

CURRENT ELECTRICITY

1. ELECTRIC CURRENT

$$I_{av} = \frac{\Delta q}{\Delta t} \text{ and instantaneous current}$$

$$i = \lim_{\Delta t \rightarrow 0} \frac{\Delta q}{\Delta t} = \frac{dq}{dt}$$

2. ELECTRIC CURRENT IN A CONDUCTOR

$$I = nAeV_d$$

$$V_d = \frac{\lambda}{\tau}$$

$$V_d = \frac{1}{\tau} \left(\frac{eE}{m} \right) \tau^2 = \frac{1}{2} \frac{eE}{m} \tau$$

$$I = neAV_d$$

3. CURRENT DENSITY

$$\vec{j} = \frac{dI}{ds} \vec{n}$$

4. ELECTRICAL RESISTANCE

$$I = neAV_d = neA \left(\frac{eE}{2m} \right) \tau = \left(\frac{ne^2\tau}{2m} \right) AE$$

$$E = \frac{V}{\ell} \text{ so } I = \left(\frac{ne^2\tau}{2m} \right) \left(\frac{A}{\ell} \right) V = \left(\frac{A}{\rho\ell} \right) V = V/R \Rightarrow V = IR$$

ρ is called resistivity (it is also called specific resistance) and

$\rho = \frac{2m}{ne^2\tau} = \frac{1}{\sigma}$, σ is called conductivity. Therefore current in conductors

is proportional to potential difference applied across its ends. This is **Ohm's Law**.

Units:

$R \rightarrow \text{ohm}(\Omega)$, $\rho \rightarrow \text{ohm-meter}(\Omega\text{-m})$

also called siemens, $\sigma \rightarrow \Omega^{-1}\text{m}^{-1}$.

Dependence of Resistance on Temperature :

$$R = R_0 (1 + \alpha \theta).$$

Electric current in resistance

$$I = \frac{V_2 - V_1}{R}$$

5. ELECTRICAL POWER

$$P = VI$$

$$\text{Energy} = \int pdt$$

$$P = I^2R = VI = \frac{V^2}{R}.$$

$$H = VIt = I^2Rt = \frac{V^2}{R}t$$

$$H = I^2RT \text{ Joule} = \frac{I^2RT}{4.2} \text{ Calorie}$$

9. KIRCHHOFF'S LAWS

9.1 Kirchhoff's Current Law (Junction law)

$$\sum I_{\text{in}} = \sum I_{\text{out}}$$

9.2 Kirchhoff's Voltage Law (Loop law)

$$\sum IR + \sum \text{EMF} = 0.$$

10. COMBINATION OF RESISTANCES :

Resistances in Series:

$R = R_1 + R_2 + R_3 + \dots + R_n$ (this means R_{eq} is greater than any resistor) and

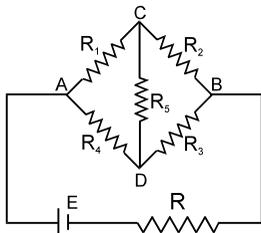
$$V = V_1 + V_2 + V_3 + \dots + V_n.$$

$$V_1 = \frac{R_1}{R_1 + R_2 + \dots + R_n} V; V_2 = \frac{R_2}{R_1 + R_2 + \dots + R_n} V;$$

2. Resistances in Parallel :

$$\boxed{\frac{1}{R_{\text{eq}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

11. WHEATSTONE NETWORK : (4 TERMINAL NETWORK)

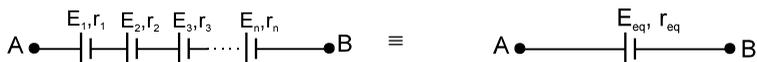


When current through the galvanometer is zero (null point or balance

point) $\frac{P}{Q} = \frac{R}{S}$, then $PS = QR$

13. GROUPING OF CELLS

13.1 Cells in Series :

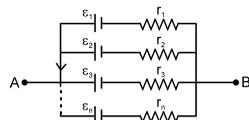


Equivalent EMF $E_{eq} = E_1 + E_2 + \dots + E_n$ [write EMF's with polarity]

Equivalent internal resistance $r_{eq} = r_1 + r_2 + r_3 + r_4 + \dots + r_n$

13.2 Cells in Parallel:

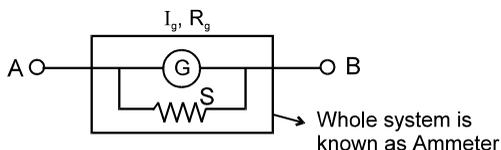
$$E_{eq} = \frac{\frac{\epsilon_1}{r_1} + \frac{\epsilon_2}{r_2} + \dots + \frac{\epsilon_n}{r_n}}{\frac{1}{r_1} + \frac{1}{r_2} + \dots + \frac{1}{r_n}} \quad [\text{Use emf with polarity}]$$



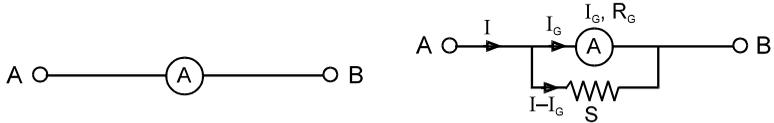
$$\frac{1}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2} + \dots + \frac{1}{r_n}$$

15. AMMETER

A shunt (small resistance) is connected in parallel with galvanometer to convert it into ammeter. An ideal ammeter has zero resistance



Ammeter is represented as follows -



If maximum value of current to be measured by ammeter is I then

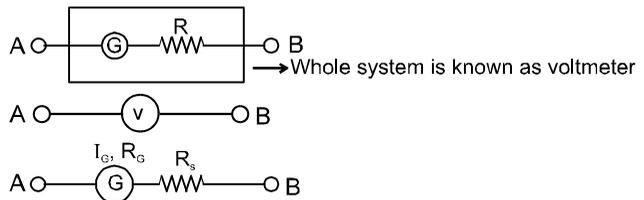
$$I_G \cdot R_G = (I - I_G)S$$

$$S = \frac{I_G \cdot R_G}{I - I_G} \quad S = \frac{I_G \times R_G}{I} \quad \text{when } I \gg I_G.$$

where I = Maximum current that can be measured using the given ammeter.

