# 6. CURRENT ELECTRICITY

## Synopsis :

**1. Electric current :**

a) Net charge flowing across the cross section of the conductor in one second is called *electric current.*

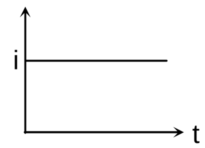
$i = Q / t$ or $Q = it$

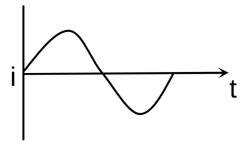
b) S.I. unit of current is ampere

$1 \text{ ampere} = \frac{1 \text{ coulomb}}{1 \text{ second}}$

c) The current flowing through a conductor is said to be one ampere when one coulomb of charge passes through it in one second.

d) If $6.25 \times 10^{18}$ electrons pass across the cross-section of a conductor in one second, the strength of the current flowing across the conductor is one ampere.




**2. Drift velocity ($V_d$) :**

a) The average velocity of the charge is called as Drift velocity ($V_d$).

b) Drift velocity is the average velocity and not instantaneous velocity of the charge.

$i = AV_d \rho_c$

where A is area of cross section of the conductor ; $V_d$ is drift velocity; $\rho_c$ is charge per unit volume.

$i = AV_d ne$

where n is number of electrons per unit volume. Drift velocity per unit field is termed as **mobility** ($\mu$).

$\mu = \frac{V_d}{E}$

3. Two terminologies are used for current regarding the direction of flow. They are

i) **Electronic current :** Here the direction of this current is taken as the direction in which the electrons are transferred.

ii) **Conventional current :** The direction of this current is taken as opposite to that of electronic current.

4. a) Free electrons are charge carriers in metals.

b) Positive and negative ions are charge carriers in liquids.

c) Positive ions and electrons are charge carriers in gases.

d) Holes and electrons are charge carriers in semiconductors.

5. The current in different situations is calculated as follows:

a) **Due to translatory motion of charge :** If n particles, each of charge q passes through a given area in time t seconds then **i** = $\frac{nq}{t}$

b) **Due to rotatory motion of charge :** If a point charge q is moving in a circle of radius r with speed v, constant frequency f and time period T then **i** = $\frac{q}{t} = \frac{e}{T} = qf = \frac{qv}{2\pi r}$

**6. AC and DC :**

a) If the magnitude and direction of current does not vary with time. It is known as direct current DC.

b) If a current is periodic i.e. magnitude varies periodically and polarity reverses after each half cycle, it is known as alternating current (AC).

7. **Electric cell :**

a) It is a device which converts chemical energy into electrical energy.

b) There are two types of cells

i) Primary cell ii) Secondary cell

c) **comparison of primary and secondary cells:**

| Primary cell | Secondary Cell |
|---|---|
| i) Converts chemical energy into electrical energy | Electrical energy is first stored in the form of chemical energy and then again gets converted into to electrical energy on drawing current from it. |
| ii) This cannot be recharged. | This can be recharged |
| iii) Their e.m.f is less and internal resistance is more | Their e.m.f is more and internal resistance is less |
| iv) In this the conversion of chemical energy into electrical energy is an irreversible process<br>**Eg:** Denial cell, voltaic cell, cadmium cell, dry cell, Laclanche cell etc. | In this the conversion of chemical energy in to electrical energy is a reversible process.<br>**Eg:** Lead accumulators, Edison cell |

8. **Electromotive force (e.m.f) of a Cell :**

a) The work done is carrying a unit positive charge once in the whole circuit including the cell, is defined as the electromotive force.

b) Electromotive force is the potential difference between the terminals of a cell in open circuit.

c) Electromotive force depends on –(1) nature of electrolyte (2) metal of the electrodes.

d) Electromotive force does not depend on (1) area of plates (2) distance between the electrodes (3) Quantity of electrolyte (4) size of the cell.

e) Electromotive force is the characteristic property of the cell. The direction of current inside the cell is always from negative to positive electrode.

f) The unit of electromotive force is volt.

