# CHAPTER-13
# CURRENT ELECTRICITY



**ELECTRODYNAMICS:**
The study of the properties and effect of electric charges when they are in motion is known as "electrodynamics"

**ELECTRICCURRENT:**
The rate of flow or motion of charges in a conductor is called electric current. If a charge of "q" coulomb flows through the section of wire in "t" seconds the current "I" through it is given by

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

The unit of current is "Ampere" its submultiples are milliampere and microampere
1 milliampere (1 mA) = $10^{-3}$ ampere
1 microampere (1μA) = $10^{-6}$ ampere

Electric current may be due to flow of negative charges it may be due to the flow positive charges or it may be due to the flow of both types of charges

**OHM'S LAW:**
This law states that "the current through a conductor is directly proportional to the potential difference between the ends of the conductor provided that the physical conditions of the conductor remain same"

If "I" be the current passing through a conductor and "V" be the potential difference between its ends then by ohm law

$$I \propto V$$
$$I = KV$$

Where "K" is a constant and is called "conductance" its value depends upon the nature of material of the conductor the reciprocal of "conductance" is

**Resistance:**
The opposition produced by a conductor in the flow of current is called "electric resistance" it is the reciprocal of conductance its value depends upon many factors and its unit is "ohm"

**Called "ELECTRIC RESISTANCE" "R"**

i.e. $K = \frac{1}{R}$

Thus equation 1 become

$$I = \frac{1}{R}V$$

$$V = IR$$

The unit of resistance is "OHM" and denoted by Ω.
If a graph is plotted between voltage "V" and current "I" will be a straight line.

**OHM:**
One ohm is the resistance of conductor through which a current of 1 ampere passes when a potential difference of 1 volt is maintained across the ends of the conductor.

**RESISTIVITY: (FACTORS ON WHICH RESISTANCE DEPENDS)**
The resistance of a conductor depends upon the following factors
1- Nature of material of the conductor

2- length of the conductor the longer the length "L" of the conductor the greater will be its resistance "R" i.e.

$$R \propto L$$

3- The area of cross section of the conductor the greater the cross sectional area "A" of the conductor the lesser will be its resistance i.e.

$$R \propto \frac{1}{A}$$



By combining the above two factors we get

$$R \propto \frac{L}{A}$$

$$R = \rho\frac{L}{A}$$

Where "$\rho$" is a constant of proportionally and is known as "resistivity" or "specific resistance"

**RESISTIVITY:**

Resistivity of a material is the resistance of a wire of the material per unit of its length and per unit of its area of cross section resistivity can also be defined as the resistance offered by a metre cube its S.I. unit is ohm x metre (Ω.m)

**DEPENDENCE OF RESISTANCE UPON TEMPERATURE:**

The electrical resistance of most material increases with the increase of temperature because atoms sitting on their sites start vibrating more increase in temperature this increase the probability of collusion of free electrons with the atoms decreases the drift velocity of electrons and increases the resistance

Experimentally it has been observed that the change in resistance of a metallic conductor with the change in the temperature of the conductor is nearly linear over a wide range of temperature above and below 0 °C .

If "$R_0$" be the resistance of wire at 0 °C and "$R_T$" be its resistance at T°C then,

Change in resistance = $R_T - R_o = \Delta R$

Change in temperature = $\Delta T = T - 0 = T\ C^o = T\ K$

It is found experimentally that the change in resistance ΔR directly depend upon original resistance $R_o$ and change in temperature $\Delta T$ i.e.

$$\Delta R \propto R_o\, \Delta T$$

$$\Delta R = \alpha\, R_o\, \Delta T$$

Where "α" is the constant of proportionality and is called "temperature coefficient". Its value depends on nature of material of substance.

**Temperature coefficient:**

It is defined as "the change in resistance per unit original resistance per unit change in temperature" its value depends upon nature of material of the wire its S.I unit is per Kelvin

$$\alpha = \frac{\frac{\Delta R}{R_O}}{\Delta T} = \frac{Fractional\ change\ in\ resistance}{Change\ in\ temperature}$$

**It is also define as "the fractional change in resistance of a substance per unit change in temperature is called TEMPERATURE COEFFICIENT of the substance".**

**EXPRESSION FOR RESISTANCE AT T°C WITH RESPECT TO THE TEMPERATURE FROM 0°C:**

As, $$\Delta R = \alpha\, R_o\, \Delta T$$

$$R_T - R_o = \alpha\, R_o\, \Delta T$$

$$R_T = R_o + \alpha\, R_o\, \Delta T$$

$$R_T = R_o(1 + \alpha\,\Delta T)$$

This expression is called expression for resistance of a substance at T°C.

