CURRENT ELECTRICITY

1. ELECTRIC CURRENT

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

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

2. ELECTRIC CURRENT IN A CONDUCTOR

$$I = nAeV.$$

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

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

$$I = neAV_d$$

3. CURRENT DENSITY

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

4. ELECTRICAL RESISTANCE

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

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

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:

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

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

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 = $\int pdt$

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

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

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

9. **KIRCHHOFF'S LAWS**

9.1 **Kirchhoff's Current Law (Junction law)**

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

9.2 **Kirchhoff's Voltage Law (Loop law)**

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

10. **COMBINATION OF RESISTANCES :**

Resistances in Series:

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

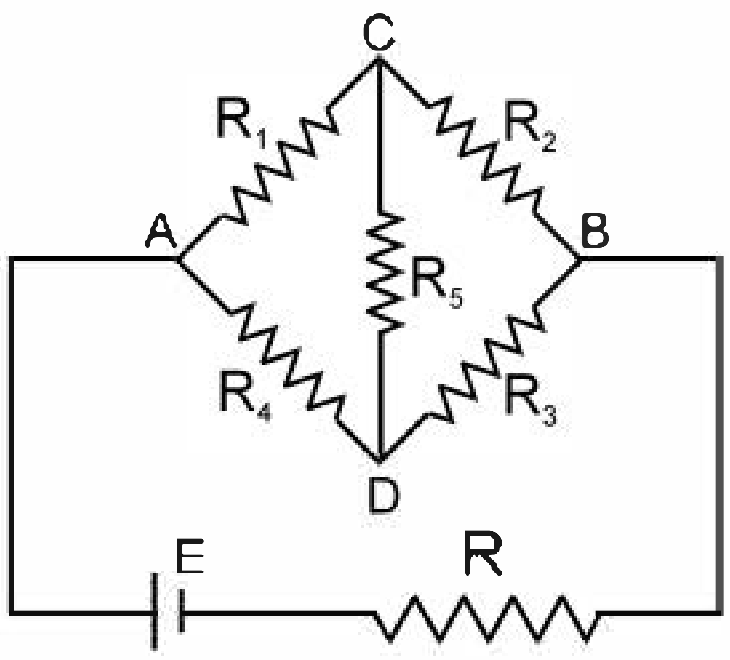
$V = V_1 + V_2 + V_3 + ... + V_n$

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

2. **Resistances in Parallel :**

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

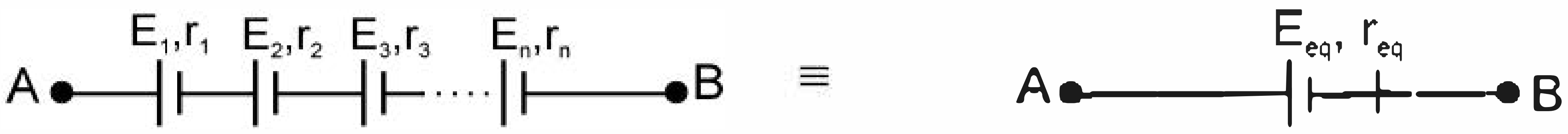
11. WHEATSTONE NETWORK : (4 TERMINAL NETWORK)



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 :

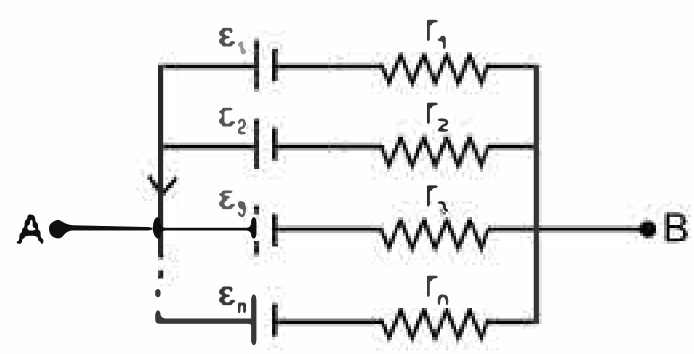


Equivalent EMF $E_{eq} = E_1 + E_2 + ... + E_n$ [write EMF's with polarity]

