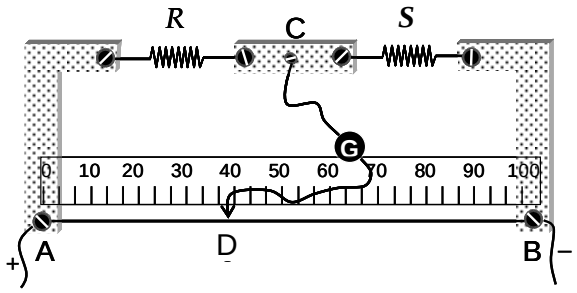
5. Electrical Measurement

1.Meter Bridge:

Principle: A *meter bridge* works on the principle of Wheatstone's bridge.

Construction: A one meter long **constantan** (or manganin) wire of uniform resistance (λ Ω/cm) is stretched between *A* and *B*, the points on the two thick copper stripes. A meter scale is set parallel to it. Two resistances *R* (unknown) and *S* (known called standard resistance) are inserted in the gaps of the copper stripes as shown in the figure. Point C is on the middle copper stripe, between the resistances *X* and *R*. A galvanometer is connected between C and a jockey, which slides over the wire. *Emf* is connected between *A* and *B*.



Working: When circuit is completed current flows through the galvanometer. Jockey is moved on the wire from *A* to *B* and a position *D* is found such that the reading of galvanometer becomes zero. In this state the bridge is balanced. The position of jockey *AD* = *x* is read on the meter scale.

Calculation: By balancing condition $\frac{R}{\lambda x}=\frac{S}{\lambda(100-x)}$. Or, $R=\frac{x}{(100-x)}S$.

Thus by reading *x*, the unknown resistance *R* is determined.

2.Sensitivity of meter bridge:

For high sensitivity:

(i) High resistance device (battery or galvanometer) is connected between junctions of two highest and two lowest resistances. Generally galvanometer has resistance more than that of a cell, hence for high sensitivity, galvanometer is added between two high and two low resistance junctions. In the given figure *R* and *S* must be either both high or both low.

(ii) The standard resistor is chosen such that null point lies nearly in the middle of the wire (between 30cm to 70cm).

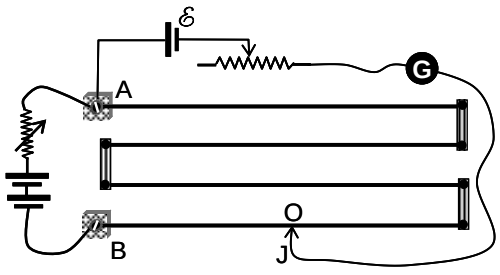
3.Limitations of a meter bridge:

➠ For very high and very low resistances can't be measured by the galvanometer due to end effects. For measuring low resistances ***Carey-Foster*** bridge is used.

4.Potentiometer:

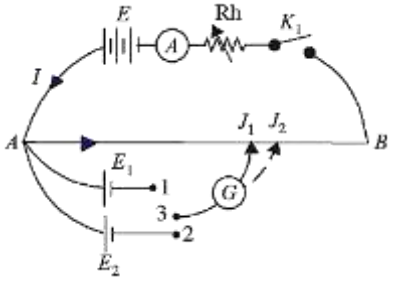
Potentiometer is a device used to compare the emf of two cells.

Construction: It consists of a long ***manganin*** wire connected between points *A* and *B*. Meter scale is provided along the wire. An HT battery is joined between *A* and *B* (*A* to the +ve terminal of HT). An auxiliary circuit with an emf seat *E*, a rheostat and a galvanometer is jointed between point *A* and jockey (*J*) which slides on the potentiometer wire.



5.Comparison of emfs of two cells by Potentiometer:

The positive terminals of the cells (E_1 and E_2) are connected to the positive terminal *A* of the potentiometer wire *AB*. The negative terminals of the cells are connected to terminals 1 and 2 of a two way key. The common terminal 3 of the two-way key is connected to the jockey through a galvanometer *G*.



Comparison of emf

(i) The key K_1 is closed and current in potentiometer wire is adjusted to a suitable constant value (say I) with the help of the rheostat. The rheostat setting is not to be disturbed throughout the experiment.

