# 15.CURRENT ELECTRICITY

## 1. ELECTRIC CURRENT

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

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

## 2. ELECTRIC CURRENT IN A CONDUCTOR

I = nAeV.

$v_d = \frac{\lambda}{\tau}$,

$v_d = \frac{\frac{1}{2}\frac{eE}{m}\tau^2}{\tau} = \frac{1}{2}\frac{eE}{m}\tau$,

$I = neAV_d$

## 3. CURRENT DENSITY

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

## 4. ELECTRICAL RESISTANCE

$I = neAV_d = neA \; \frac{eE}{2m} \; \tau = \frac{ne^2\tau}{2m} \; AE$

$E = \frac{V}{\ell}$ so $I = \frac{ne^2\tau}{2m} \; \frac{A}{\ell} \; V = \frac{A}{\rho\ell} \; V = V/R$ $V = IR$

$\rho$ is called resistivity (it is also called specific resistance) and $\rho = \frac{2m}{ne^2\tau} = \frac{1}{\sigma}$, $\sigma$ is called conductivity.

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

Units: $R$ ohm($\Omega$), $\rho$ ohm$-$meter($\Omega - m$) also called siemens, $\sigma$ $\Omega^{-1}m^{-1}$.

**Dependence of Resistance on Temperature :**

$R = R_o (1 + \alpha\,\theta)$.

**Electric current in resistance**

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

## 5. ELECTRICAL POWER

**P = V I**

Energy = pdt

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

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

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

## 9. KIRCHHOFF'S LAWS

### 9.1 Kirchhoff s Current Law (Junction law)

$\Sigma I_{in} = \Sigma I_{out}$

### 9.2 Kirchhoff s Voltage Law (Loop law)

$\Sigma IR + \Sigma EMF = 0$ .

## 10. COMBINATION OF RESISTANCES :

**Resistances in Series:**

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

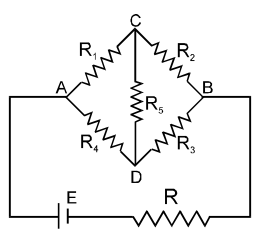
$V = V_1 + V_2 + V_3 + \ldots\ldots\ldots\ldots + V_n$ .

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

### 2. Resistances in Parallel :

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

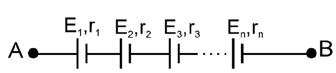
## 11. WHEATSTONE NETWORK : (4 TERMINAL NETWORK)

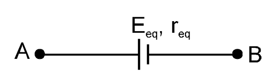



When current through the galvanometer is zero (null point or balance point) $\frac{P}{Q} = \frac{R}{S}$ , then PS = QR

## 13. GROUPING OF CELLS

### 13.1 Cells in Series :



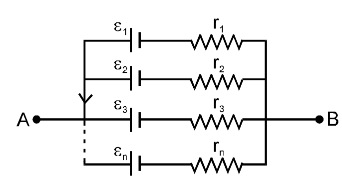




Equivalent EMF $E_{eq} = E_1 + E_2 + \ldots\ldots + E_n$ [write EMF's with polarity]

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

### 13.2 Cells in Parallel:

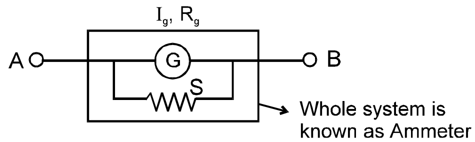
$$E_{eq} = \frac{\frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2} + \ldots + \frac{\varepsilon_n}{r_n}}{\frac{1}{r_1} + \frac{1}{r_2} + \ldots + \frac{1}{r_n}}$$ [Use emf with polarity]



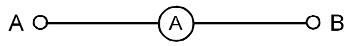

$$\frac{1}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2} + \ldots + \frac{1}{r_n}$$

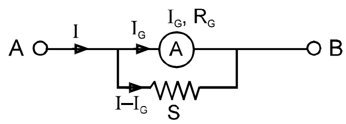
**15. AMMETER**

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

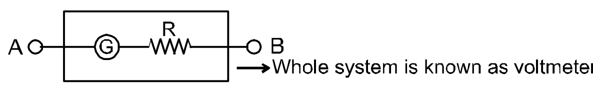
$I_G \cdot R_G = (I \quad I_G)S$

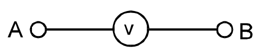
$$S = \frac{I_G . R_G}{I - I_G} \qquad S = \frac{I_G \quad R_G}{I} \quad \text{when} \quad I >> I_G.$$

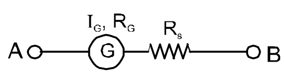
where $I$ = Maximum current that can be measured using the given ammeter.