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

13.2 Cells in Parallel:

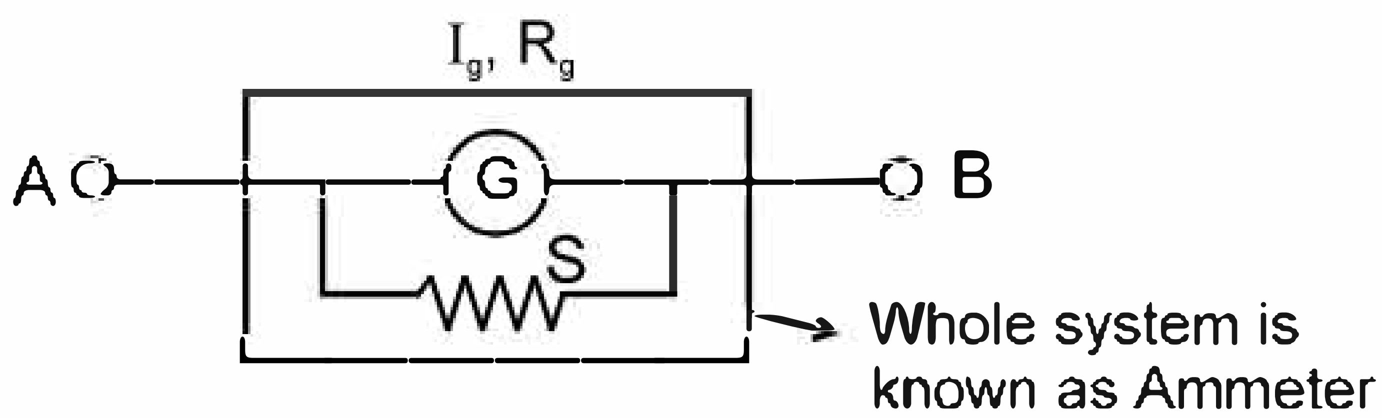
$$E_{eq} = \frac{\varepsilon_1/r_1 + \varepsilon_2/r_2 + ... + \varepsilon_n/r_n}{1/r_1 + 1/r_2 + ... + 1/r_n}$$ [Use emf with polarity]



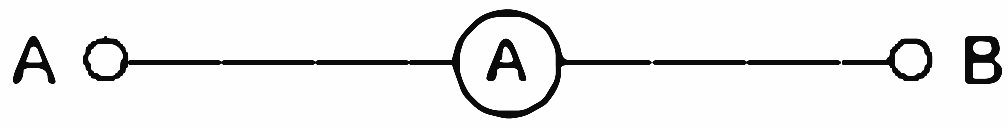
$$\frac{1}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2} + ... + \frac{1}{r_n}$$