16. VOLTMETER

A high resistance is put in series with galvanometer. It is used to measure potential difference across a resistor in a circuit.

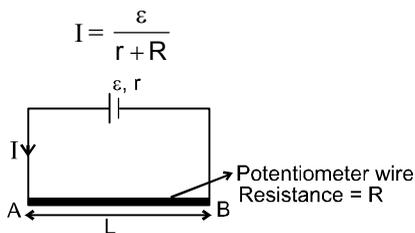


For maximum potential difference

$$V = I_G \cdot R_s + I_G R_G$$

$$R_s = \frac{V}{I_G} - R_G \quad \text{if } R_G \ll R_s \Rightarrow R_s \approx \frac{V}{I_G}$$

17. POTENTIOMETER



$$V_A - V_B = \frac{\epsilon}{R+r} \cdot R$$

Potential gradient (x) → Potential difference per unit length of wire

$$x = \frac{V_A - V_B}{L} = \frac{\epsilon}{R+r} \cdot \frac{R}{L}$$

Application of potentiometer

(a) To find emf of unknown cell and compare emf of two cells.

In case I,

In figure (1) is joint to (2) then balance length = l_1

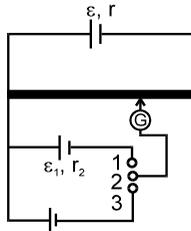
$$\varepsilon_1 = x l_1 \quad \dots(1)$$

in case II,

In figure (3) is joint to (2) then balance length = l_2

$$\varepsilon_2 = x l_2 \quad \dots(2)$$

$$\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2}$$



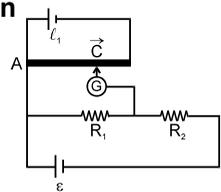
If any one of ε_1 or ε_2 is known the other can be found. If x is known then both ε_1 and ε_2 can be found

(b) To find current if resistance is known

$$V_A - V_C = x l_1$$

$$I R_1 = x l_1$$

$$I = \frac{x l_1}{R_1}$$



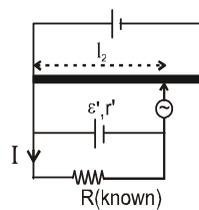
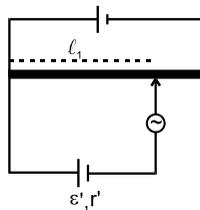
Similarly, we can find the value of R_2 also.

Potentiometer is ideal voltmeter because it does not draw any current from circuit, at the balance point.

(c) To find the internal resistance of cell.

1st arrangement

2nd arrangement



by first arrangement $\varepsilon' = x l_1$... (1)
 by second arrangement $IR = x l_2$

$$I = \frac{x l_2}{R}, \quad \text{also } I = \frac{\varepsilon'}{r'+R}$$

$$\therefore \frac{\varepsilon'}{r'+R} = \frac{x l_2}{R} \quad \Rightarrow \quad \frac{x l_1}{r'+R} = \frac{x l_2}{R}$$

$$r' = \left[\frac{l_1 - l_2}{l_2} \right] R$$

(d) Ammeter and voltmeter can be graduated by potentiometer.

(e) Ammeter and voltmeter can be calibrated by potentiometer.

18. METRE BRIDGE (USE TO MEASURE UNKNOWN RESISTANCE)

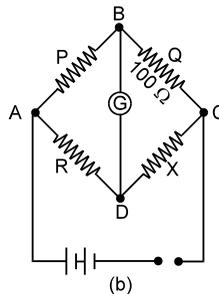
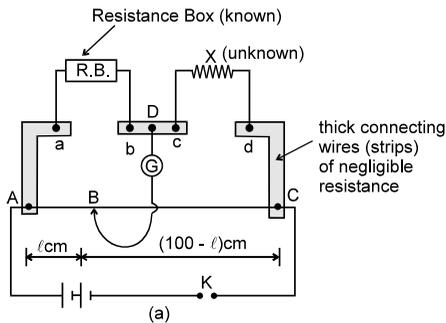
If $AB = l$ cm, then $BC = (100 - l)$ cm.

Resistance of the wire between A and B, $R \propto l$

[\because Specific resistance ρ and cross-sectional area A are same for whole of the wire]

$$\text{or } R = \sigma l \quad \dots (1)$$

where σ is resistance per cm of wire.



If P is the resistance of wire between A and B then

$$P \propto l \quad \Rightarrow \quad P = \sigma(l)$$

Similarly, if Q is resistance of the wire between B and C, then

$$Q \propto 100 - l$$

$$\therefore Q = \sigma(100 - l) \quad \dots (2)$$

Dividing (1) by (2),

$$\frac{P}{Q} = \frac{l}{100 - l}$$

Applying the condition for balanced Wheatstone bridge, we get $R Q = P X$

$$\therefore x = R \frac{Q}{P} \quad \text{or} \quad X = \frac{100 - \ell}{\ell} R$$

Since R and ℓ are known, therefore, the value of X can be calculated.