**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

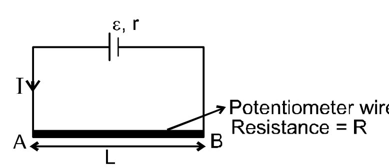
$$V = I_G \cdot R_S + I_G R_G$$

$$R_S = \frac{V}{I_G} \quad R_G \qquad \text{If} \qquad R_G << R_S$$

$$R_S \quad \frac{V}{I_G}$$

**17. POTENTIOMETER**

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




$$V_A \quad V_B = \frac{\varepsilon}{R + r} . R$$

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

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

**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 = $\ell_1$

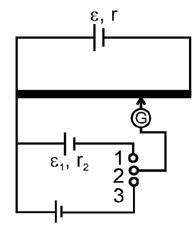
$\varepsilon_1 = x\ell_1$ ....(1)

**in case II,**

In figure (3) is joint to (2) then balance length = $\ell_2$

$\varepsilon_2 = x\ell_2$ ....(2)

$$\frac{\varepsilon_1}{\varepsilon_2} = \frac{\ell_1}{\ell_2}$$



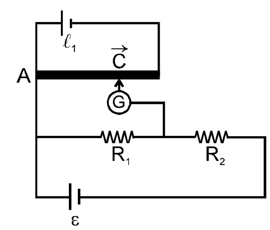

If any one of $\varepsilon_1$ or $\varepsilon_2$ is known the other can be found. If x is known then both $\varepsilon_1$ and $\varepsilon_2$ can be found

**(b) To find current if resistance is known**

$V_A \quad V_C = x\ell_1$

$IR_1 = x\ell_1$

$$I = \frac{x\ell_1}{R_1}$$

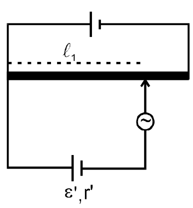


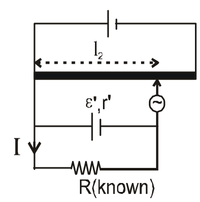

Similarly, we can find the value of $R_2$ also.

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.**

I[st] arrangement 2[nd] arrangement




by first arrangement $\varepsilon = x\ell_1$ ...(1)

by second arrangement $IR = x\ell_2$

$$I = \frac{x\ell_2}{R}, \quad \text{also } I = \frac{\varepsilon'}{r'+R}$$

$$\therefore \quad \frac{\varepsilon'}{r'+R} = \frac{x\ell_2}{R} \qquad \frac{x\ell_1}{r'+R} = \frac{x\ell_2}{R}$$

$$r = \frac{\ell_1 - \ell_2}{\ell_2} R$$

**(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)**

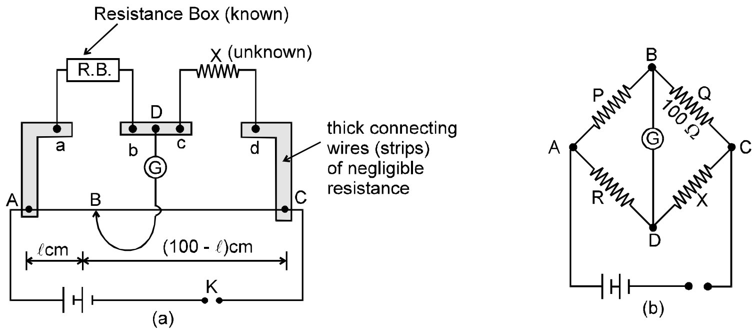
If AB = $\ell$ cm, then BC = (100 $\ell$) cm.

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

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

or $R = \sigma\ell$ ...(1)

where $\sigma$ is resistance per cm of wire.




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

$P \quad \ell \qquad\qquad P = \sigma(\ell)$

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

$Q \quad 100 \quad \ell$

$\therefore \qquad Q = \sigma(100 \quad \ell) \qquad$ ....(2)

Dividing (1) by (2), $\dfrac{P}{Q} = \dfrac{\ell}{100-\ell}$

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

$\therefore \qquad x = R\,\dfrac{Q}{P} \qquad$ or $\qquad X = \dfrac{100-\ell}{\ell}\,R$

Since R and $\ell$ are known, therefore, the value of X can be calculated.