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POTENTIOMETER

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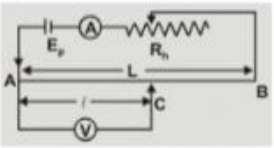
It is a device used to measure unknown potential difference accurately.

Working principle : The potential drop across any section of wire of uniform cross-section and composition is proportional to length of that section if a constant current flows through it.



If I is the current in potentiometer wire AB of uniform cross-sectional area A, length L and specific resistance ρ then unknown potential difference across AC is $V = \frac{I\rho\ell}{A}$ and known potential difference across AB is $E_p = \frac{I\rho L}{A}$

At balance point unknown potential difference = known potential difference

or $\frac{V}{\ell} = \frac{E_p}{L}$ or $V = \left(\frac{E_p}{L}\right)\ell$ or $V = x\,\ell$ so $V \propto \ell$.

where $x = E_p/L$ = potential gradient i.e. fall of potential per unit length of potentiometer.

Important Points

[1] Potentiometer was devised by **Poggendorf**.

[2] The positive terminals of driving cell and unknown cell must be connected to the same end of potentiometer wire to obtain a balance point.

[3] A balance point is obtained on potentiometer wire if the fall of potential along potentiometer wire due to driving cell E_p is greater than emf of cell to be balanced.

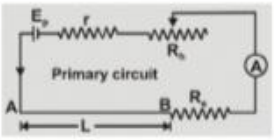
[4] The diameter of potentiometer wire must be uniform, specific resistance ρ must be large and temperature coefficient α of material of wire must be small.

[5] It is based of null deflection method i.e. while measuring emf it does not draw any current from source of driving emf.

[6] While measuring unknown potential difference the resistance of potentiometer wire becomes infinite.

POTENTIAL GRADIENT

The fall of potential per unit length of potentiometer wire is called potential gradient.



r = internal resistance of driving cell; R_h = resistance of rheostat, R_e = external series resistance, R is resistance of potentiometer wire, L is length of potentiometer wire.

The current through primary circuit $I = \frac{E_p}{r + R_h + R_e + R}$.

[1] If $R_h = 0$ and $R_e = 0$ $\quad x = x_{max} = \dfrac{E_p R}{(r+R)L}$

[2] $x = x_{min} = \dfrac{E_p}{R + R_h + R_e + R}\left(\dfrac{R}{L}\right)$

[3] $x = \dfrac{V}{L} = \dfrac{\text{current} \times \text{resistance of potentiometer wire}}{\text{length of potentiometer wire}} = I\left(\dfrac{R}{L}\right)$

where R/L is resistance per unit length of potentiometer wire.

[4] $R = \dfrac{\rho L}{A}$ or $\dfrac{R}{L} = \dfrac{\rho}{A}$ so $x = \dfrac{I\rho}{A} = \dfrac{I \times \text{specific resistance of material}}{\text{area of cross-section}}$

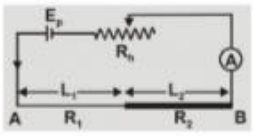
[5] Unit of potential gradient is volt/meter and dimensions are $M^1 L^1 T^{-3} A^{-1}$.

[6] The potential gradient depends only on primary circuit and is independent of secondary circuit.

[7] On increasing the temperature of potentiometer wire there is no change in potential gradient if a constant current is maintained. If current is altered due to change in resistance of wire then potential gradient will change.

[8] Keeping the thickness of potentiometer wire constant if the length is changed from L_1 to L_2 then ratio of potential gradient will be $\dfrac{x_1}{x_2} = \dfrac{L_2}{L_1}$

[9] If two wires of length L_1 and L_2, resistances R_1 and R_2 are joined in series with a battery of emf E_p and a rheostat than the ratio of potential gradients can be calculated as



$$x_1 = \left(\frac{E_p}{R_1 + R_2}\right)\frac{R_1}{L_1} \quad \text{and} \quad x_2 = \left(\frac{E_p}{R_1 + R_2}\right)\frac{R_2}{L_2} \quad \text{or} \quad \frac{x_1}{x_2} = \frac{R_1}{R_2} \cdot \frac{L_2}{L_1}$$

[10] The potential gradient depends on

(a) emf of battery in primary circuit (E_p) and its internal resistance (r).

(b) Length of potentiometer wire (L), its radius and its resistance (R).

(c) Specific resistance of material of wire (ρ).

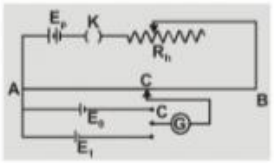
(d) Current flowing through the wire.

(e) Additional resistance like resistance of rheostat (R_h) and series external resistance (R_e).

5.	It has a high sensitivity.	Its sensitivity is low.
6.	It is used for various applications like measurement of internal resistance of cell, calibration of ammeter and voltmeter, measurement of thermo emf, comparision of emf's etc.	It is only used to measure emf or unknown potential difference.

Standardisation of Potentiometer

The process of determination of potential gradient on wire of potentiometer is known as standardisation of potentiometer. A standard cell is one whose emf remains constant. Cadmium cell with emf 1.0186 V at 20°C is used as a standard cell. In laboratory a Daniel cell with emf 1.08 V is usually used as a standard cell.



If ℓ_0 is the balancing length for standard emf E_0 then potential gradient $x = \frac{E_0}{\ell_0}$.

The unknown potential $E_1 = x\ell_1 = \left(\frac{E_0}{\ell_0}\right)\ell_1$.

Sensitivity of Potentiometer

[1] Smaller the potential difference that can be measured with a potentiometer more is the sensitivity of the potentiometer.

[2] The sensitivity of potentiometer is inversely proportional to potential gradient ($S \propto 1/x$).

[3] The sensitivity can be increased by (a) Increasing length of potentiometer wire (b) For a potentiometer wire of fixed length potential gradient is decreased by reducing the current in circuit.