**Resistivity and temperature:**

Sine Resistivity is directly proportional to the resistance of the wire (substance) therefore,

$$\rho_T = \rho_o(1 + \alpha\,\Delta T)$$

Where $\rho_o$ = resistivity at 0 °C

$\rho_T$ = resistivity at T°C



**RESISTORS IN SERIES:**

Resistors are said to be in series if there is one conducting path for the current. Series network is also known as voltage divider network or end to end connection network of resistors.

**Derivation:**

Consider three resistors of resistances $R_1$, $R_2$ & $R_3$ are connected in series with a battery of voltage "$V_{ad}$" if "I" be the current which is flowing through the battery therefore this current will also flow from each of the three resistors.

Thus,

p. d across $R_1 = V_{ab} = IR_1$

p. d across $R_2 = V_{bc} = IR_2$

p. d across $R_3 = V_{cd} = IR_3$

The total potential drop "$V_{ad}$" is given by

$V_{ad} = V_{ab} + V_{bc} + V_{cd}$ ----------------(i)

If "$R_e$" be the equivalent resistance which is connected to the same battery then same current "I" will pass through it

p .d across $R_e = V_{ad} = IR_e$

By putting the values of $V_{ab}$ ,$V_{bc}$ ,$V_{cd}$ and $V_{ad}$ in eq$^n$ (i), we get

$IR_e = IR_1 + IR_2 + IR_3$

$IR_e = I\,(R_1 + R_2 + R_3)$

$R_e = R_1 + R_2 + R_3$

Thus equivalent resistance is equal to the sum of the individual resistances of resistors connected in series.



**RESISTORS IN PARALLEL:**

Resistors are said to be connected in parallel if potential difference across each resistor is same. Parallel connection is also known as current divider network or ends to ends connections network.

**Derivation:**

Consider three resistors of resistances $R_1$, $R_2$ & $R_3$ are connected in parallel with a battery of voltage "V" if "I" be the current which is flowing through the battery then this current will divide into three parts at terminal "a". Let $I_1$, $I_2$ and $I_3$ be the current through $R_1$, $R_2$ & $R_3$ respectively then,

$I = I_1 + I_2 + I_3$ ------------------(ii)

$I_1$= electric current through $R_1 = \frac{V}{R_1}$

$I_2$= electric current through $R_2 = \frac{V}{R_2}$

$I_3$= electric current through $R_3 = \frac{V}{R_3}$

If "$R_e$" be the equivalent resistance of $R_1$, $R_2$ & $R_3$ and is connected through the same battery then the whole current "I" will pass through it

I = electric current through $R_e = \frac{V}{R_e}$

Therefore by putting the values of $I_1$, $I_2$ $I_3$ and I in $eq^n$(ii), we get,



$$\frac{V}{R_e} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\frac{V}{R_e} = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

$$\frac{1}{R_e} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

This shows that the reciprocal of equivalent resistance is equal to the sum of the reciprocals of individual resistances OR the equivalent conductance is obtained by adding the conductance of the individual conductors of the circuit.

**POWER DISSIPATION IN RESISTOR:**

Suppose a battery voltage "V" is connected across a resistor "R" if the current "I" flows through this resistor for a time "t" the charge "Q" is transported between the terminals of the battery is given by,

$Q = It$ since, $I = \frac{Q}{t}$

the charge 'Q" moving due to potential difference V" loses its potential energy equal to "VQ" which in converted into heat

i.e. heat produced = VQ

but Q = It

heat produced = $VIt = (IR)\times I\times t = I^2R\times t = \left(\frac{V}{R}\right)^2 \times R \times t = \frac{V^2}{R}t$

The heat produced or energy spent per unit time is called power.

$$\text{Power} = \frac{heat\ produced}{time} = \frac{energy\ spent}{time} = \frac{work\ done}{time}$$

$$\text{Power} = \frac{VIt}{t} = VI$$

$$\text{Power} = \frac{I^2R\times t}{t} = I^2R$$

$$\text{Power} = \frac{\frac{V^2}{R}t}{t} = \frac{V^2}{R}$$

The unit of power is "watt" its multiples are kilowatt and Megawatt.

1KW= $10^3$ watts,

1Mega watt=$10^6$ watts

**Kilo watt hour:**

Usually the energy supplied by electric supply corporation through its generating stations in Kilowatt-hour(KWh)

One Kilo-watt hour in the energy derived by the current in one hour when it supplied energy at the rate of 1000 joules per second i.e.

$$1\ KWh = \frac{1000\ joules \times I\ hour}{Sec}$$

$$= \frac{1000\ J \times 3600\ s}{s}$$

$$1KWh = 3.6 \times 10^6\ J$$

## ELECTROMOTIVE FORCE:

(The potential difference between the terminals of a battery or any source of electrical energy when it is not connected to any external circuit is called its electromotive force (E.M.F.). It is denoted by "E".