9. **Internal resistance (r) :** The internal resistance of a cell is the resistance offered by the column of the electrolyte between the positive plate and the negative plate.

i) The internal resistance of a perfect cell or ideal cell is zero.

ii) Internal resistance depends on

a) strength of electrolyte ($r \propto$ strength)

b) distance between plates ($r \propto d$)

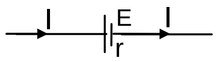
c) area of the plates $\left[r \propto \frac{1}{A}\right]$

d) temperature of electrolyte $\left[r \propto \frac{1}{t}\right]$

10. **Relation between EMF and PD**:

1) In case of charging of a cell

a) The current flows from +ve to –ve terminal inside the cell.



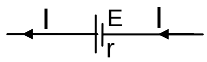

b) $V > E$

c) $V = E + ir$

2) In case of discharge of a cell

a) The current flows from –ve to +ve terminal inside the cells

b) $V < E$

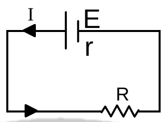



c) $V = E - ir$

3) The difference between E and V is called **lost volts**

$\therefore$ lost volts $= E - V = ir$

4) A cell of emf 'E' and its resistance 'r' is connected to resistance 'R'.




a) $i = \dfrac{E}{R+r}$

b) P.D. across resistance R is given by

$V = iR = \dfrac{ER}{R+r}$

c) Fraction of energy useful $= \dfrac{V}{E} = \dfrac{R}{R+r}$

d) % of fractional useful energy$= \left(\dfrac{V}{E}\right)100 = \left(\dfrac{R}{R+r}\right)100$

e) Fraction of energy lost $= \dfrac{E-V}{E} = \dfrac{ir}{E} = \dfrac{r}{R+r}$

f) % of lost energy $= \left(\dfrac{r}{R+r}\right)100$

g) $r = \dfrac{(E-V)R}{V}$

h) For single cell, the condition for maximum current is $R = r$.

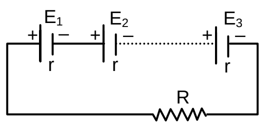
11. **Back emf :**

a) The copper electrode gets covered with a layer of hydrogen and this hinders flow of current. In the neighbourhood of both electrodes, the concentrations of ions get altered. This results in an emf acting in a direction opposite to the emf of the cell. This is called *back emf*.

b) This formation of hydrogen around the anode is called *polarization.*

c) To reduce the back e.m.f manganese dioxide and potassium dichromite are added to electrolyte of cell. These are called ***depolarizers****.*

12. **Series combination of cells :**




a) $E = E_1 + E_2 + E_3 + \ldots E_n$

b) $r = r_1 + r_2 + r_3 + \ldots\ldots. r_n$

c) When cells of e.m.f.'s $E_1$, $E_2$, $E_3$…. and of internal resistances $r_1$, $r_2$, $r_3$….. are connected in series across an external resistance R, the current i is given by

$$i = \frac{E_1 + E_2 + E_3 ........}{R + (r_1 + r_2 + r_3 + .....)}$$

d) If the e.m.f s of all the n cells and their internal resistances are same, then $i = \frac{nE}{(R + nr)}$

e) If n r >> R, then i = E/r, i.e the current obtained from n cells is equal to that obtained from a single cell.

f) If n r << R then i = n E/R.

g) This type of combination is used when the internal resistance of battery is negligible in comparison to the external resistance and e.m.f required is high.

h) In this combination same current flows through all the cells.