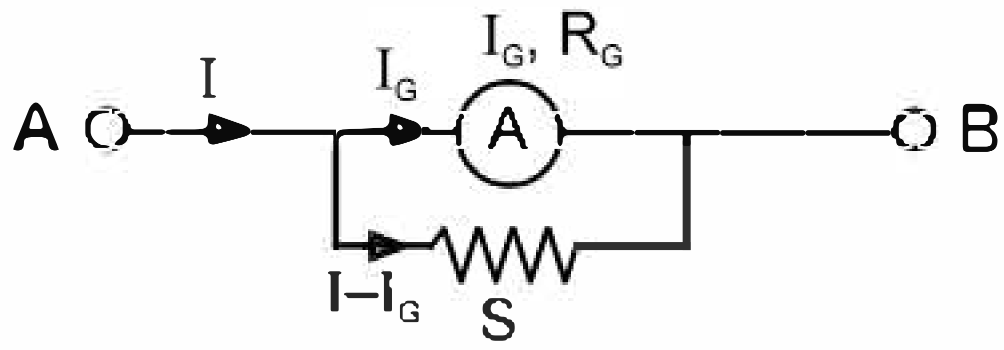
15. AMMETER

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 -





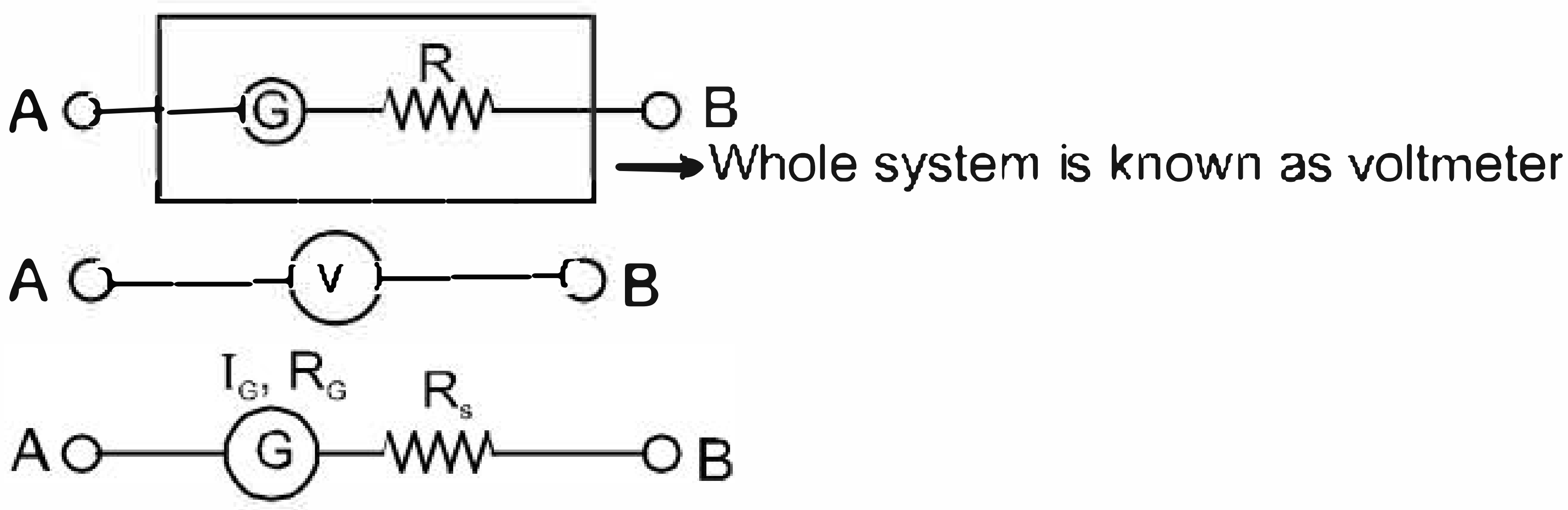
If maximum value of current to be measured by ammeter is I then
$I_G \cdot R_G = (I - I_G)S$

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

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.



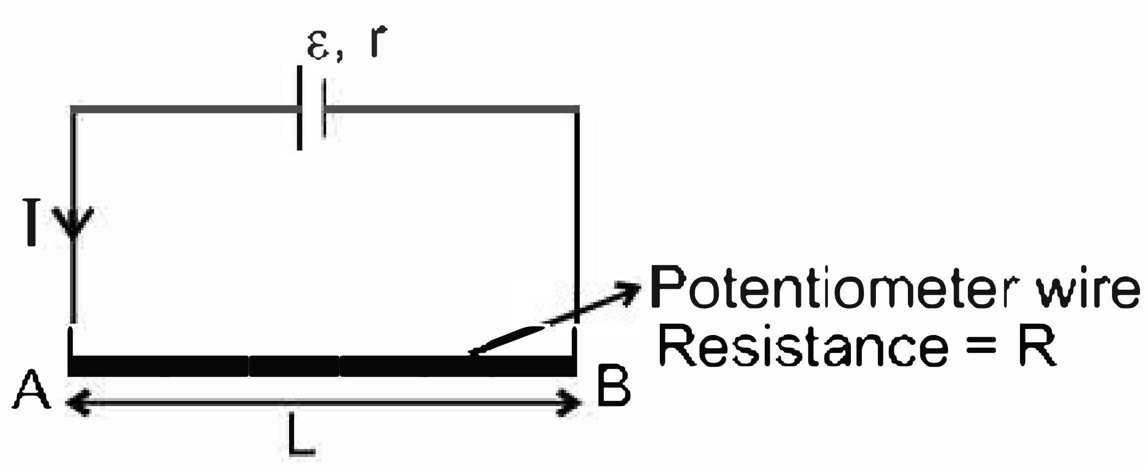
For maximum potential difference

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

$$R_S = \frac{V}{I_G} - R_G \qquad \text{If} \qquad R_G << R_S \Rightarrow R_S \approx \frac{V}{I_G}$$