As charges pass through a source of electrical energy i.e. a cell or a battery, work is done on them; the electromotive force may be defined as "the work done per coulomb on the charges".

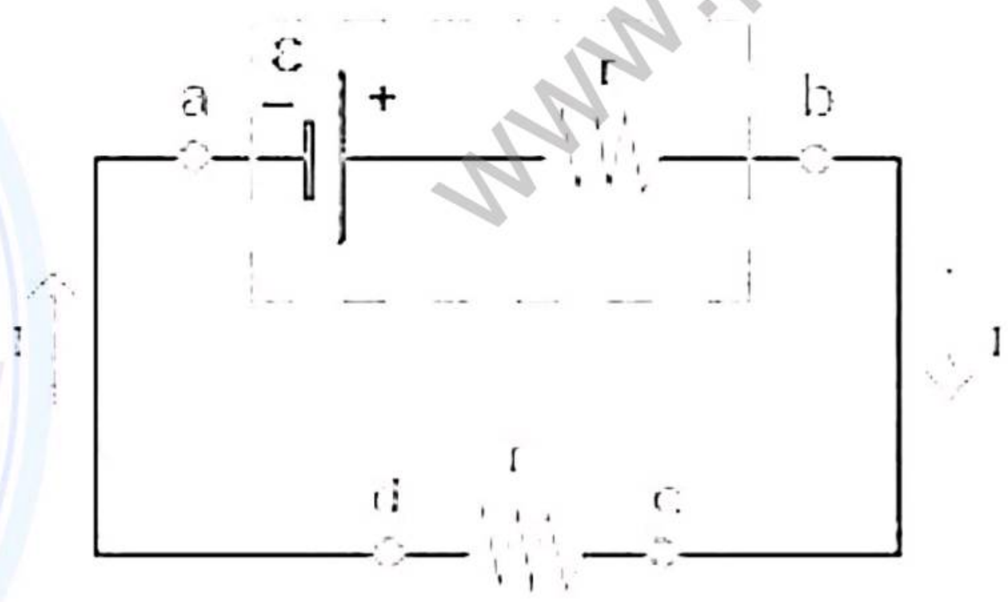
### Sources of emf:

In the case of battery chemical energy is converted into electrical energy in a generator mechanical energy is converted into electric energy and in a thermocouple heat energy is converted into electrical energy and so on.

### Explanation:

Consider a circuit in which a resistor "R" is connected by leads of negliable resistance to the terminals of a battery a current "I" flow through the resistor in a direction from "b" to "a" the potential "$V_b$" being higher then potential "$V_a$" the same current will flow through the battery from its negative terminal to the positive terminals the battery is made of some electrolyte and electrodes for the production of e. m. f. and hence when this current flows the battery, it encounters some resistance by the electrolyte present between its two electrodes this resistance is known as INTERNAL RESISTANCE "r" of the battery

Thus the current in the circuit by ohm's law is given by relation




$$I = \frac{E}{R+r}$$

$$E = I(R + r)$$

$$E = IR + Ir \text{ ----------(i)}$$

Here "IR" is the voltage to drive the current "I" through the external resistor "R" and "Ir" is the lost voltage driving current "I" through the internal resistance "r"

If we denote "IR" by "V" then eq1 becomes

$$E = V + Ir$$

$$V = E - Ir$$

This shows that the potential difference between the terminals of a battery drops when it delivers a current. However when no current is drawn, there is no potential drop across the internal resistance so that the terminal potential difference is equal to its e. m. f i.e. $V=E$

### E.M.F sources in series:

When the e. m. f of a single cell is too small for a particular application two or more cells can be connected in series as shown in fig the e. m. f of the set is sum of e. m. f of the individual cells and the internal resistance of the set is the sum of individual resistances

i.e. $E = E_1 + E_2 + E_3 + \text{--------} + E_n$

$r = r_1 + r_2 + r_3 + \text{-----------} + r_n$

A familiar example of such an arrangement is use of lead acid cells in series to make a 12V battery of a car.

**E. M. F sources in parallel:**

When the e. m. f of a battery or cell is sufficient but its capacity is too small, two or more batteries or cell can be connected in parallel to give more current the total current "I" is the sum of the current delivered from the individual battery or cell.

i.e. $I=I_1+I_2+I_3+ \text{--------} +I_n$

**Electronic current:**

The current due to low of electrons in a circuit is called "electronic current"

**Conventional Current:**

The current due to flow of positive charges in te circuit is called "conventional current" direction of electronic current the conventional current is an ideal current and its direction is opposite to the direction of electronic current direct in of conventional current its effect is the same as that of electronic current.