13. **Wrongly connected cells :**

Suppose by mistake m cells are wrongly connected in above circuit then

a) Total emf = emf due to properly connected cells – emf due to wrongly connected cells

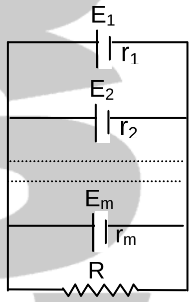
= (n – m) E – mE = (n – 2m) E

b) Total internal resistance of cells = nr

c) Total resistance in the circuit = R + nr

d) The current in circuit = $\frac{(n - 2m)E}{R + nr}$

14. **Cell in parallel :**




i) $i = i_1 + i_2 + i_3 + .......... i_n$

ii) The e.m.f of the combination is equal to the e.m.f of a single cell i.e. $E = E_1 = E_2 = E_3$ = ……$i = \frac{E}{\left(R + \frac{r}{m}\right)}$

iii) If r >> R then $I = mE/r$

$i = n \times$ (current obtained from a single cell)

iv) If r << R then $i = E/R$

This type of combination is used when r >>R and more current is required in the circuit.

v) If the e.m.f of m cells and their internal resistance are different then

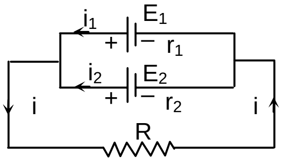
1) $i = i_1 + i_2 + i_3 ....... i_n$

2) $$I = \frac{\left[\frac{E_1}{r_1} + \frac{E_2}{r_2} + ....... \frac{E_m}{r_n}\right]}{\left[1 + R\left(\frac{1}{r_1} + \frac{1}{r_2} + ........... \frac{1}{r_n}\right)\right]} = \frac{\left(\frac{\sum \frac{E}{r}}{\sum \frac{1}{r}}\right)}{\left(R + \frac{1}{\sum \frac{1}{r}}\right)}$$

3) $E_{total} = \frac{\sum \frac{E}{r}}{\sum \frac{1}{r}}$ 4) $r_{total} = \frac{1}{\sum \frac{1}{r}}$

15. If two cells of emf $E_1$ and $E_2$ having internal resistances $r_1$ and $r_2$ are connected in parallel to an external resistance R, then

i)




a) The effective emf, $E = \dfrac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$

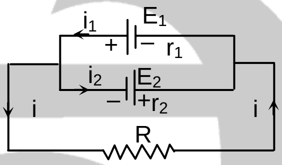
b) The effective internal resistance, r = $\dfrac{r_1 r_2}{r_1 + r_2}$

c) Current through the circuit, $i = \dfrac{E}{r + R}$

d) $i = i_1 + i_2$

e) $i_1 = \dfrac{E_1 - iR}{r_1}$ and $i_2 = \dfrac{E_2 - iR}{r_2}$

ii)




a) The effective emf, $E = \dfrac{E_1 r_2 - E_2 r_1}{r_1 + r_2}$

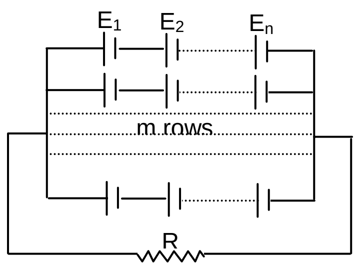
b) The effective internal resistance, r = $\dfrac{r_1 r_2}{r_1 + r_2}$

c) Current through the circuit, $i = \dfrac{E}{r + R}$

d) $i = i_1 - i_2$

e) $i_1 = \dfrac{E_1 - iR}{r_1}$ and $i_2 = \dfrac{E_2 + iR}{r_2}$

16. **Mixed grouping of cells :**




i) The e.m.f of cells in a row = nE.

ii) Total e.m.f of the combination = nE

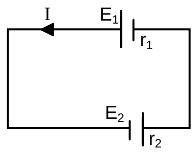
iii) The total internal resistance = $\frac{nr}{m}$

iv) The total resistance of the circuit = R + $\frac{nr}{m}$

v) The current flowing through the external resistance (i) $= \frac{nE}{R + \frac{nr}{m}} = \frac{mnE}{mR + nr}$

vi) For maximum current to flow through the external circuit, the external resistance should be equal to the total internal resistance. or R = $\frac{nr}{m}$ or, mR = nr

17. Two cells if e.m.f.s $E_1$ and $E_2$ be connected in a circuit. Let $r_1$ and $r_2$ be the internal resistance of the cells.



