Potentiometer, Cell & their Combinations

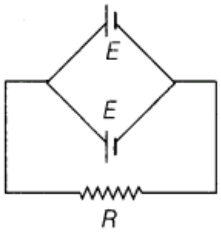
1 Mark Questions

1.State the underlying principle of a potentiometer? [Delhi 2014 c]

Ans.The potentiometer works on the principle that potential difference across any two points of uniform current carrying conductor is directly proportional to the length between the two points.

2.Two identical cells, each of emf E, having negligible internal resistance, are connected in parallel with each other across an external resistance What is the current through this resistance? [All India 2013]

Ans.The cells are arranged as shown in the circuit

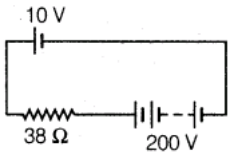


As the internal resistance of cells is negligible, so total resistance of the circuit = R

So. current through the resistance. **I=E/R**

(In parallel combination, potential is same as the single cell)

3. A 10 V battery of negligible internal resistance is connected across a 200 V battery and a resistance of 38 Ω as shown in the figure. Find the value of the current in circuit.



[Delhi 2013]

Ans. Since, the positive terminal of the batteries are connected together, so the equivalent emf of the batteries is given by £ = 200 -10 = 190 V

Hence, the current in the circuit is given by I=E/R=190/38=5 A

4.The emf of a cell is always greater than its terminal voltage. Why? Give reason. [Delhi 2013]

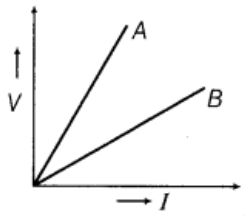
Ans.The emf of a cell is greater than its terminal voltage because there is some potential drop across the cell due to its small internal resistance

5.A cell of emf E and internal resistance r draws a current Write the relation between terminal voltage V in terms of E, I and r.[Delhi 2013]

Ans. When a current Idraws from a cell of emf E and internal resistance r, then the terminal voltage is

V = E – Ir.

6.A resistance R is connected across a cell of emf E and internal resistance r. Now, a potentiometer measures the potential difference between the terminals of the cells as V. Write the expression for r in terms of E, V and R.



[Delhi 2011, 2010]

Ans.

Internal resistance, $r = R\left(\frac{E}{V} - 1\right)$

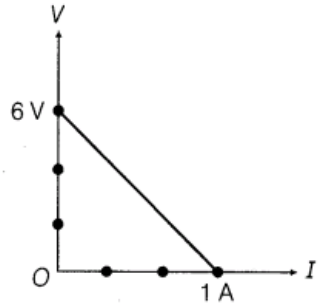
where, signs are as usual.

7.A (i) series (ii) parallel combination of two given resistors is connected, one-by-one, across a cell. In which case, will the terminal potential difference across the cell have a higher value?[All India 2008 C]

Ans.The equivalent resistance combination of resistances is (i) greater than the greatest resistance in series combination and (ii) smaller than the least value of resistance in parallel combination.

The terminal potential difference across the cell is higher in series combination as V = E – Ir and due to higher resistance, current I is less in series combination.

8.The plot of the variation of potential difference across a combination of three identical cells in series versus current is as shown in figure. What is the emf of each cell?



[Delhi 2008]

Ans. Terminal potential difference across a cell can be obtained by subtracting potential drop across internal resistance of the cell from the emf of the cell.

v Terminal voltage across cell combination,

V = E – Ir

when current I=0

=> V = E

From graph, when I = 0, V = 6 V

=> emf E = 6 V

2 Marks Questions

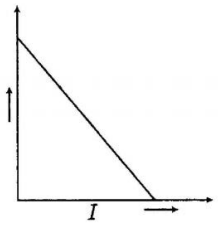
9.A cell of emf E and internal resistance r is connected across a variable resistor Plot a graph showing variation of terminal voltage V of the cell versus the current I. Using the plot, show the emf of the cell and its internal resistance can be determined.[All India 2014]

Ans.

We know that,

$$V = E - Ir$$

The plot between V and I is a straight line of positive intercept and negative slope as shown in figure below



(*i*) The value of potential difference corresponding to zero current gives emf of the cell. **(1)**

(*ii*) Maximum current is drawn when terminal voltage is zero, so

$$V = E - Ir$$

$$\Rightarrow \quad 0 = E - I_{max} r \Rightarrow r = \frac{E}{I_{max}} \qquad \textbf{(1)}$$

10. A potentiometer wire of length 1 m has a resistance of 10 Ω. Determine the emf of the primary cell which gives a balance point at 40 cm.

[Delhi 2014]

Ans.

Given, length of wire, $l = 1\ \text{m} = 100\ \text{cm}$

Resistance, $R = 10\ \Omega$

Emf of a battery, $E_1 = 6\ \text{V}$

$R_1 = 5\ \Omega$

$x = 40\ \text{cm}$

$$\therefore \text{ Current, } I = \frac{E_1}{R + R_1} = \frac{6}{10 + 5} = \frac{6}{15}\ \text{A}$$

$$V_{AB} = IR = \frac{6}{15} \times 10 = \frac{60}{15} = 4\ \text{V}$$

$$\therefore \text{ Emf of the primary cell } = \frac{V_{AB}}{l} \times x$$

$$= \frac{4}{100} \times 40 = 1.6\ \text{V}$$

11. A potentiometer wire of length 1 m has a resistance of 5 Ω. It is connected to a 8 V battery in series with a resistance of 15 Ω. Determine the emf of the primary cell which gives a balance point at 60 cm.

[Delhi 2014]

Ans.Refer to ans. 10. (Ans. 1.2V).

12. A potentiometer wire of length 1.0 m has a resistance of 15 Ω. It is connected to a 5 V battery in series with a resistance of 5 Ω. Determine the emf of the primary cell which gives a balance point at 60 cm.

