CURRENT ELECTRICITY

POTENTIOMETER

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A potentiometer is used to compare e. m. fs. of two cells or to measure internal resistance of a cell.

Principle:

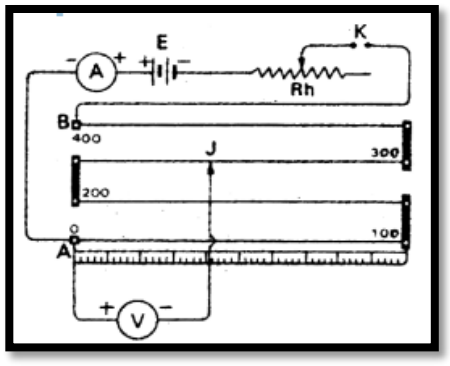
The potentiometer is based upon the principle that when a constant current is passed through a wire of uniform area of cross-section, the potential drop across any portion of the wire is directly proportional to the length of that portion.

Construction:

A potentiometer consists of a number of segments of wire of uniform area of cross section stretched on a wooden board between two thick copper strips. Each segment of wire is 100 cm long. The wire is usually of constantan or manganin. A meter rod is fixed parallel to its length. A battery connected across the two end terminals sends current through the wire, which is kept constant by using a rheostat.

Theory:

Let V be potential difference across certain portion of wire, whose resistance is R. If I is the current through the wire, then $V = IR$



We know that $\therefore R = \rho \frac{l}{A},$

Where l, A and ρ are length, area of cross-section and resistivity of the material of wire respectively.

$$R = I\rho \frac{l}{A}$$

If a constant current is passed through the wire of uniform area of cross-section, then I and A are constants. Since, for a given wire, ρ is also constant, we have

$$V = \text{constant} \times l$$

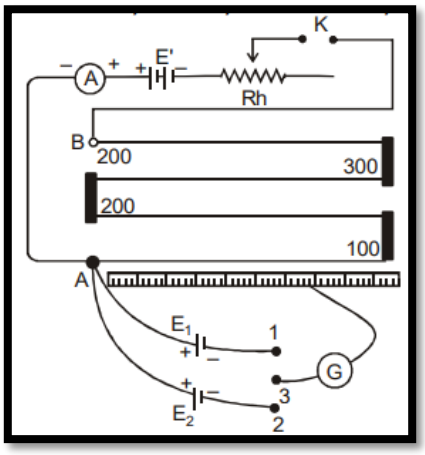
$$V \propto l$$

Hence, if a constant current flows through a wire of uniform area of cross-section, then potential drop along the wire is directly proportional to the length of the wire

Applications of a potentiometer. A potentiometer can be put to following uses:

1. To compare e. m. fs. of two cells:

Two cells, whose e. m. fs. Are E_1 and E_2, can be compared by making use of the circuit as shown in figure. The positive poles of both the cells are connected to the terminal A of the potentiometer. The negative poles of the two cells are connected to terminals 1 and 2 of a two-way key. while its common terminal is connected to a jockey j through a galvanometer G. An auxiliary or driver battery of e. m. f E′, an ammeter A, rheostat Rh and a one-way key K are connected between the end terminals A and B of the potentiometer. Thus, the positive poles of the two cells as well as the positive pole of auxiliary battery are connected at the common point A. It may be pointed that the e. m. f of auxiliary battery should always be greater than the e. m. f of either of the two cells.



To compare the e. m. fs of the two cells, a constant current is passed through the potentiometer wire between points A and B. The current is kept constant by using the rheostat.

When the plug is put in the gap between the terminals 1 and 3 of the two-way key, the cell of e. m. f. E1 will come in the circuit. Suppose the balancing length (between points A and J) is l_1. If x is the resistance per unit length of the potentiometer wire and I, the constant current flowing through it, then

$$E_1 = (X1_1)I$$

When the key is put in the gap between the terminals 2 and 3 and removed from the gap between 1and 3, the cell of e. m. f E_2 will be included in the circuit. Let the balancing length be l_2 in this case. Then,

$$E_2 = (X1_2)I$$

Dividing above equation

$$\frac{E_1}{E_2} = \frac{l_1}{l_2}$$

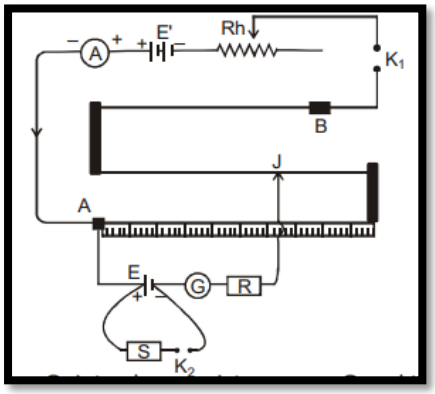
Note:

It may be pointed out that the e. m. f of auxiliary battery should always be greater than the e. m. f. of the either of the two cells.