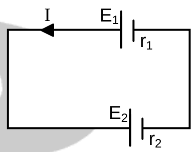

a) The current through the circuit I = $\frac{E_1 + E_2}{r_1 + r_2}$

b) The terminal voltage across the cells

$V_1 = E_1 - Ir_1$

$V_2 = E_2 - Ir_2$

18. Let two cells of e.m.f.s $E_1$ and $E_2$ be connected in parallel in a circuit. Let $r_1$ and $r_2$ be the internal resistance of the cells.




a) The direction of the resultant current is determined by the direction of the higher e.m.f.

b) If $E_1 < E_2$, the current through the circuit is I = $\frac{E_1 - E_2}{r_1 + r_2}$.

c) While the cell $E_1$ is discharging, the cell $E_2$ is in the charging. The terminal voltage across the cells $V_1 = E_1 - Ir_1$ and $V_2 = E_2 + Ir_2$.

19. **Ohm's law :** At constant temperature, the current (i) flowing through a conductor is directly proportional to the potential difference (V) between its ends.

$V \alpha$ i or V = iR where R is the electrical resistance of the conductor

a) Ohm's law is not a universal law.

b) Conductors which obey Ohm's law are called **ohmic** (or) **linear conductors**. Ex. metals.

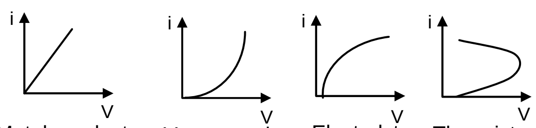
c) The graph between V and I for ohmic conductor is straight line passing through the origin.

d) Conductors which do not obey Ohm's law are called **Non ohmic** (or)**Non linear conductors**.

**Ex:**Carbon compounds, electrolytes, transistors, diodes, semiconductors, discharge tubes, Thermionic valves, vacuum tubes.

e) The graph between V and i for non ohmic resistance is a curve

f)




Metal conductor Vacuum tube Electrolyte Thermistor

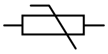
20. **Thermistor :**

a) It is a thermal resistor.

b) It is a heat sensitive nonohmic device.

c) Made of semiconductor compounds as oxides of nickel, iron, cobalt and Cu.

d) It is enclosed in a capsule with an epoxy surface.

e) Symbol is  or 

f) One type of thermistor has high positive temperature co-efficient (PTC) of resistance.

g) Another type of thermistor has high negative temperature co-efficient (NTC) of resistance.

h) (i) NTC thermistor is used as resistance thermometer for measuring low temperatures of the order of 10 K.

(ii) High resistance at low temperature makes it possible to measure low temperature very accurately.

i) Thermistors one in the form of beads, discs or rods to which a pair of platinum wires are provided at leads.

j) A tiny bead form thermistor serves as thermometer and can measure temperature changes of the order as small is $10^{-3}$ K.

k) Thermistor used in measuring the rate of energy (power) in a mino wave beam.

l) Thermistor used in radio circuits to avoid sudden and large surge of current.

m) Thermistor is used as thermostat.

21. **Resistance :**

a) The property by virtue of which a conductor opposes the flow of charge in it is known as resistance.

b) It is measured as the ratio between potential difference between the ends of the conductor and current flowing in the conductor $\Rightarrow$ R= V/i.

c) SI unit of resistance is Ohm.

*1 ohm = 1 volt / 1 amp*

d) Ohm is the resistance of a conductor through which a current of 1 ampere flows when the potential difference between its ends is 1 volt.

e) Dimensions formula R is $ML^2T^{-3}I^{-2}$.

f) For good conductors resistance is very low and
for insulators or bad conductors it is high.