[Delhi 2014]

Ans.Refer to ans. 10. (Ans. 2.25 V).

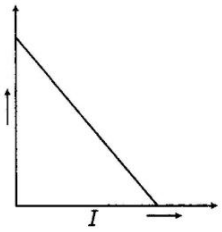
13. Distinguish between emf (ε) and terminal voltage (V) of a cell having internal resistance r. Draw a plot showing the variation of terminal voltage (V) *versus* the current (I) drawn from the cell. Using this plot, show how does one can determine the internal resistance of the cell?

[All India 2014 C]

Ans.

Difference between emf (ε) and terminal voltage (V)

S. No.	Emf	Terminal voltage
1.	It is the potential difference between two terminals of the cells when no current is flowing through it.	1. It is the potential difference between two terminals when current passes through it.
2.	It is the cause.	2. It is the effect.

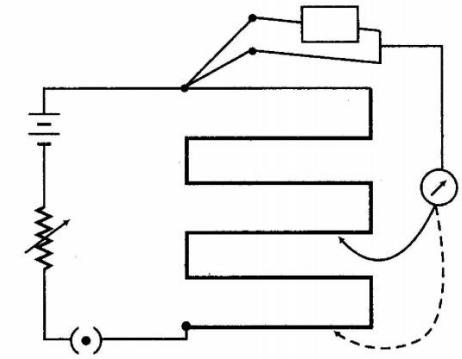


Negative slope gives internal resistance. **(2)**

14.Describe briefly with the help of a circuit diagram, how a potentiometer is used to determine the internal resistance of a cell.[All India 2013]

Ans.

Measurement of internal resistance of a cell using potentiometer.



(1)

The cell of emf, E (internal resistance r) is connected across a resistance box (R) through key K_2.

$$E = \phi\, l_2 \qquad \text{...(i)}$$

When K_2 is open balance length is obtained at length $AN_1 = l_1$

$$\therefore \quad V = \phi\, l_2$$

From Eqs. (i) and (ii), we get

$$\frac{E}{V} = \frac{l_1}{l_2} \qquad \text{...(iii)}$$

$$E = l(r + R)$$

$$V = lR$$

$$\frac{E}{V} = \frac{r + R}{R} \qquad \text{...(iv)}$$

From Eqs. (iii) and (iv) we get

$$\frac{R + r}{R} = \frac{l_1}{l_2}$$

$$\therefore \quad \frac{E}{V} = \frac{l_1}{l_2}$$

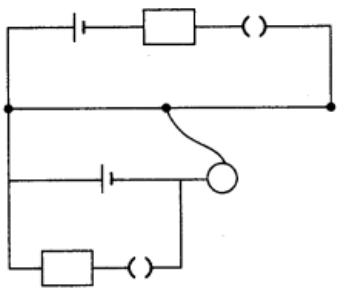
$$\because \quad r = R\left(\frac{E}{V} - 1\right)$$

$$\therefore \quad r = R\left(\frac{l_1}{l_2} - 1\right)$$

We known l_1, l_2 and E, so we can calculate r.

(1)

15.Two students X and Y perform an experiment on potentiometer separately using the circuit given below



Keeping other parameters unchanged, how will the position of the null point be affected if

(i)X increases the value of resistance R in the set up by keeping the key closed and the key K_2 open?

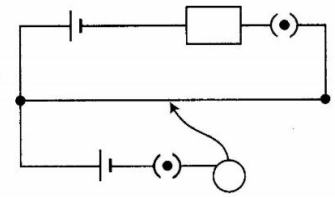
(ii)Y decreases the value of resistance S in the set up, while the key K_2 remains open and then K_t closed?

Justify your answer.[HOTS; Foreign 2012]

Ans.

When K_1 is closed and K_2 is open, then only the cell connected in upper part branch will work.
When K_2 is closed and K_1 is open, then only the cell connected in lower branch will work.

(*i*) $K_1 \rightarrow$ closed, $K_2 \rightarrow$ open



Suppose null point occurs at *J*.

Apply KVL in smaller loop,

$$E - IR = 0 \qquad \ldots(i)$$

where, R = resistance

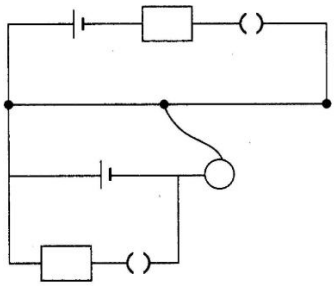
$$E = IR \Rightarrow I = \frac{E}{R}$$

As, *X* increases the value of resistance *R*. So, current in the circuit (wire) decreases. Hence, *R* will be increased. Then *I* will decrease.

We can say, as *X* increases the value of *R*, null point decrease. **(1)**

(*ii*) $K_2 \rightarrow$ open, $K_1 \rightarrow$ closed.

Then the circuit will be same as shown earlier.



We see that resistance *S* is not involved in the circuit because K_2 is open.

So, from Eq. (i)

$$E = RI \quad \Rightarrow \quad I = \frac{E}{R}$$

Here, *R* does not depend on the value of resistance *S*.

So, *R* null point is not affected by decreasing the value of resistance *S*. **(1)**

16.Two cells of emf 2E and E and internal resistances 2r and r respectively, are connected in parallel. Obtain the expressions for the equivalent emf and the internal resistance of the combination.[All India 2010 C]

Ans.