2. to measure internal resistance of a cell.

The internal resistance of a cell may be found by using a potentiometer by setting up the circuit as shown in figure.

A constant current I is maintained through the potentiometer wire with the help of the rheostat. Plug in the key K_2 is kept out and the jockey is moved over the potentiometer wire so as to balance the e. m. f. E of the cell, whose internal resistance is to be found. Let l_1 be the balancing length of the potentiometer wire between point A and jockey J. If x is resistance per unit length of the wire, then



$$E = (x\, l_1)\, I$$

With the help of resistance box S, introduce resistance say S and then put the plug-in key K_2. Now find the balance point for the terminal potential difference V between the two poles of the cell. If l_2 is the balancing length, then

$$V = (x\, l_2)\, I$$

Dividing above equation, we have

$$\frac{E_1}{E_2} = \frac{l_1}{l_2}$$

The internal resistance* of the cell is given by

$$r = \left[\frac{E}{V} - 1\right] S$$

Using above equation, we have

$$r = \left[\frac{l_1}{l_2} - 1\right] S \text{ or } r = \frac{l_1 - l_2}{l_2} \times S$$

Knowing the values of l_1, l_2 and S, the internal resistance r of the cell can be found.

Note:

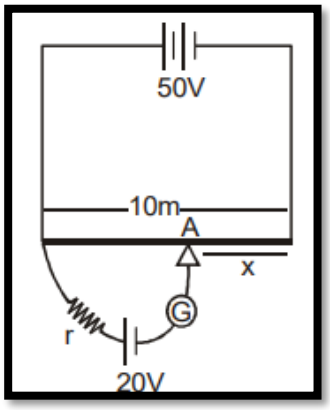
Apart from uses, a potentiometer can be used to compare unknown resistances and to calibrate voltmeter or an ammeter.

We use potentiometer for two tasks:

(i) to find emf of a cell

(ii) to find internal resistance of a cell We will first analyses the first task $\rightarrow$ to find emf of a cell through some examples.

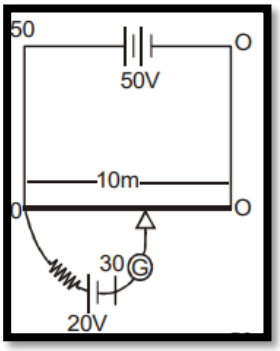
Ex. Find the value of x if A is the null point?



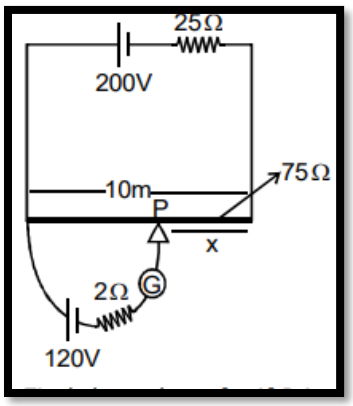
Sol. Potential gradient $= \frac{50}{10} \quad = 5$ V/m

For 20V potential difference

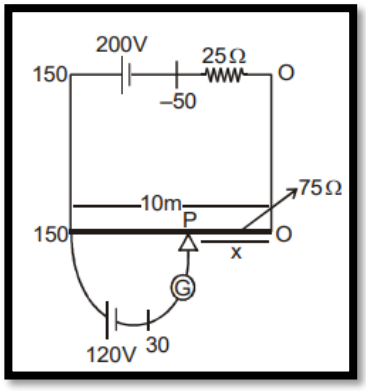
$\Rightarrow \frac{20}{5} = 4m \qquad \therefore x = 10 - 4 = 6$m



