CURRENT ELECTRICITY

6. POTENTIOMETER

POINTS TO REMEMBER

1. Potentiometer :

   It is a device which is used to

   a) compare the e.m.f.s of two cells,
   b) to determine the e.m.f of a cell
   c) determine the internal resistance of a cell
   d) calibrate a voltmeter and an ammeter
   e) determine the current in a circuit,
   f) determine unknown resistance,
   g) measure thermo emfs.

2. Potentiometer is a device used to compare the emf's of two cells. (or) to find the emf of a cell (or) to find the internal resistance of a cell (or) to measure potential difference.

   Unknown potential difference = Known potential difference.

3. **Comparison of emfs using potentiometer :**

   a) ℓ_1 and ℓ_2 are balancing lengths when two cells of emfs, E_1 and E_2 are connected in the secondary circuit.

   one after the other then, $\frac{E_1}{E_2} = \frac{\ell_1}{\ell_2}$

   b) By sum and difference method,

   $\frac{E_1 + E_2}{E_1 - E_2} = \frac{L_1}{L_2}$ or $\frac{E_1}{E_2} = \frac{L_1 + L_2}{L_1 - L_2}$.

4. Internal resistance of a cell

   $r = \left(\frac{E - V}{V}\right)R = \left(\frac{\ell_1 - \ell_2}{\ell_2}\right)R$

   When ℓ_1 = balancing length for the cell connected in the secondary circuit.

   ℓ_2 = balancing length when a resistance R is connected in parallel to the cell.

   E = emf of the cell in the secondary circuit

   V = Terminal voltage

LONG ANSWER QUESTIONS

1. Explain the principle of potentiometer. Describe a experiment for the comparison of e.m.fs of two cells.

A. **Potentiometer:** Potentiometer is a device used to compare the emf's of two cells. (or) to find the emf of a cell (or) to find the internal resistance of a cell (or) to measure potential difference.

Description: A potentiometer consists of uniform wire of length 10m arranged between A and B as 10 wires each of length 1m on a wooden board. The wire has specific resistance and low temperature coefficient of resistance (constantan (or) manganine A meter scale is arranged parallel to the wires to measure the balancing length. The resistance of the total wire of the potentiometer is about 5Ω. A Jockey J can be moved on the wire. The balancing length is measured from the end which is connected to the positive terminal of the battery.

Principle: An unknown emf (or) potential difference is compared with known variable potential difference produced on the potentiometer wire.

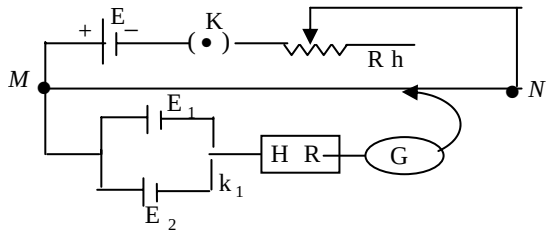
In null deflection position,

Unknown potential difference = Known potential difference.

When steady current passes through the uniform wire of the potentiometer, the potential difference across any part of the wire is directly proportional to the length of the wire.

Comparison of emf two cells : The circuit is shown in the diagram. In the primary circuit a cell of emf E, plug key K and a rheostat Rh are connected with positive terminal of the cell to M and negative terminal to N.

In the secondary circuit, the cells whose emfs are to be compare are connected as shown, with a two way plug key k_1, HR galvanometer G and Jockey J. The positive terminals of the cells are connected to M.



Primary circuit is closed by pressing the key k . Now the key k_1 is slided over to one side so that the cell E_1 is connected in the circuit. The balance point ℓ_1 is measurement by process the Jockey on the potentiometer wire. Now the key k_1 is slided over to other side so that the cell E_2 is connected in the circuit and balancing is point ℓ_2 is measured.

From the principle of potentiometer.

$E_1 \alpha \ell_1$ and $E_2 \alpha \ell_2$ $\Rightarrow \frac{E_1}{E_2} = \frac{\ell_1}{\ell_2}$

Precautions :

1. Jockey should not be dragged along the wire
2. The current value should be as small as possible
3. Current should be passed only while taking the readings.

2. Describe the construction and principle of potentiometer and explain how the internal resistance of a cell is determined by using potentiometer.

A. **Potentiometer :** Potentiometer is a device used to compare the emf's of two cells. (or) to find the emf of a cell (or) to find the internal resistance of a cell (or) to measure potential difference.