Given,

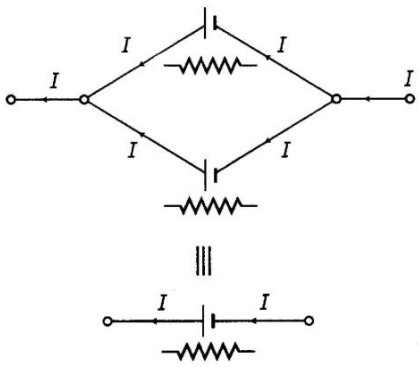
Emf of first cell = $2E$

Emf of second cell = E

Internal resistance of first cell = $2r$

Internal resistances of second = r

Net current $I = I_1 + I_2$ ...(i) **(1/2)**



For cell-I

$$V = V_A - V_B = 2E - I_1(2r) \Rightarrow I_1 = \frac{2E - V}{2r} \quad ...(ii)$$

For cell-II,

$$V = V_A - V_B = E - I_2 r$$

$$\Rightarrow \quad I_2 = \frac{E - V}{r} \quad ...(iii)$$

$\because$ From Eqs. (ii) and (iii), substituting in Eq. (i),

$$I = \frac{2E - V}{2r} + \frac{E - V}{r}$$

On rearranging the term, we get

$$V = \frac{4E}{3} - I\left(\frac{2r}{3}\right) \quad \textbf{(1)}$$

But for equivalent of combination,

$$V = E_{eq} - I\,(r_{eq})$$

On comparing,

$$E_{eq} = \frac{4E}{3}, \quad \textbf{(1/2)}$$

$$r_{eq} = \frac{2r}{3} \quad \textbf{(1/2)}$$

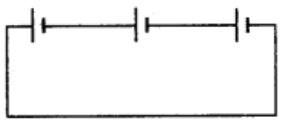
NOTE Two cells of emfs E_1 and E_2 and internal resistances r_1 and r_2 connected in parallel combination, then equivalent emf

$$E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$$

Equivalent resistance, $r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$

17.Three cells of emf E,2E and 5 Eh aving internal resistances r, 2r and 3r, variable resistance R as shown in the figure. Find the expression for the current. Plot a graph for variation of current with R.

[All India 2010 C]



Ans.

In these type of questions, we have to look out the connections of different cells, if the opposite terminals of all the cells are connected, then they support each other, i.e. these individual emf's are added up. If the same terminals of the cells are connected, then the equivalent emf is obtained by taking the difference of emf's.

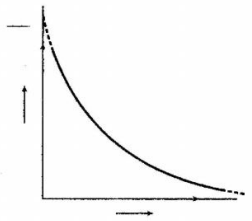
Net emf of combination $= E_1 - 2E_1 + 5E_1 = 4E_1$

Net resistance of current $= r + 2r + 3r + R$

$= 6r + R$

$\therefore$ Current, $I = \frac{V}{R}$ (from Ohm's law)

$$I = \frac{4E_1}{6r + R} \quad \textbf{(1)}$$



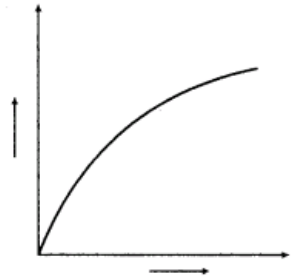
(1)

18.A cell of emf E and internal resistance r is connected across a variable resistor R. Plot a graph showing the variation of terminal potential V with resistance!?.[Delhi 2009]

Ans.

$\because \quad V = \left(\frac{E}{R+r}\right)R = \frac{E}{1 + r/R}$ **(1/2)**

$\Rightarrow$ with the increase of R, V increases



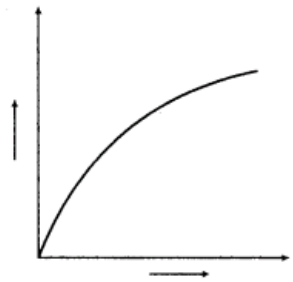
$\left(1\frac{1}{2}\right)$

19.Plot a graph showing the variation of terminal potential difference across a cell of emf E and internal resistance r with current drawn from it. Using this graph, how does one determine the emf of the cell? [Delhi 2009 c]

Ans.

$\because \quad V = \left(\frac{E}{R+r}\right)R = \frac{E}{1 + r/R}$ **(1/2)**

$\Rightarrow$ with the increase of R, V increases

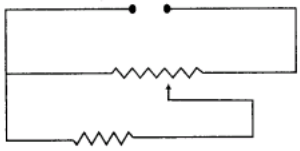


$\left(1\frac{1}{2}\right)$

3 Marks Questions

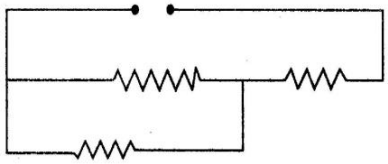
20. A resistance of $R\,\Omega$ draws current from a potentiometer as shown in the figure. The potentiometer has a total resistance R_0 Ω. A voltage V is supplied to the potentiometer. Derive an expression for the voltage across R when the sliding contact is in the middle of the potentiometer.

[All India 2014]



Ans.

The equivalent circuit is redrawn as shown in figure below



So, the equivalent resistance of the circuit is given by

$$R_{eq} = \frac{R_0}{2} + \frac{R \cdot \frac{R_0}{2}}{R + \frac{R_0}{2}} \qquad \textbf{(1)}$$

$\therefore$ Current in the circuit,

$$I_{circuit} = \frac{V}{R_{eq}} \qquad \textbf{(1)}$$

$$\Rightarrow \quad V = I\,R_{eq}$$

$$= I\left[\frac{R_0}{2} + \frac{R \cdot \frac{R_0}{2}}{R + \frac{R_0}{2}}\right]$$

$$= I\left(\frac{R_0}{2} + \frac{RR_0}{2R + R_0}\right)$$

$$= \frac{IR_0}{2}\left(1 + \frac{2R}{2R + R_0}\right) \qquad \textbf{(1)}$$

21.(i) State the underlying principle of a potentiometer. Why is it necessary to (i) use a long wire, (ii) have uniform area of cross-section of the wire and (iii) use a driving cell whose emf is taken to be greater than the emfs of the primary cells?