22. **Conductance :**

a) The reciprocal of resistance is known as conductance $\Rightarrow$ G = 1 /R.

b) SI unit of G is siemen (S) (or $ohm^{-1}$ or mho)

c) Conductance decreases on increasing temperature

23. **Dependence of resistance :**

a) Resistance of a conductor is directly proportional to its length and inversely proportional to its area of cross section.

$$R \propto \frac{\ell}{A} \Rightarrow R = S\frac{\ell}{A} \text{ or } \rho\frac{\ell}{A}$$

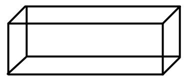
Here S or $\rho$ is known as resistance or specific resistance

$R = \dfrac{\rho\ell}{\pi r^2}$ Where r is radius of cross section.

b) $R = \frac{\rho l}{A} = \frac{\rho l^2}{V} = \frac{\rho V}{A^2} = \frac{\rho m}{A^2 d} = \frac{\rho l^2 d}{m}$

c) Resistance does not depend on current and potential difference.

Through resistance of a linear conductor is independent of applied voltage, for a given body it is not unique and depends on length and area of cross section. (i.e how the potential difference is applied)If $\ell$,b, h denote length, breadth and thickness of a slab, ($\ell$>b>h), $R_{max} = \frac{\rho\ell}{bh}$ and $R_{min} = \frac{\rho h}{\ell b}$



24. **Specific resistance :**

a) It is equal to resistance of the conductor of unit length and unit area of cross section.

b) $R \alpha \frac{\ell}{A}$ or $R = \frac{s\ell}{A}$ or $s = \frac{RA}{\ell}$

c) S.I. unit : Ohm – metre

d) It depends only on the material of the conductor and temperature.

e) It is independent of dimensions of the conductor.

f) For silver and copper specific resistance is small

g) For Nichrome, constantan, Maganin it is large.

25. **Conductivity : (or) specific conductance (σ) :**

a) It is reciprocal of resistivity. $\sigma = \frac{1}{s} = \frac{\ell}{RA}$

b) S.I unit : siemen / m

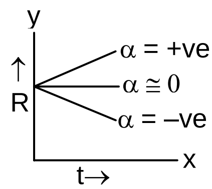
c) For insulators $\sigma = 0$

d) For perfect conductors, $\sigma$ = infinity

26. **Temperature co-efficient of resistance (α)** :

a) It is defined as the change in specific resistance (or resistance) per 1°C rise of temperature to the original specific resistance (or resistance) at 0°C.

b) $\alpha = \frac{\rho_t - \rho_0}{\rho_0 t}$




c) $\alpha = \frac{R_t - R_0}{R_0 t}$

c) $\rho_t = \rho_0(1 + \alpha\Delta t)$ …(1)

d) $R_t = R_0 (1 + \alpha\Delta t)$ …(2)

$\rho_0$ and $R_0$ are the specific resistance and resistance at 0°C,

$\rho_t$ and $R_t$ are the corresponding values at t°C.

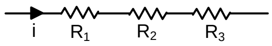
e) If $R_1$ and $R_2$ are resistances at $t_1$°C and $t_2$°C then

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

f) For small temperature variation, $\rho_T = \rho_{T_o}[1 + \alpha(T - T_o)]$ where $\rho_{T_o}$ and $\rho_T$ are the resistivities at temperatures $T_o$ and T respectively and $\alpha$ is a constant for a given material and is called the temperature coefficient of resistivity.

$\alpha = \frac{1}{\rho} \cdot \frac{d\rho}{dT}$

27. **Series connection** :




i) Current is the same through all the resistors

ii) Total p.d.= sum of individual p.d.s across each resistor.

iii) Individual p.d. is directly proportional to individual resistor.

iv) Total resistance is greater than the greatest individual resistance.

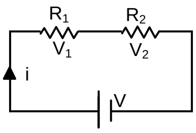
v) Total resistance = sum of the individual resistances.

$R = R_1 + R_2 + R_3 + \ldots\ldots.$

vi) Two resistances in series :

a) The total resistance $R_S = R_1 + R_2$

b) $V_1 = \dfrac{VR_1}{R_1 + R_2}$

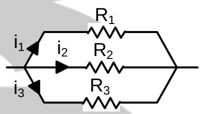



c) $V_2 = \dfrac{VR_2}{R_1 + R_2}$

d) $i = \dfrac{V_1}{R_1} = \dfrac{V_2}{R_2}$

vii) A **conductor and Semi conductor** are connected in series. If the resistance of the combination is same at all temperatures then $R_1\,\alpha_1 = R_2\alpha_2$ where $R_1$, $R_2$ are resistances of conductor and semi conductor.

