons get drifted towards the positive terminal under the effect of the applied electric field.
- J = IA=qAt=neAt

we know that I=neAvd or IA=nevd

Therefore, J=nevd

Limitations of Ohm's Law

The Ohm's law ceases to be valid in following cases:

V ceases to be proportional to *I*.
Sign of V affects the relation between *V* and *I*.
There is more than one value of *V* for the same current.

Factors that affect resistance

I. Length of the conductor

Resistance is directly proportional to the length of the conductor i.e.

$R \propto l$ Where, $l \rightarrow$ length of the conductor

II. Cross-section of the conductor

Resistance is inversely proportional to the area of cross-section of the conductor i.e.

$$R \propto 1A$$

$A \rightarrow$ area of cross-section

So, $R \propto lA$

Or,

$$R = \rho lA$$

Where, ρ is the proportionality constant, called the **electrical resistivity** of the material of the conductor. It is also known as specific resistance.

- The SI unit of resistivity is Ω m (Ohm-meter).
- Resistivity is the characteristic property of a material. It only depends on the nature of the material and not its dimensions. This is one of the major differences between resistance and resistivity. But like resistance, resistivity also varies with temperature.
- Metals have low resistivities. It is in the range of 10^{-8} Ω m to 10^{-6} Ω m. Insulators have resistivities 10^{18} times greater than metals. Semi-conductors lie in between them. The following table shows the resistivity of some materials at 20 °C.

Conductivity
The reciprocal of resistivity is known as conductivity. Its SI unit is ohm-1metre-1 or Ω-1m-1 or siemen metre-1.
$\sigma = 1\rho = lRa$

Finding resistance of the carbon resistor

TABLE 3.2 RESISTOR COLOUR CODES			
Colour	**Number**	**Multiplier**	**Tolerance (%)**

Black	0	1	
Brown	1	10^1	
Red	2	10^2	
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	
Blue	6	10^6	
Violet	7	10^7	
Gray	8	10^8	
White	9	10^9	
Gold		10^{-1}	5
Silver		10^{-2}	10
No colour			20

The resistance of the carbon resistor is found by using the table

Here, first two bands from one end indicate the first two significant figures of resistance in ohms.
Third band indicates the decimal multiplier.
The last band stands for tolerance. Its absence indicates a tolerance of 20%.

Temperature Dependence of Resistivity

- On increasing temperature, the number of collisions of electrons and ions in conductors increases; this, in turn, increases their resistivity.
- Relation between resistivity and temperature:

  ρ = ρ0 (1 + alphat)
  Here, alpha is the temperature coefficient of resistance of the material of a conductor

- The resistivity of a metallic conductor increases with increase in temperature.
- The resistivity of an alloy has a weak temperature dependence.
- The resistivity of a semiconductor decreases rapidly with increasing temperature.

Alloys are used for preparing standard resistance coils because of their high resistance and low temperature coefficient of resistance.

Superconductivity

- Superconductivity is the phenomenon in which a material loses its resistivity completely.
- Superconducting cables can be used for power distribution without loss.
- Speed of a computer can be increased by superconducting wires.
- Superconductivity can help produce a very strong magnetic field without power loss.
- Superconductivity exists at subzero temperature, which hinders its use at normal temperature.

Thermistor

- Thermistor is a heat-sensitive semiconductor device whose resistance changes very rapidly with change in temperature.
- It is used for remote sensing, voltage stabilisation, temperature control, etc.

Electric Energy

It is the work done by the source of *emf* in maintaining the electric current in the circuit for a given time.

$W = VIt$

Electric Power

It is the rate at which work is done by the source of *emf* in maintaining the electric current in a circuit.

P=V2R=I2R

Electric Cell

- Primary Cell − In a primary cell, chemical energy is directly converted to electrical energy. They cannot be reused once completely discharged.

For example, simple voltaic cell, Leclanche cell

- Secondary Cell− In a secondary cell also, chemical energy is directly converted to electrical energy. But the basic difference between primary and secondary cells is that secondary cells are reusable as they can be charged using external sources. Thus, when secondary cells are charged, electric energy gets converted into chemical energy.

Examples of secondary cells: lead acid cell, Ni−Cd cell

Emf

Potential difference between the two poles of the cell in an open circuit is called *emf* of the cell.

Internal resistance (*r*) of cell

Resistance offered by the electrolyte of the cell when the electric current flows through it is,
r=EV-1R
where,

E − *emf* of cell

r − Internal resistance of the cell

R − External resistance

K − Key

V − Voltmeter

Combination of cells

Series combination of the cells

The equivalent emf of a series combination of n cells (E_{eq})

$E_{eq} = E_1 + E_2 + ... + E_n$

The equivalent internal resistance of a series combination of n cells (r_{eq})

$r_{eq} = r_1 + r_2 + ... + r_n$

Parallel combination of the cells

For a parallel combination of n cells with emfs E_1 , E_2........ and E_n and internal resistances r_1, r_2............. and r_n

Equivalent emf:

E_{eq} = E1r1+E2r2+..............Enrn

Equivalent internal resistance(r_{eq}) :

1req=1r1+1r1...........+1rn