(ii) In a potentiometer experiment, if the area of the cross-section of the wire increases uniformly from one end to the other, draw a graph showing how potential gradient would vary as the length of the wire increases from one end.[All India 2014 C]

Ans.(i) Principle of Potentiometer The potential drop across the length of a steady current carrying wire of uniform cross-section is proportional to the length of the wire.

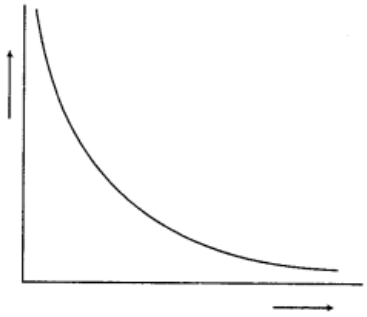
(a)We use a long wire to have a lower value of potential gradient (i.e a lower "least count" or greater sensitivity of the potentiometer.

(b)The area of cross-section has to be uniform to get a 'uniform wire' as per the principle of the potentiometer.

(c)The emf of the driving cell has to be greater than the emf of the primary cells as otherwise, no balance point would be obtained

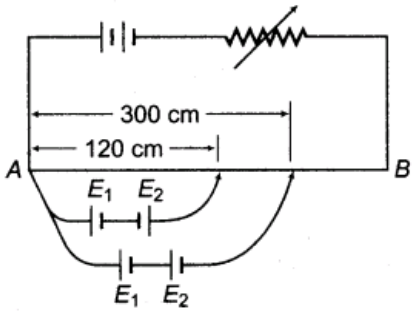
(*ii*) Potential gradient, $K = \frac{V}{L}$

$\therefore$ The required graph is as shown below



(1)

22.In the figure, a long uniform potentiometer wire AB is having a constant potential gradient along its length. The null points for the two primary cells of emfs E_x and E_2 connected in the manner shown, are obtained at a distance of 120 cm and 300 cm from the end A



Find (i) E1 / E_2 and

(ii) position of null point for the cell E1

How is the sensitivity of a potentiometer increased? [Foreign 2014; Delhi 2012]

Ans.

(*i*) Let potential gradient be *K*.

$\because \quad E_1 - E_2 = K \times 120 \quad \ldots(i)$

(cells are connected in opposite order)

$E_1 + E_2 = K \times 300 \quad \ldots(ii)$

(cells are connected in supporting order)

$\left(2 \times \frac{1}{2} = 1\right)$

$$\frac{E_1 + E_2}{E_1 - E_2} = \frac{K \times 300}{K \times 120}$$

$$= \frac{5}{2}$$

Now, apply componendo and dividendo

$$\frac{(E_1 + E_2) + (E_1 - E_2)}{(E_1 + E_2) - (E_1 - E_2)} = \frac{5 + 2}{5 - 2}$$

$$\frac{E_1}{E_2} = \frac{7}{3}$$

(1/2)

(*ii*) ∵ $\frac{E_1}{E_2} = \frac{7}{3}$, $E_2 = \frac{3}{7}E_1$

From Eq. (i)

$E_1 - \frac{3}{7}E_1 = K \times 120$, $\frac{4}{7}E_1 = K \times 120$

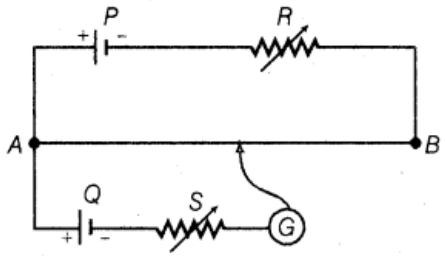
$DE_1 = K \times 120 \times \frac{7}{4}$

$E_1 = K \times 210$

Null point for E_1 is obtained at 210 cm. **(1)**

The sensitivity of potentiometer be increased by increasing the length of wire. **(1/2)**

23.State the underlying principle of a potentiometer. Write two factors on which the sensitivity of a potentiometer depends.



In the potentiometer circuit shown in the figure, the balance point is at X. State, giving reason, how the balance point is shifted when

(i)resistance R is increased

(ii)resistance S is increased, keeping R constant?[Compartment 2013]

Ans. We use a long wire to have a lower value of potential gradient (i.e a lower "least count" or greater sensitivity of the potentiometer The two factors on which the sensitivity of a potentiometer depends are

(a)the value of potential gradient (K)

(b)by increasing the length of potentiometer wire. From the circuit diagram,

(i) if R is increased, the current through the potentiometer wire will decrease. Due to it, the potential gradient of potentiometer wire will also decrease. Thus, the position of **J** will shift towards **B.**

(ii) if S is increased, keeping R constant, the position of J will shift towards A.

24. An ammeter of resistance 0.80 Ω can measure current upto 1.0 A.

(*i*) What must be the value of shunt resistance to enable the ammeter to measure current upto 5.0 A?

(*ii*) What is the combined resistance of the ammeter and the shunt?

[Delhi 2013]

Ans.

Here, resistance of ammeter $R_A = 0.80\ \Omega$ and maximum current across ammeter, $I_A = 1.0$ A.
So, voltage across ammeter,

$$V = IR = 1.0 \times 0.80 = 0.8\ \text{V}$$

Let the value of shunt be x.