28. **Parallel connection** :




i) Potential difference remains the same across each resistor.

ii) Total current=sum of the individual currents.

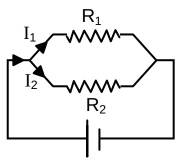
iii) Individual currents are inversely proportional to the individual resistances.

iv) Effective resistance is less than the least individual resistance.

v) When a number of conductors are connected in parallel, the reciprocal value of the resultant resistance is equal to the sum of the reciprocal values of the individual resistances.

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + .....$$

vi) Two resistances in parallel




a) The total resistance

$R_P = \dfrac{R_1R_2}{R_1 + R_2}$

b) $I_1 = \dfrac{IR_2}{R_1 + R_2}$

c) $I_2 = \dfrac{IR_1}{R_1 + R_2}$ ; $V = I_1R_1 = I_2R_2$

29. If $R_S$ and $R_P$ be the resultant resistance of resistances $R_1$ and $R_2$, when connected in series and parallel then

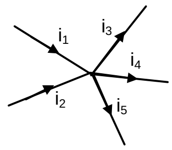
$R_1 = \dfrac{1}{2}\left(R_S + \sqrt{R_S^2 - 4R_sR_P}\right)$

$R_2 = \dfrac{1}{2}\left(R_S + \sqrt{R_S^2 - 4R_sR_P}\right)$

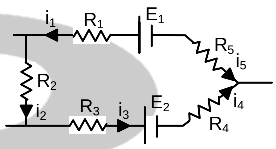
30. If n equal resistances each of resistance R are connected to form triangle (or) Square (or) Polygon then effective resistance between any two adjacent corners is $R^1 = \left(\frac{n-1}{n}\right)R$ .

31. When twelve identical resistors each of resistance R Ω are connected in the form of a skeleton cube, the effective resistance across
    (i) the ends of a side is (7r/12)Ω,
    (ii) the opposite vertices on the same face is (3r/4)Ω and
    (iii) the diagonally opposite vertices is (5r/6)Ω.

32. **Kirchhoff's laws :**
    a) First law :
       i) The algebraic sum of electric currents meeting at a junction is zero.
          for the junction 'P' ;
          $i_1 + i_2 - i_3 - i_4 - i_5 = 0$ (or) $i_1 + i_2 = i_3 + i_4 + i_5$

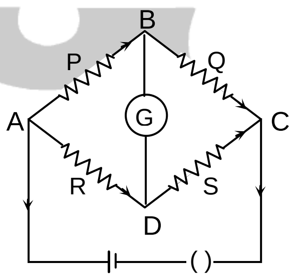



       ii) Kirchhoff's first law is known as junction law or point law of kirchhoff's current law
       iii) Kirchhoff's first law obeys law of conservation of electric charge.
    b) **Second Law :**
       i) the algebraic sum of emfs or potential differences around a closed circuit is zero.
          For the closed circuit ABCDEA
          $+ E_1 - i_1 R_1 - i_1R_2 - i_3R_3 - E_2 - i_4R_4 + i_5R_5 = 0$




       ii) Second law is known as loop theorem or kirchhoff's voltage law.
       iii) Kirchhoff's second law obeys law of conservation of energy.
    c) **Sign convention in kirchhoff's laws:**
       i) While going from +ve of a battery to the negative through a cell, emf is negative.
       ii) While going in the direction of the current through a conductor, potential difference is negative.