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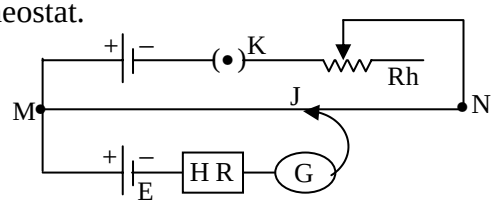
Principle: An unknown emf (or) potential difference is compared with known variable potential difference produced on the potentiometer wire.

In null deflection position,

Unknown potential difference = Known potential difference.

When steady current passes through the uniform wire of the potentiometer, the potential difference across any part of the wire is directly proportional to the length of the wire.

To measure the emf of a cell : A cell of emf E, plug key K and rheostat Rh are connected in series to the terminals M are N of the potentiometer wire. This is called primary circuit. A cell of emf $E_{1,a}$ high resistance HR, Galvanometer G and a Jockey J are connected a shown in the figure. This is called secondary circuit. Let R be the resistance in the rheostat.



The Jockey is pressure along the wire until the galvanometer shows zero deflection. Then the potential drop across the wire MJ is equal and opposite to the emf E_1. At the balancing condition there is no current, through the primary circuit. Let ℓ be the balancing length and ρ be the resistance per unit length of the potentiometer wire.

Potential difference across MJ = $i(\ell\rho)$

This potential difference is balanced against the cell of emf E_1 in the secondary.

$$\therefore\ E_1 = i\,\ell\,\rho = (i\rho)\ell \ldots\ldots (1)$$

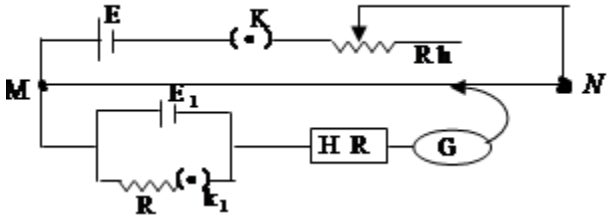
Where $i\rho$ is the potential difference per unit the length of the wire (potential gradient). This can be determined by using a standard cadmium cell $(E_3 = 1.018V)$ in the secondary circuit. When the cadmium cell is connected in the circuit,

$$E_S = (i\rho)L_s \qquad \Rightarrow (i\rho) = \frac{E_s}{L_s}$$

From equation (1), $\quad E_1 = \left(\frac{E_s}{L_s}\right)\ell \quad \Rightarrow E\alpha\,\ell$

To find the internal resistance of a cell : In the primary circuit the positive terminal of the cell of emf E is connected to the end M. The negative terminal is connected to N through a plug key K and rheostat Rh. In the secondary circuit, a cell E_1 whose internal resistance is to be determined is connected through galvanometer, HR and Jockey J. The positive terminal of the cell E_1 is connected to the end M of the potentiometer wire.

A known resistance R is connected across the cell E_1 through a plug key k_1 as shown



The primary circuit is closed by the pressing the key K. The key k_1 is open, so that the resistance R is not connected in the secondary circuit and the balancing length ℓ_1 is measured

$\therefore E_1 \alpha \ell_1$ …(1)

Now the key k_1 is pressure so that R is included in the secondary circuit and the balancing point ℓ_2 is the measured. Let r be the internal resistance of the cell E_1. The potential difference across the resistance of the secondary is given by

$V = \left(\frac{E_1}{R+r}\right)R$

$\therefore V \alpha \ell_2$ …(2)

From (1) and (2) $\frac{E_1}{V} = \frac{\ell_1}{\ell_2}$ (or) $\frac{E_1(R+r)}{E_1 R} = \frac{\ell_1}{\ell_2}$

$\frac{R+r}{R} = \frac{\ell_1}{\ell_2}$ (or) $1 + \frac{r}{R} = \frac{\ell_1}{\ell_2}$

$\frac{r}{R} = \frac{\ell_1}{\ell_2} - 1 = \frac{\ell_1 - \ell_2}{\ell_2} \quad \Rightarrow r = \left(\frac{\ell_1 - \ell_2}{\ell_2}\right)R$

This experiment is repeated for varying values of R and the average internal resistance 'r' can be determined.

Precautions :

1. Jockey should not be dragged along the wire
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SHORT ANSWER QUESTIONS

1. Explain the principle of potentiometer.

A. Potentiometer is a device used to compare the emf's of two cells. (or) to find the emf of a cell (or) to find the internal resistance of a cell (or) to measure potential difference.