(*i*) Resistance of ammeter with shunt,

$$R = \frac{R_A x}{R_A + x} = \frac{0.8x}{0.8 + x}$$

when current through ammeter, $I = 5$ A. **(1)**

Now for $V = IR$, $\left(\frac{0.8\,x}{0.8 + x}\right) \times 5 = 0.8$

$$\Rightarrow 0.8x \times 5 = 0.8\,(0.8 + x)$$

$$\Rightarrow \quad 4x = 0.64 + 0.8x$$

$$\therefore \quad x = \frac{0.64}{3.2} = 0.2$$

Hence, the value of resistance must be 0.2 Ω. **(1)**

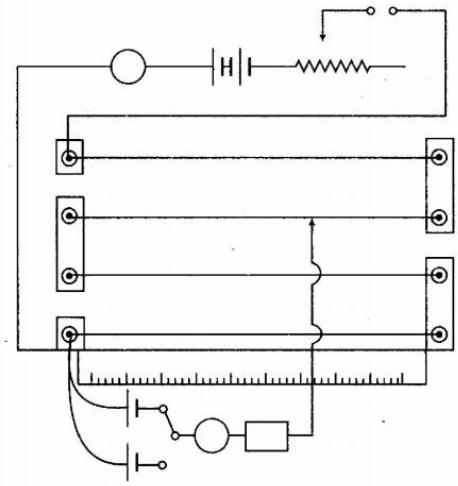
(*ii*) With the help of value of shunt resistance combined resistance of the ammeter and the shunt,

$$R = \frac{0.8x}{0.8 + x} = \frac{0.8 \times 0.2}{0.8 + 0.2} = 0.16\ \Omega$$ **(1)**

25.With the help of circuit diagram, explain how a potentiometer can be used to compare emf of two primary cells? [Delhi 2011]

Ans.

The required circuit diagram is shown in the figure below.



The main circuit comprises of battery of emf E, key (K) and rheostat (R_h). The auxiliary circuit comprises of two primary cells of emfs E_1 and E_2, galvanometer, jockey and resistance box (RB) to prevent large current flowing through the galvanometer.

When key K_1 is closed and K_2 kept open, the cell, E_1 comes into action. The jockey J is moved on the wire AB till null point is obtained in galvanometer. Let null point is obtained at length l_1 then emf of first cell is given by

$$E_1 = kl_1 \qquad \ldots(i)$$

(1)

where, k is the potential gradient along the wire AB due to battery E.

Now, key K_2 is closed and K_1 kept open and null point is obtained at length l_2, then

$$E_2 = kl_2 \qquad \ldots(ii) \quad \textbf{(1)}$$

Therefore, $\frac{E_1}{E_2} = \frac{kl_1}{kl_2} = \frac{l_1}{l_2} \Rightarrow \frac{E_1}{E_2} = \frac{l_1}{l_2}$ **(1)**

NOTE The null point is obtained only when

(*i*) emf of battery E must be greater than emfs of two primary cells E_1 and E_2 each.

(*ii*) all the positive terminals of cells and battery must be connected at the same point.

26.State the underlying principle of a potentiometer. Describe briefly, giving the necessary circuit diagram, how a potentiometer is used to measure the internal resistance of a given cell?[Foreign 2011]

Ans. Principle of Potentiometer The potential difference across any two points of current carrying , wire, having uniform cross-sectional area and material of the potentiometer is directly proportional to the length between the two points

i.e. $V \propto l$

$$\because \quad V = IR = I\left(\rho\frac{l}{A}\right)$$

(from Ohm's law)

$$V = \left(\frac{l\rho}{A}\right)I$$

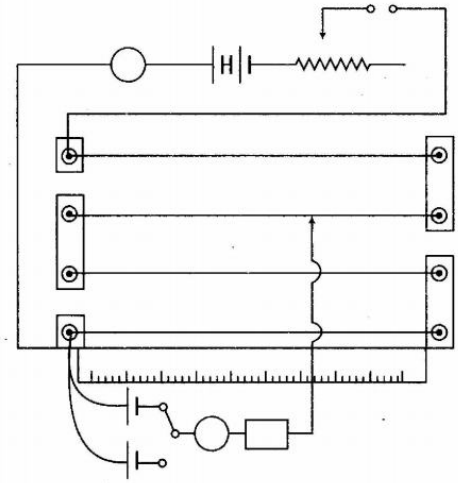
For uniform current and cross-sectional area

$$\frac{l\rho}{A} = \text{constant}$$

$$\Rightarrow \quad V \propto I \qquad \textbf{(1)}$$

The circuit diagram of potentiometer for determining internal resistance of a given cell is shown

The required circuit diagram is shown in the figure below.



The main circuit comprises of battery of emf E, key (K) and rheostat (R_h). The auxiliary circuit comprises of two primary cells of emfs E_1 and E_2, galvanometer, jockey and resistance box (RB) to prevent large current flowing through the galvanometer.

When key K_1 is closed and K_2 kept open, the cell, E_1 comes into action. The jockey J is moved on the wire AB till null point is obtained in galvanometer. Let null point is obtained at length l_1 then emf of first cell is given by

$$E_1 = kl_1 \qquad \ldots(\text{i})$$

(1)

where, k is the potential gradient along the wire AB due to battery E.

Now, key K_2 is closed and K_1 kept open and null point is obtained at length l_2, then

$$E_2 = kl_2 \qquad \ldots(\text{ii}) \quad \textbf{(1)}$$

Therefore, $\frac{E_1}{E_2} = \frac{kl_1}{kl_2} = \frac{l_1}{l_2} \Rightarrow \frac{E_1}{E_2} = \frac{l_1}{l_2}$ **(1)**

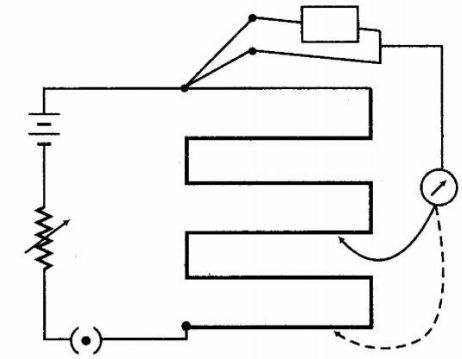
NOTE The null point is obtained only when

(*i*) emf of battery E must be greater than emfs of two primary cells E_1 and E_2 each.