17. POTENTIOMETER

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



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

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 = ℓ_1

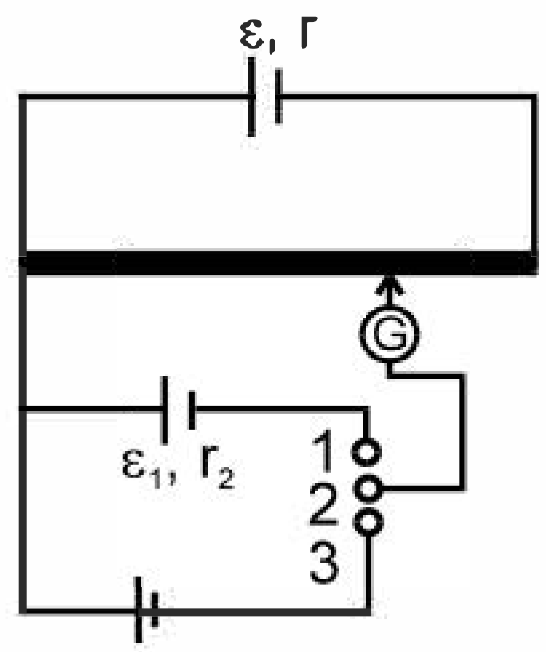
$\varepsilon_1 = x\ell_1$ ....(1)

in case II,

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

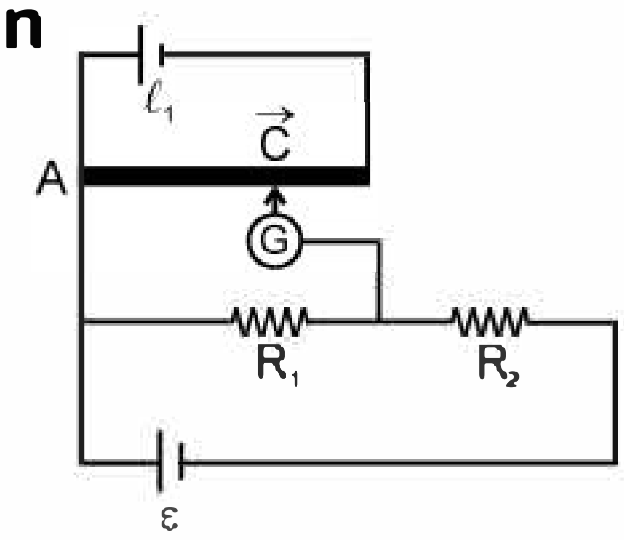
$\varepsilon_2 = x\ell_2$ ....(2)

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



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



$V_A - V_C = x\ell_1$

$IR_1 = x\ell_1$

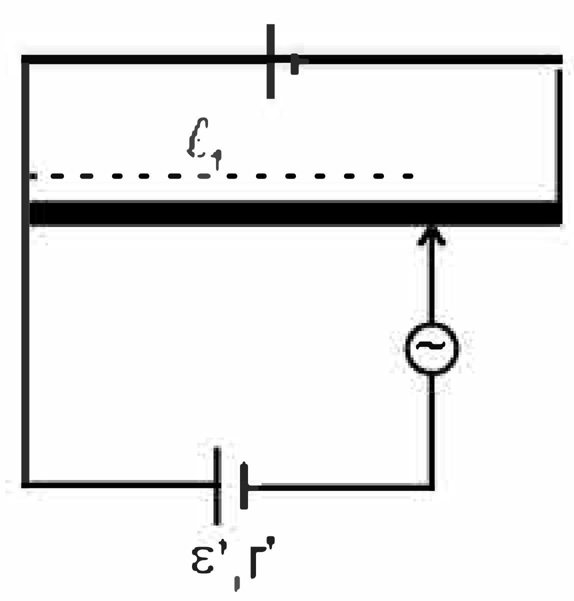
$$I = \frac{x\ell_1}{R_1}$$

Similarly, we can find the value of R_2 also.

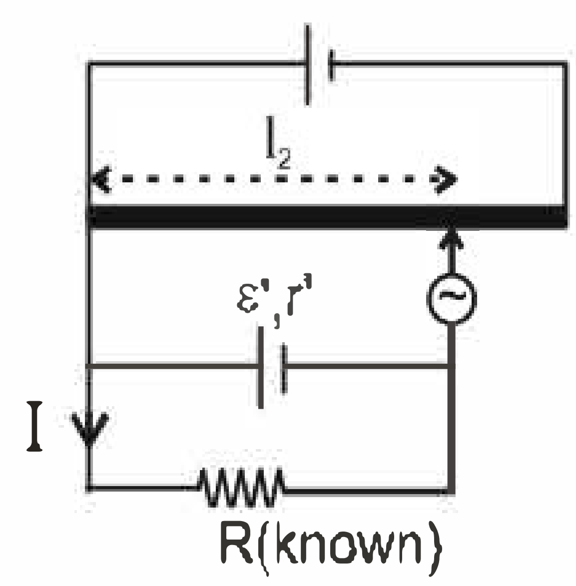
Potentiometer is ideal voltmeter because it does not draw any current from circuit, at the balance point.