33. **Wheatstone bridge :**
    i) Wheastone bridge is a circuit used to compare the ratio of nearly equal resistance. It consists of four ams, each consisting a resistor.




    ii) If two of the resistors of the four are known, the other two can be compared.
    iii) If three resistances are known the fourth one can be calculated.
    iv) If the current through the galvanometer in a Wheastone bridge is made zero, then the bridge is balanced.
    v) **Under balanced condition :**
       a) $\frac{P}{Q} = \frac{R}{S}$
       b) The same current passes through the P& Q.
       c) The same current passes through the R & S
       d) The P.D. across the ends of the galvanometer is zero.
       e) When galvanometer and cell are interchanged, the balance point is not effected.
       f) The effective resistance = $\frac{(P+Q)(R+S)}{P+Q+R+S}$
    vi) Wheatstone's bridge is more sensitive if P = Q = R = S
    vii) The number of closed circuits in bridge = 7.

34. **Meter bridge** :

i) It works on the principle of Wheastone Bridge. It is the simplified form of Wheatstone Bridge.

ii) It is used to find

a) unknown resistance of a wire

b) specific resistance of the wire

c) and also to compare resistances.

iii) When the Meter bridge is balanced then $\frac{\text{resistance in the left gap}}{\text{resistance in the right gap}} = \frac{\ell}{100-\ell}$

Where $\ell$ is the balancing length from the left end.

iv) A high resistance box is connected in series to the galvanometer to protect it from higher currents.

v) The bridge wire (manganin wire) ha low $\alpha$-value.

vi) Meter bridge is more sensitive if $\ell_1$ = 50 cm

vii) The resistance of copper strip is called end resistance.

viii) The resistance in two gaps (x and R) are interchanged to reduce the effect of end resistance.

ix) If a conductor is connected in the left gap and it is heated then blanching point shifts towards right.

x) If a semiconductor is connected in the left gap and it is heated then balancing point shifts towards left.

35. **Potentiometer :**

i) It is a device which is used to

a) compare the e.m.f.s of two cells,

b) to determine the e.m.f of a cell

c) determine the internal resistance of a cell

d) calibrate a voltmeter and an ammeter

e) determine the current in a circuit,

f) determine unknown resistance,

g) measure thermo emfs.

ii) A cell of E and internal resistance r in the primary circuit maintains uniform potential gradient along the length of its wire.

iii) Current through the potentiometer wire, $i = \frac{E}{r+R}$

iv) Potential gradient or potential drop per unit length = $\frac{iR}{\ell}$ where 'l' is the total length of potentiometer wire, 'R' is the total resistance of the wire and 'i' is the current through potentiometer wire due to primary circuit.

v) If a resistance $R_s$ is connected in series with the potentiometer wire then i = $\frac{E}{r+R+R_S}$ .

vi) potential drop per unit length = $\left(\frac{E}{r+R+R_S}\right)\frac{R}{\ell}$

vii) **Comparison of emfs using potentiometer :**

a) $\ell_1$ and $\ell_2$ are balancing lengths when two cells of emfs, $E_1$ and $E_2$ are connected in the secondary circuit.

one after the other then, $\frac{E_1}{E_2} = \frac{\ell_1}{\ell_2}$

b) By sum and difference method,

$\frac{E_1 + E_2}{E_1 - E_2} = \frac{L_1}{L_2}$ or $\frac{E_1}{E_2} = \frac{L_1 + L_2}{L_1 - L_2}$.

viii) Internal resistance of a cell

$$r = \left(\frac{E - V}{V}\right)R = \left(\frac{\ell_1 - \ell_2}{\ell_2}\right)R$$

When $\ell_1$ = balancing length for the cell connected in the secondary circuit.

$\ell_2$ = balancing length when a resistance R is connected in parallel to the cell.

E = emf of the cell in the secondary circuit

V = Terminal voltage

ix) The sensitivity of potentiometer can be increased by decreasing the potential gradient. i.e., by increasing the length of potentiometer wire for a given B.

x) The best instrument for accurate measurement of the e.m.f of cell is potentiometer because it does not draw current from cell.

xi) Potentiometer acts like a voltmeter of infinite resistance.

xii) $E_b$ (emf of battery in the primary circuit ) must be greater then $E_c$ ( emf of cell in the secondary circuit) otherwise e.m.f will not be balanced even over the complete length of wire.

xiii) + ve terminals of both battery and cell must be connected at same point otherwise $I_b$ and $I_c$ will be in same direction and null point is never obtained.

