Electrical Circuits

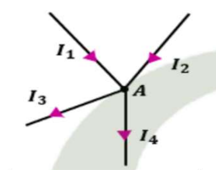
Kirchhoff's Current law (KCL)

The algebraic sum of current meeting at a point (junction) is always zero. i.e. $\sum I = 0$

Restatement:

$sum\ of\ entering\ current = sum\ of\ leaving\ current$

- **KCL is based on principle of conservation of charge**



$\boldsymbol{I_1 + I_2 = I_3 + I_4}$

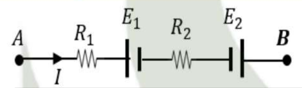
Kirchhoff's Voltage law (KVL)

The total sum of potential in a closed circuit (loop or mesh) is always zero. i.e. $\sum V = 0$

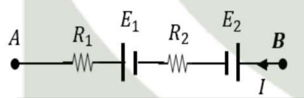
Here, $V = E\ (emf),\ for\ a\ cell$

$V = IR\ (pd),\ for\ a\ resistor$

- **KVL is based on principle of conservation of energy.**
- **Sign convention:** Gain in potential is positive. Loss in potential is negative
- **Kirchhoff's laws can be used in ac too.**



$V_A - IR_1 - E_1 - IR_2 + E_2 = V_B$



$V_A + IR_1 - E_1 + IR_2 + E_2 = V_B$

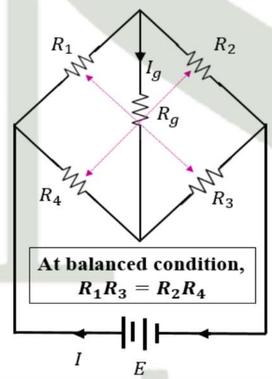
Wheatstone bridge:

- **Used to measure an unknown resistance.**
- Works at balanced condition ($I_g = 0$)

  At balanced Wheatstone bridge,

  $\mathbf{R_1R_3 = R_2R_4}$ **and vice-versa**
- **The bridge is most sensitive if $R_1 = R_3 = R_2 = R_4$**
- On changing the position of galvanometer and cell, the balance point will not be affected.
- **At balanced condition, the effective resistance of the circuit is** $R = (R_1 + R_2) \parallel (R_4 + R_3)$

  And current is $I = \frac{E}{R}$

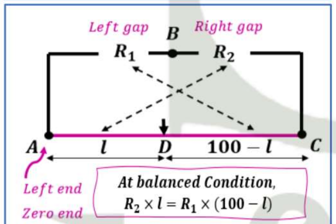


Meter bridge:

- Used to measure an unknown resistance.
- It works on the basis of Wheatstone bridge.
- Works at balanced condition,

  At balanced condition of meter bridge,

  $\boldsymbol{R_1 \times (100 - l) = R_2 \times l}$
- The bridge is most sensitive if balance point is obtained at the center.
- On changing the position of galvanometer and cell, the balance point will not be affected.
- If the resistance: R_1 and R_2 are interchanged, the balanced length also will be interchanged.
- If $R_1 = R_2$, balanced point will be exactly at center.



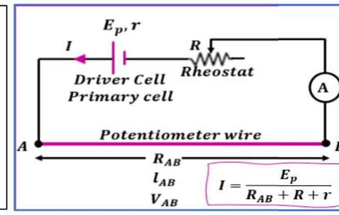
- If **R_1 is increased,** the balance length increases (shift towards right).
- For a wire of length l and cross sectional area A,

  $R = \frac{\rho l}{A}$ $\quad A = \frac{\pi d^2}{4}$

Principle of potentiometer:

"When a constant current is passed through a wire (conductor) of uniform cross-sectional area, ***the potential drop across any segment of the wire is directly proportional to the length of the segment.***"

i.e., $V \propto l$



✓ While measuring the emf of a cell using a potentiometer, it is operated at null deflection condition, and hence, no current is drawn from the cell and can give actual value of emf. Hence, Potentiometer is preferred over voltmeter in measuring emf of a cell.

Potentiometer is an ideal voltmeter.

- For a potentiometer, $\boldsymbol{V = kl}$

  or, $\boldsymbol{k = \frac{V}{l}}$

Here, the proportionality constant (k) is called as ***potential gradient*** $[unit: Vm^{-1}]$.
Smaller the potential gradient, more sensitive (and hence more accurate) will be the potentiometer.

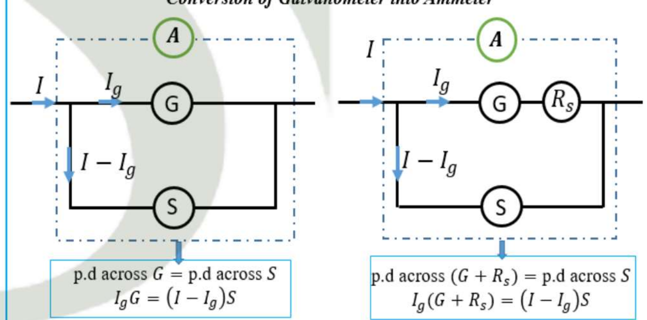
When k decreases, the balance point shifts towards right.

⟹Comparing EMFs of two cells: $\frac{E_1}{E_2} = \frac{l_1}{l_2}$, ⟹ Internal resistance of a cell $r = \left(\frac{l_1}{l_2} - 1\right)R$

(If series resistance is given (or asked) in questions, first find current in primary circuit)

$\Rightarrow I = \frac{E_p}{R_{AB} + R}$ and then find potential gradient (k): $k = \frac{V}{l} = \frac{V_{AB}}{l_{AB}} = \frac{IR_{AB}}{l_{AB}}$

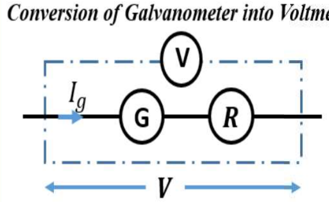
Conversion of Galvanometer into Ammeter



G =Resistance of Galvanometer coil, S = Shunt, I_g = Current across Galvanometer R_s =Series Resistance, The equivalent resistance of ammeter is $\frac{1}{R_{eq}} = \frac{1}{S} + \frac{1}{G}$

Shunt is used to increase range of ammeter & protect the galvanometer from high currents.

Conversion of Galvanometer into Voltmeter



In above circuit, $V = I_gG + I_gR$

$R = \frac{V}{I_g} - G$

Where, G = Resistance of coil

And, R = Multiplier (high resistance)

The equivalent internal resistance of the voltmeter is, $R_{eq} = G + R$

Superconductor: The material which shows *Zero Electric Resistance* or *Infinite Conductivity* below a certain temperature is known as superconductor.

Joules Law of Heating: when current flows through a conductor, the amount of heat produced in it is directly proportional to. Square of current flowing through the conductor for a given resistance and time. i.e. $H = I^2Rt$