(c) To find the internal resistance of cell.

I^{st} arrangement



2^{nd} arrangement



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

by second arrangement $\quad IR = x\ell_2$

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

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

$$r' = \left[\frac{\ell_1 - \ell_2}{\ell_2}\right]R$$

(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)

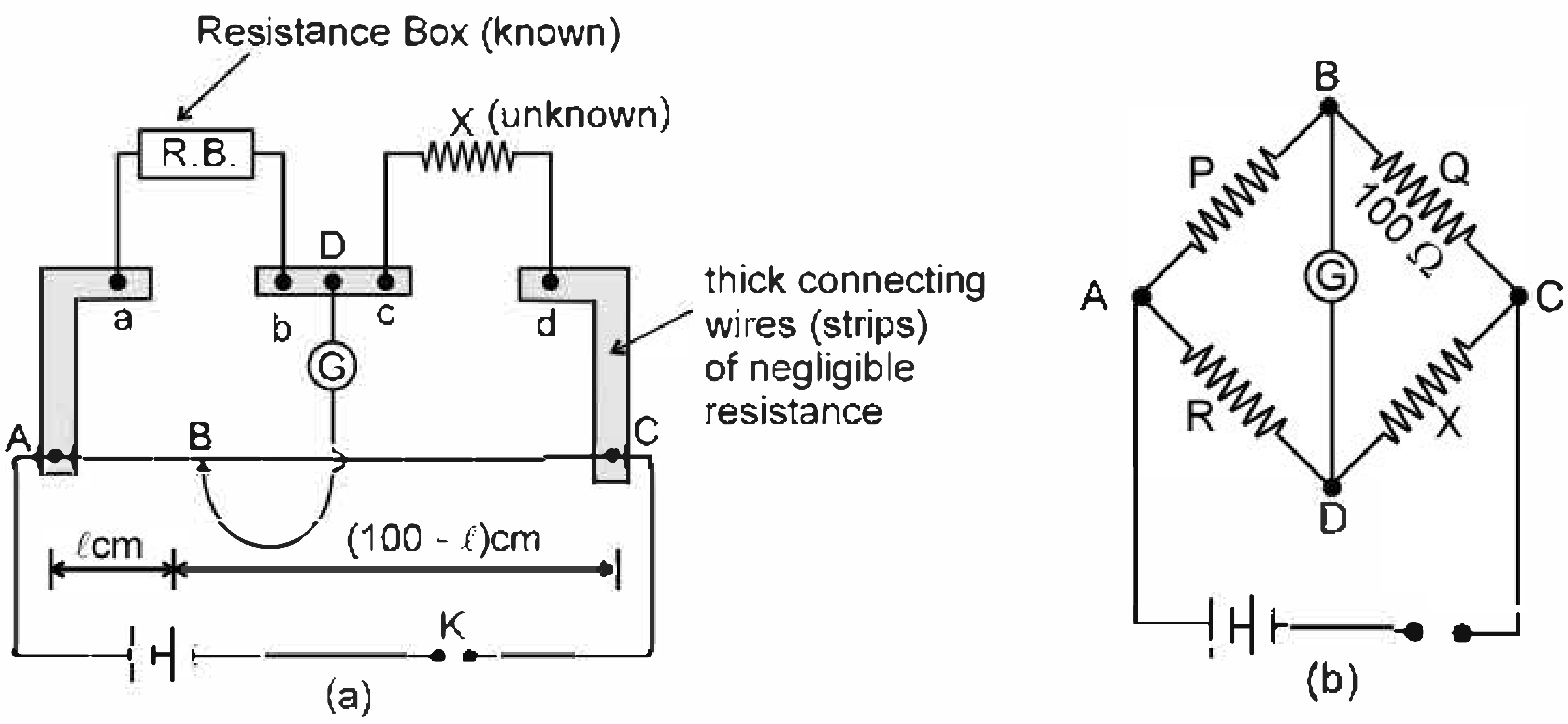
If AB = ℓ cm, then BC = $(100 - \ell)$ cm.

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

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

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

where σ is resistance per cm of wire.



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

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

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

$$Q \propto 100 - \ell$$

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

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

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

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

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