(*ii*) all the positive terminals of cells and battery must be connected at the same point.

Measurment of Internal Resistance of a Cell Using Potentiometer

Measurement of internal resistance of a cell using potentiometer.



(1)

The cell of emf, E (internal resistance r) is connected across a resistance box (R) through key K_2.

$$E = \phi l_2 \quad \text{...(i)}$$

When K_2 is open balance length is obtained at length $AN_1 = l_1$

$$\therefore \quad V = \phi l_2$$

From Eqs. (i) and (ii), we get

$$\frac{E}{V} = \frac{l_1}{l_2} \quad \text{...(iii)}$$

$$E = l(r + R)$$

$$V = lR$$

$$\frac{E}{V} = \frac{r + R}{R} \quad \text{...(iv)}$$

From Eqs. (iii) and (iv) we get

$$\frac{R + r}{R} = \frac{l_1}{l_2}$$

$$\therefore \quad \frac{E}{V} = \frac{l_1}{l_2}$$

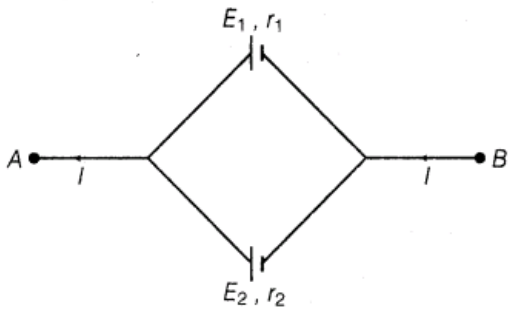
$$\because \quad r = R\left(\frac{E}{V} - 1\right)$$

$$\therefore \quad r = R\left(\frac{l_1}{l_2} - 1\right)$$

We known l_1, l_2 and E, so we can calculate r.

(1)

27.Two cells of emf E_x, E_2 and internal resistances r_a and r_2 respectively are connected in parallel as shown in the figure.



Deduce the expressions for

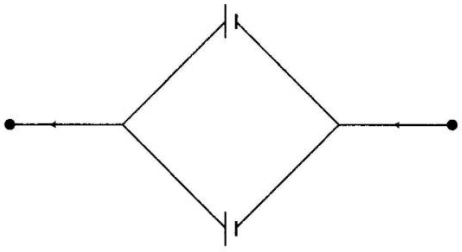
(i)the equivalent emf of the combination.

(ii)the equivalent resistance of the combination and

(iii)the potential difference between the points A and [Foreign 2010]

Ans.

Let, I_1 and I_2 be the currents in two cells with emfs, E_1 and E_2 and internal resistances, r_1 and r_2.



So, $I = I_1 + I_2$

Now, let V be the potential difference between the points, A and B. Since, the first cell is connected between the points A and B.

V = potential difference across first cell

$V = E_1 - I_1 r_1$

or $I_1 = \dfrac{E_1 - V}{r_1}$ **(1)**

Now, the second cell is also connected between the points, A and B. So,

$$I_2 = \frac{E_2 - V}{r_2}$$

Thus, substituting for I_1 and I_2

$$I = \frac{E_1 - V}{r_1} + \frac{E_2 - V}{r_2}$$

or $$I = \left(\frac{E_1}{r_1} + \frac{E_2}{r_2}\right) - V\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$$

$$V = \left(\frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}\right) - I\left(\frac{r_1 r_2}{r_1 + r_2}\right) \quad ...(i)$$

If E is effective emf and r, the effective internal resistance of the parallel combination of the two cells, then

$V = E - Ir$ ...(ii) **(1)**

Comparing Eqs. (i) and (ii), we get

(*i*) $E = \dfrac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$

This is equivalent emf of the combination.

(*ii*) $r = \dfrac{r_1 r_2}{r_1 + r_2}$

This is equivalent resistance of the combination.

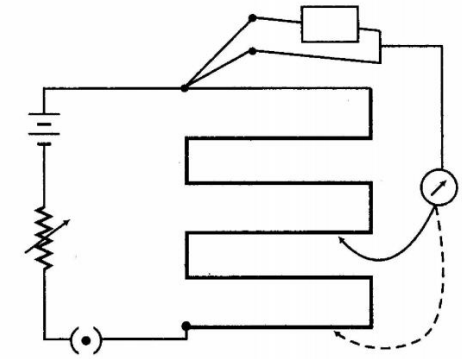
(*iii*) the potential difference between the points A and B is **(1)**

$V = E - Ir$

28.Draw the circuit diagram of a potentiometer which can be used to determine the internal resistance r of a given cell of emf Explain briefly how the internal resistance of the cell is determined? [Delhi 2010,2008 C]

Ans.

Measurement of internal resistance of a cell using potentiometer.



(1)

The cell of emf, E (internal resistance r) is connected across a resistance box (R) through key K_2.

$$E = \phi l_2 \quad \text{...(i)}$$

When K_2 is open balance length is obtained at length $AN_1 = l_1$

$$\therefore \quad V = \phi l_2$$

From Eqs. (i) and (ii), we get

$$\frac{E}{V} = \frac{l_1}{l_2} \quad \text{...(iii)}$$

$$E = l(r + R)$$

$$V = lR$$

$$\frac{E}{V} = \frac{r + R}{R} \quad \text{...(iv)}$$

From Eqs. (iii) and (iv) we get

$$\frac{R + r}{R} = \frac{l_1}{l_2}$$

$$\therefore \quad \frac{E}{V} = \frac{l_1}{l_2}$$

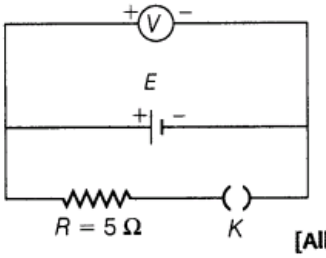
$$\because \quad r = R\left(\frac{E}{V} - 1\right)$$

$$\therefore \quad r = R\left(\frac{l_1}{l_2} - 1\right)$$

We known l_1, l_2 and E, so we can calculate r.