Principle: An unknown emf (or) potential difference is compared with known variable potential difference produced on the potentiometer wire.

In null deflection position,

Unknown potential difference = Known potential difference.

When steady current passes through the uniform wire of the potentiometer, the potential difference across any part of the wire is directly proportional to the length of the wire.

Very Short Answer Questions

1. Which of the two, namely voltmeter and potentiometer is preferable to measure the e.m.f of a battery. Why?

A. Potentiometer is preferable to measure the e.m.f of a battery because it does not draw any current from the cell whose emf is to be measured.

2. What is the principle of potentiometer?

A. An unknown emf (or) potential difference is compared with known variable potential difference produced on the potentiometer wire.
In null deflection position,
Unknown potential difference = Known potential difference.

3. What are the advantages of using a potentiometer?

A. Advantages of using a potentiometer:

1. It is a null deflection method. Hence sensitivity is high.

2. When the potentiometer is balanced, there is no current passing through the potentiometer. Hence measurement of potential difference will be accurate (when compared to a voltmeter).

1. When the potentiometer is balanced, there is no current passing through the cell in the secondary circuit. Hence e.m.f of a cell can be measured accurately

2. E.M.F and internal resistance of a cell can be measured accurately.

SOLVED PROBLEMS

1. A cell in the secondary circuit gives null deflection for 1.5m length of a potentiometer of total length 10m. Find the position of the null point when the total length of the potentiometer wire is increased by one meter without changing the cell in the primary circuit. The emf of the cell in the primary circuit is 10V.

Sol. $\frac{V}{l}=\left(\frac{E}{r+R+R_S}\right)\frac{R}{L}$

As there is no series resistance, $R_S=0$ and assuming that the internal resistance of the cell in the primary circuit is zero i.e., r = 0, we get

$$\frac{V}{l}=\left(\frac{E}{L}\right).$$

When the length of the potentiometer wires changes from L_1 to L_2 keeping ε and V constant then the balancing length changes from l_1 and l_2.

$$\therefore \frac{l_1}{l_2}=\frac{L_1}{L_2}$$

L_1 = 10 m, $l_1=1.5\text{m}, L_2=11\text{m}, l_2=?$

$$\frac{1.5}{l_2}=\frac{10}{11} \quad \Rightarrow l_2=\frac{1.5\times 11}{10}=1.65\text{m}$$

2. A cell emf 1.25V when placed in the secondary circuit gives the balance point at 35 cm. The cell is replaced by another cell and the new balance point is 63 cm. Find the emf of the second cell.

Sol. $\frac{E_1}{E_2}=\frac{l_1}{l_2} \Rightarrow E_2=E_1\left(\frac{l_2}{l_1}\right)=1.25\times\frac{63}{35}=2.25\text{V}$

UNSOLVED PROBLEMS

1. In a potentiometer experiment, the balancing length with a cell is 560 cm. When an external resistance of 10Ω is connected in parallel to the cell, the balancing length changes by 60 cm. find the internal resistance of the cell.

A. $l_1 = 560\,cm \;\; ; \;\; R = 1\Omega$

Change in balancing length $= l_1 - l_2 = 60m$

$l_2 = l_1 - 60 = 560 - 60 = 500cm$

Internal resistance of cell = $r = \left(\frac{l_1 - l_2}{l_2}\right) R = \frac{60 \times 10}{500} = 1.2\Omega$

2. In a potentiometer experiment when a battery of emf 2 V is included in the secondary circuit. The balance point is 500 cm. Find the balancing length from the same end when cadmium cell of e.m.f 1.108V is connected to the secondary circuit.

A. $\frac{E_2}{E_1} = \frac{l_2}{l_1} \;\; \Rightarrow \; l_2 = \frac{E_2}{E_1}.l_1 = \frac{1.018}{2} \times 500$

$\therefore l_2 = 254.5cm$

3. In the secondary circuit of a potentiometer, a cell of internal resistance 1.5Ω gives a balancing length of 52 cm. to get a balancing length of 40 cm, how much resistance is to be connected across the cell?

A. $r = 1.5\Omega \;\; ; \;\; l_1 = 52cm \;\; ; \;\; l_2 = 40cm$

External resistance = R

$r = \left(\frac{l_1 - l_2}{l_2}\right) R \Rightarrow R = \frac{rl_2}{l_1 - l_2} = \frac{1.5 \times 40}{52 - 40} = 5\Omega$