**36. ELECTRICAL POWER:**

The rate at which work is done in maintaining the current in electric circuit.

Electrical power

$$P = \frac{W}{t} = VI = I^2R = \frac{V^2}{R} \text{ watt (or) joule / sec}$$

**37. Electrical Energy :**

The electric energy consumed in a circuit is defined as the total workdone in maintaing the current in an electric circuit for a given time.

Electrical Energy = Vt = Pt = $I^2Rt = \frac{V^2t}{R}$

S.I. unit of electric energy is joule

where

1 Joule=1watt $\times$ 1 sec = 1 volt $\times$ ampere $\times$ 1 sec

$1\text{Kwh} = 1000\text{Wh} = 3.6 \times 10^6 \text{J}$

**38. Bulbs connected in Sereies:**

1 If Bulbs (or electrical appliances) are connected in series, the current through each resistance is same. Then power of the electrical appliance $P \propto R$ & $V \propto R \left[\because P = i^2Rt\right]$

i.e. In series combination; the potential difference and power consumed will be more in larger resistance.

2 When the appliances of power are in series, the effective power consumed (P) is $\frac{1}{P} = \frac{1}{P_1} + \frac{1}{P_2} + \frac{1}{P_3} + .........$ i.e. effective power is less than the power of individual appliance.

If 'n' appliances, each of equal resistance 'R' are connected in series with a voltage source 'V', the power dissipated 'Ps' will be $Ps = \frac{V^2}{nR}$ .

**39. Bulbs connected in parallel:**

1 If Bulbs (or electrical appliances) are connected in parallel, the potential difference across each resistance is same. Then $P \propto \frac{1}{R}$ and $I \propto \frac{1}{R}$.

i.e. The current and power consumed will be more in smaller resistance.

2. When the appliances of power $P_1, P_2, P_3....$ are in parallel, the effective power consumed (P) is $P = P_1 + P_2 + P_3 + .........$

i.e. the effective power of various electrical applicance is more than the power of individual appliance.

3. If 'n' appliances, each of resistance 'R' are connected in parallel with a voltage source 'V', the power dissipated 'Pp' will be

$$P_P = \frac{V^2}{(R/n)} = \frac{nV^2}{R}$$

$$\frac{P_P}{P_S} = n^2 \ (or)\ P_P = n^2 P_S$$

This shows that power consumed by 'n' equal resistances in parallel is $n^2$ times that of power consumed in series if voltage remains same.

4) In parallel grouping of bulbs across a given sources of voltage, the bulb of greater wattage will give more brightness and will allow more current through it, but will have lesser resistance and same potential difference across it.

5) For a given voltage V, if resistance is changed from 'R' to $\left(\frac{R}{n}\right)$, power consumed changes from 'P' to 'nP' $P = \frac{V^2}{R}$ where $R' = \frac{R}{n}$, then $P' = \frac{V^2}{(R/n)} = \frac{nV^2}{R} = np$.

6) Filament of lower wattage bulb is tinner thinner that of higher wattage bulb i.e. filament of 60 watt bulb is higher than that of 100 watt bulb.

7) If 'I' is the current through the fuse wire of length '$\ell$', radius 'r', specific resistance 'P' and 'Q' is the rate of loss of heat per unit area of a fuse wire, then at steady state,

$$I^2R = QA \text{ or } \frac{I^2P\ell}{\pi r^2} = Q \times 2\pi r \times \ell$$

$$I^2 = \frac{2\pi^2 Q}{P} r^3 \Rightarrow I \propto r^{3/2}$$

Hence current capacity of a fuse is independent of its length and various with its radius as .

8) If $t_1$, $t_2$ are the time taken by two different coils for producing same heat with same supply, then

If they are connected in series to produce same heat, time taken $t = t_1 + t_2$

If they are connected in parallel to produce same heat, time taken is $t = \frac{t_1 t_2}{t_1 + t_2}$.