(1)

29.Write any two factors on which internal resistance of a cell depends. The reading on a high resistance voltmeter, when a cell is connected across it, is 2.2 V. When the terminals of the cell are also connected to a resistance of 5 ohms as shown in the circuit, the voltmeter reading drops to 1.8 V. Find the internal resistance of the cell.



[All India 2010]

Ans. The high resistance voltmeter means that no current with flow through it hence, there is no potential difference across it. So, the reading shown by the high resistance voltmeter can be taken as the emf of the cell.

The internal resistance of a cell depends on

(i) the concentration of electrolyte and

(ii) distance between the two electrodes

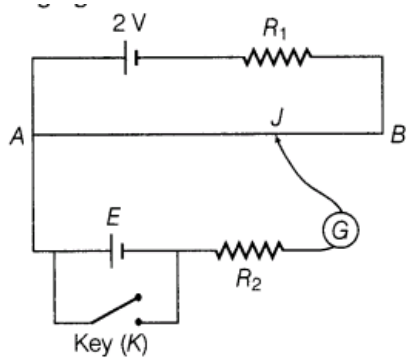
The emf of cell (E) = 2.2 V
The terminal voltage across cell when 5 Ω resistance (R) connected across it (V) = 1.8 V
Let internal resistance = r
∵ Internal resistance,

$$r = R\left(\frac{E}{V} - 1\right) \quad \textbf{(1)}$$

$$\therefore \quad r = 5\left(\frac{2.2}{1.8} - 1\right) = 5 \times \frac{0.4}{1.8} = \frac{2}{1.8} = \frac{10}{9}\ \Omega$$

$$\Rightarrow r = \frac{10}{9}\ \Omega \quad \textbf{(1)}$$

30.(i)State the principle of working of a potentiometer.
(ii)Figure shows the circuit diagram of a potentiometer for determining the emf of E cell of negligible internal resistance.



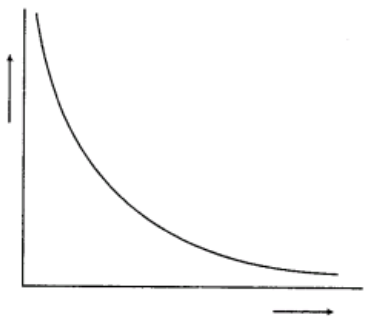
(a)What is the purpose of using high resistance ?
(b)How does the position of balance point (J) change when the resistance i?$_x$ is decreased?
(c)Why cannot the balance point be obtained

- **when the emf E is greater than 2 V.**
- **when the key (K) is closed?[Foreign 2009]**

Ans.(i) Principle of Potentiometer The potential drop across the length of a steady current carrying wire of uniform cross-section is proportional to the length of the wire.
(a)We use a long wire to have a lower value of potential gradient (i.e a lower "least count" or greater sensitivity of the potentiometer.
(b)The area of cross-section has to be uniform to get a 'uniform wire' as per the principle of the potentiometer.
(c)The emf of the driving cell has to be greater than the emf of the primary cells as otherwise, no balance point would be obtained

(*ii*) Potential gradient, $K = \frac{V}{L}$

∴ The required graph is as shown below



(1)

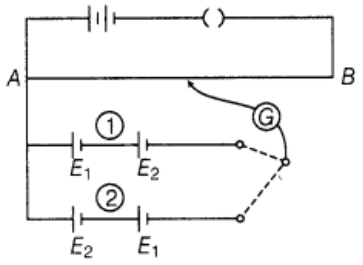
(ii) (a) To protect the galvanometer from flow of high current.
(b) Balance point, J shift towards **A**
(c)Potential drop across the cell cannot become equal to potential difference across any two

point of the curve. Potential difference across cell become zero

31.A circuit using a potentiometer and battery of negligible internal resistance is set up as shown to develop a constant potential gradient along the wire Two cells of emfs E_1 and E_2 are connected in series as shown in combinations (1) and (2). The balance points are obtained respectively at 400 cm and 240 cm from the point A. Find

(i)E_1 /E_2.

(ii)balancing length for the cell E1 only.



[Delhi 2009]

Ans.

In combination 1, net emf of combination is $E_1 + E_2$, whereas for combination 2 net emf is $E_2 - E_1$.

$$E_1 + E_2 = Kl_1 \quad \ldots(i)$$

where, K = potential gradient

$l_1 = 400$ cm

For combination 2,

$$E_2 - E_1 = Kl_2 \quad \ldots(ii)$$

where, $l_2 = 240$ cm **(1/2)**

$$\because \quad \frac{E_1 + E_2}{E_2 - E_1} = \frac{Kl_1}{Kl_2} = \frac{400}{240} = \frac{5}{3}$$

$$\frac{E_1 + E_2}{E_2 - E_1} = \frac{5}{3}$$

Applying componendo and dividendo theorem, we get

$$\frac{(E_1 + E_2) + (E_2 - E_1)}{(E_1 + E_2) - (E_2 - E_1)} = \frac{5 + 3}{5 - 3}$$

$$\frac{E_2}{E_1} = \frac{8}{2} \Rightarrow \frac{E_1}{E_2} = \frac{1}{4} \quad \textbf{(1)}$$

(*ii*) $\because$ $\frac{E_1}{E_2} = \frac{1}{4} \Rightarrow E_1 = E$ (say)

Then, $E_2 = 4E$

$\Rightarrow E_1 + E_2 = K \times 400 \Rightarrow 5E = K \times 400$

$$K = \frac{5E}{400} = \frac{E}{80} \quad \textbf{(1/2)}$$

Now, let balancing length for E_1 is l_1

$\therefore \quad E_1 = Kl_1 \Rightarrow E = \frac{E}{80} \times l_1$

$\Rightarrow \quad l_1 = 80$ cm **(1)**

32.A number of identical cells, n each of emf E, internal resistance r, connected in series are charged by a DC source of emf E', using a resistor, R.