Ex. Find the value of x if P is a null point



Sol. Current in the main circuit



$200 - 25\,i - 75\,i = 0$

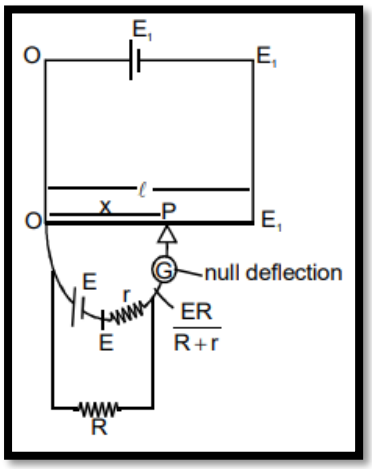
$i = 2\ A$

$$\text{Potential gradient} = \frac{150V}{10m} = 15V/m$$

$$\text{For 120 V} \Rightarrow \frac{120V/m}{15V} = 8m$$

$x = 10$ ñ $8 = 2m$

Now we will analyses the other task to find internal resistance of the cell using potentiometer The main key point is that first analyses the main circuit then the auxiliary circuit



(Supplementary circuit)

$$\text{Potential gradient} = \frac{E_1}{\ell}$$

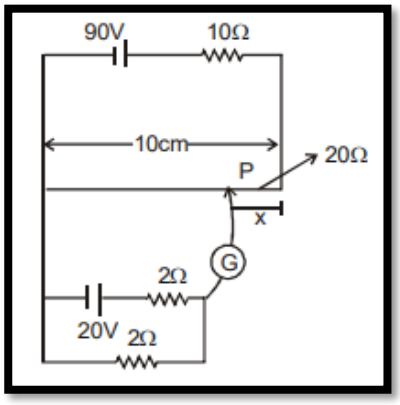
Now for the auxiliary circuit

$$i = \frac{E}{R+r}$$

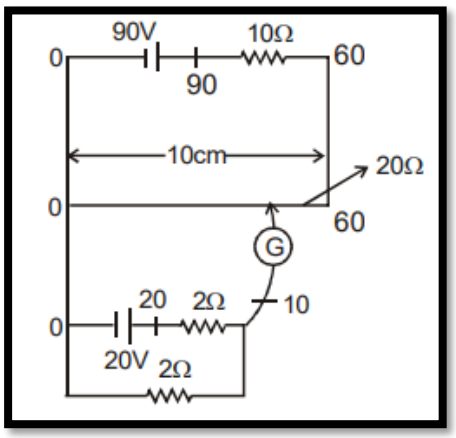
$$E - ir = E - \frac{Er}{R=r} = \frac{ER}{R+r} \qquad \therefore \ \frac{ER}{R+r} = \frac{E_1}{\ell} X$$

Let we take some examples to understand the topic in better way.

Ex. Find x if P is a null point?



Sol. First analyzing the main circuit,



$90 - 10i_1 - 20\, i_1 = 0$

$i_1 = 3$ A.

$$\text{Potential gradient} = \frac{60V}{10m} = 6\text{V/m}$$

Now analyzing the auxiliary circuit

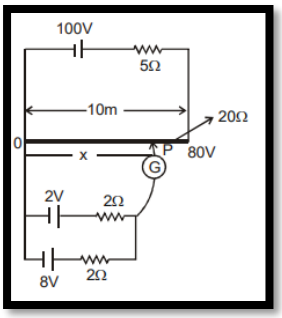
$20 - 2i_2 - 2i_2 = 0$

$i_2 = 5$ A.

$$\text{For 10 Ve} \Rightarrow \frac{10}{6} = \frac{5}{3}m$$

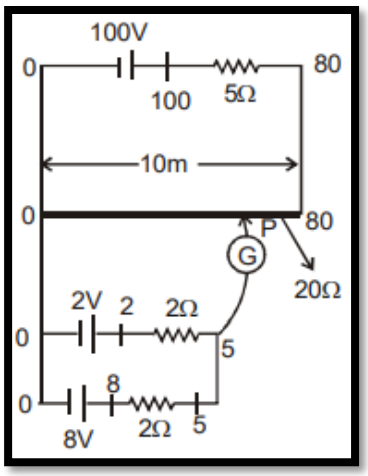
$$x = 10 - \frac{5}{3} = \frac{25}{3}m$$

Ex. Find x if P is a null point?



Sol. $100 - 5i_1 - 20\, i_1 = 0$

$i_1 = 4$ A



$$\text{Potential gradient} = \frac{80}{10} = 8\text{V/m}$$

$8 - 2i_2 - 2i_2 - 2 = 0$

$$i_2 = \frac{3}{2}A$$

$$\text{for 5 volts} \Rightarrow \frac{5V}{8V/m} = \frac{5}{8}m$$

$$X = \frac{5}{8}m$$