Potentiometer.

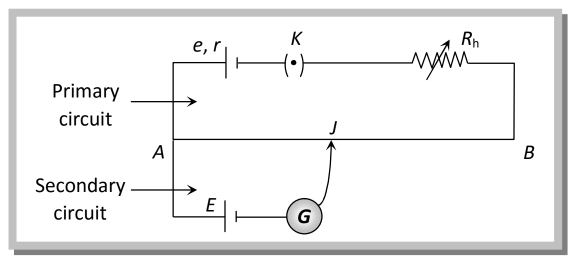
Potentiometer is a device mainly used to measure emf of a given cell and to compare emf's of cells. It is also used to measure internal resistance of a given cell.

(1) Superiority of potentiometer over voltmeter: An ordinary voltmeter cannot measure the emf accurately because it does draw some current to show the deflection. As per definition of emf, it is the potential difference when a cell is in open circuit or no current through the cell. Therefore voltmeter can only measure terminal voltage of a give n cell.

Potentiometer is based on no deflection method. When the potentiometer gives zero deflection, it does not draw any current from the cell or the circuit i.e. potentiometer is effectively an ideal instrument of infinite resistance for measuring the potential difference.

(2) Circuit diagram: Potentiometer consists of a long resistive wire AB of length L (about 6m to 10 m long) made up of mangnine or constantan. A battery of known voltage e and internal resistance r called supplier battery or driver cell. Connection of these two forms primary circuit.

One terminal of another cell (whose emf E is to be measured) is connected at one end of the main circuit and the other terminal at any point on the resistive wire through a galvanometer G. This forms the secondary circuit. Other details are as follows



J = Jockey

K = Key

R = Resistance of potentiometer wire,

ρ = Specific resistance of potentiometer wire.

Rh = Variable resistance which controls the current through the wire AB

(3) Points to be remember

(i) The specific resistance (ρ) of potentiometer wire must be high but its temperature coefficient of resistance (α) must be low.

(ii) All higher potential points (terminals) of primary and secondary circuits must be connected together at point A and all lower potential points must be connected to point B or jockey.

(iii) The value of known potential difference must be greater than the value of unknown potential difference to be measured.

(iv) The potential gradient must remain constant. For this the current in the primary circuit must remain constant and the jockey must not be slided in contact with the wire.

(v) The diameter of potentiometer wire must be uniform everywhere.

(4) Potential gradient (x): Potential difference (or fall in potential) per unit length of wire is called potential gradient i.e. $x = \frac{V}{L}\frac{volt}{m}$ where $V = iR = \left(\frac{e}{R + R_h + r}\right).R$. So

$$x = \frac{V}{L} = \frac{iR}{L} = \frac{i\rho}{A} = \frac{e}{(R + R_h + r)}.\frac{R}{L}$$

(i) Potential gradient directly depends upon

(a) The resistance per unit length (R/L) of potentiometer wire.

(b) The radius of potentiometer wire (i.e. Area of cross-section)

(c) The specific resistance of the material of potentiometer wire (i.e. ρ)

(d) The current flowing through potentiometer wire (i)

(ii) x indirectly depends upon

(a) The emf of battery in the primary circuit (i.e. e)

(b) The resistance of rheostat in the primary circuit (i.e. Rh)

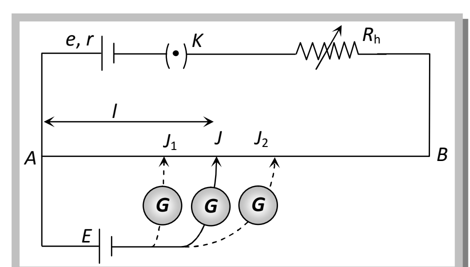
Note: When potential difference V is constant then $\frac{x_1}{x_2} = \frac{L_2}{L_1}$

Two different wire are connected in series to form a potentiometer wire then $\frac{x_1}{x_2} = \frac{R_1}{R_2}.\frac{L_2}{L_1}$

If the length of a potentiometer wire and potential difference across its ends are kept constant and if its diameter is changed from d1 $\rightarrow$ d2 then potential gradient remains unchanged.

The value of x does not change with any change effected in the secondary circuit.

(5) Working: Suppose jockey is made to touch a point J on wire then potential difference between A and J will be $V = xl$

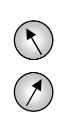


At this length (l) two potential difference are obtained

(i) V due to battery e and

(ii) E due to unknown cell

If V > E then current will flow in galvanometer circuit in one direction



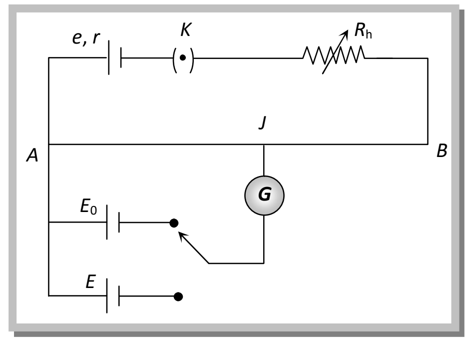
If V < E then current will flow in galvanometer circuit in opposite direction

If V = E then no current will flow in galvanometer circuit this condition to known as null deflection position, length l is known as balancing length.

In balanced condition $E = xl$ or $E = xl = \frac{V}{L}l = \frac{iR}{L}l = \left(\frac{e}{R + R_h + r}\right) \cdot \frac{R}{L} \times l$

Note: If V is constant then $L \propto l$ $\Rightarrow \frac{L_1}{L_2} = \frac{l_1}{l_2}$

(6) Standardization of potentiometer: The process of determining potential gradient experimentally is known as standardization of potentiometer.



Let the balancing length for the standard emf E0 is l0 then by the principle of potentiometer E0 = xl0 $\Rightarrow x = \frac{E_0}{l_0}$

(7) Sensitivity of potentiometer: A potentiometer is said to be more sensitive, if it measures a small potential difference more accurately.

(i) The sensitivity of potentiometer is assessed by its potential gradient. The sensitivity is inversely proportional to the potential gradient.

(ii) In order to increase the sensitivity of potentiometer

(a) The resistance in primary circuit will have to be decreased.

(b) The length of potentiometer wire will have to be increased so that the length may be measured more accuracy.

(8) Difference between voltmeter and potentiometer

	Voltmeter	Potentiometer
(i)	It's resistance is high but finite	Its resistance is high but infinite
(ii)	It draws some current from source of emf	It does not draw any current from the source of

		known emf
(iii)	The potential difference measured by it is lesser than the actual potential difference	The potential difference measured by it is equal to actual potential difference
(iv)	Its sensitivity is low	Its sensitivity is high
(v)	It is a versatile instrument	It measures only emf or potential difference
(vi)	It is based on deflection method	It is based on zero deflection method