(ii) The terminals 1 and 3 are closed by a plug so that only the cell of e.m.f. E_1 is active in the circuit. The jockey is moved on the potentiometer wire till galvanometer reads zero (null point). Let this point be J_1 on the wire and let distance $AJ_1 = l_1$.

(iii) The plug between the terminals 1 and 3 is removed and is inserted between terminals 2 and 3. Thus the cell of e.m.f. E_2 is active in the circuit. The procedure is repeated till null point is obtained at point J_2 on the potentiometer wire. Let distance $AJ_2 = l_2$.

Calculation: When jockey is at null point no current flows through the galvanometer. Supposed resistance of the potentiometer wire per unit length is λ.

Hence $E_1 = I\lambda l_1$ and $E_2 = I\lambda l_2$. Now $\boxed{\frac{E_1}{E_2} = \frac{l_1}{l_2}}$.

If one of the emf is known, another can be determined.

6.Determination of internal resistance of a cells by potentiometer:

The emf seat whose internal resistance is to be determined is inserted in auxiliary circuit and a resistance R is given parallel to it as shunt.

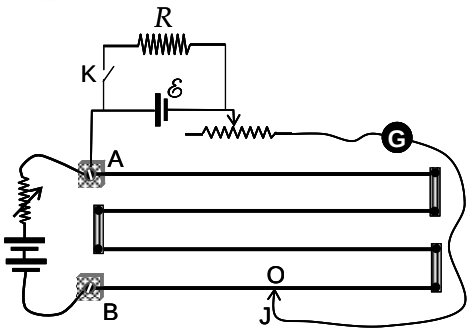
Let internal resistance = r.

When K is open, null point is obtained at x_1 from A. After K is pressed, null point is determined again. Let it be x_2 from A.

Calculation: When K is open, $E = I\lambda x_1$,

When K is closed, $V = I\lambda x_2$, where V is terminal pd of the cell because current is flowing through the emf seat.

Now $\frac{E}{V} = \frac{x_1}{x_2}$. $\Rightarrow \frac{I(R+r)}{IR} = \frac{x_1}{x_2}$. $\Rightarrow 1 + \frac{r}{R} = \frac{x_1}{x_2}$, or, $\boxed{r = \frac{x_1 - x_2}{x_2} R}$.



Determination of internal resistance

7. Reasons of no null point:

No null point is obtained, if:

(i) The connection of cell is wrong, i.e., positive of ***E*** is connected to point B in place of A.

In this case the current through the galvanometer *grows* as jockey is moved from A to B and never becomes zero.

(ii) The experimental cell has emf greater than total potential drop across the potentiometer wire.

In this case, current through the galvanometer falls as jockey is moved from A to B but never becomes zero.

8.Sensitiveness of a potentiometer:

The **sensitiveness** of a potentiometer indicates the smallest potential difference that can be measured with it. Sensitiveness *S* of the potentiometer is given as the length of the wire through which fall of potential is unity. This is inverse of potential gradient (fall of the potential per unit length) of the potentiometer wire. Therefore $S = L/V$.

Therefore, the sensitivity of a potentiometer can be increased by decreasing the potential gradient by:

(*i*) increasing the length of potentiometer wire.

(*ii*) reducing the current in the potentiometer wire with a resistance in series with potentiometer wire. This is equivalent to increasing the length of potentiometer wire.

9.Advantages and disadvantages of potentiometer:

Advantages:

(*i*) It is a null-deflection method therefore, the balance condition can be found with a high degree of sensitivity.

(*ii*) No current is drawn from the circuit under test. Therefore, it can measure the e.m.f. of a cell accurately.

(*iii*) The scale can be made long for maximum accuracy.

(*iv*) Results are dependent only on measurements of lengths and the values of standard resistances and standard e.m.f.s.

(*v*) The potentiometer is more accurate than the moving-coil voltmeter for measuring the e.m.f. The moving coil voltmeter has finite resistance and while connected across a cell, and draws current. Therefore, the voltmeter measures the e.m.f. of a cell approximately.

(*vi*) A potentiometer is a voltmeter with infinite resistance. Therefore, it is an ideal *voltmeter*.

Disadvantages

(*i*) It is slow in operation.

(*ii*) The potentiometer wire must be of uniform thickness.

(*iii*) The temperature of potentiometer wire must remain constant.

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