(i)Draw the circuit arrangement.

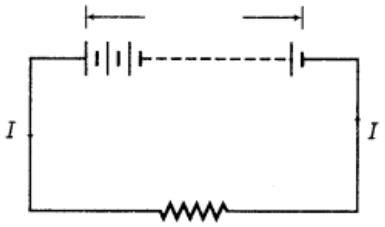
(ii)Deduce the expressions for

(a)the changing current and

(b)the potential difference across the combination of the cells. [Delhi 2008]

Ans.

(*i*) Net emf = $E' - nE$ **(1)**



(*ii*) (*a*) Net internal resistance of the combination of cells = nr

Net resistance = $nr + R$

where, R = external resistance

$\therefore$ Charging current, $I = \dfrac{\text{Net emf}}{\text{Net resistance}}$

$$I = \frac{E' - nE}{nr + R}$$

(1)

(*b*) Potential difference across the combination of cells

$$V = nE + I(nr) = nE + \left(\frac{E' - nE}{nr + R}\right) nr$$

$$= \frac{nE(nr + R) + (E' - nE)\, nr}{nr + R}$$

$$= \frac{n^2Er + nER + E'nr - n^2Er}{nr + R} = \frac{n(ER + E'r)}{nr + R}$$ **(1)**

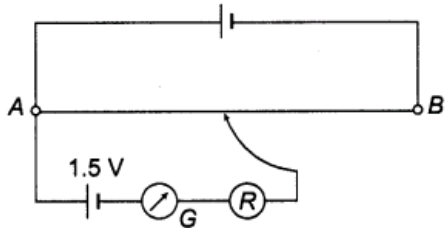
NOTE Here, series cell combination is being charged.

$$V_A - nE - (nr)\, I = V_B$$

$$\Rightarrow \quad V_A - V_B = nE + (nr)\, I$$

$\therefore$ Terminal voltage, $V = V_A - V_B = nE + Inr$

33.A potentiometer wire of length lm is connected to a driver cell of emf 3 V as shown in the figure. When a cell of 1.5 V emf is used in the secondary circuit, the balance point is found to be 60 cm. On replacing this cell and using a cell of unknown emf, the balance point shifts to 80 cm.



(i)Calculate unknown emf of the cell.

(ii)Explain with reason, whether the circuit works, if the driver cell is replaced with a cell of emf 1 V.

(iii)Does the high resistance R, used in the secondary circuit affect the balance point? Justify your answer.[Delhi 2008]

Ans.

(*i*) For comparing emfs of two cells using potentiometer, we have

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

Here, $E_1 = 1.5$ V, $l_1 = 60$ cm,

$E_2 = ?$, $l_2 = 80$ cm,

$$\therefore \quad \frac{1.5}{E_2} = \frac{60}{80} \Rightarrow E_2 = \frac{80}{60} \times 1.5 = 2 \text{ V}$$

$E_2 = 2$ V **(1)**

34. Four identical cells, each of emf 8 V and internal resistance 2.5 Ω are connected in series and charged by a 100 V DC supply, using a 24 Ω resistor in series. Calculate the following

(*i*) Changing current in the circuit.

(*ii*) Potential difference across the cells during recharging. **[Foreign 2008]**

Ans. (i) Net emf applied in the circuit = Applied potential difference – Total emf of all cells = 100 V-4 x 8 V = 68 V

NOTE During changing of the current, positive terminal of the battery is connected to positive terminal of the series combination of the cells.

Net resistance of the circuit = Internal resistance of charging cell + Total internal resistance of cells.

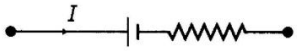
$$= 24 + 4 \times 2.5 = 34\ \Omega$$

$$\therefore \text{ Charging current, } I = \frac{V}{R} = \frac{68}{34} = 2 \text{ A}$$

(1½)

(*ii*) ∴ Potential difference across the cell combination $V = E + Ir$

During charging of the cell.



$V_A - E - Ir = V_B$

$\Rightarrow \quad V = V_A - V_B = E + Ir; \quad V = E + Ir$

$\Rightarrow \quad V = 4 \times 8 + 2 \times (4 \times 2.5) = 32 + 20$

$V = 52$ V **(1½)**

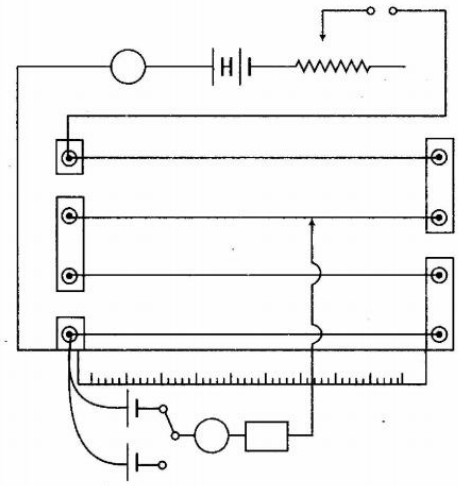
5 Marks Questions

35.(i) State the working principle of a potentiometer. With the help of the circuit diagram, explain how a potentiometer is used to compare the emf's of two primary cells. Obtain the required expression used for comparing the emfs.

(ii) Write two possible causes for one sided deflection in a potentiometer experiment.[Delhi 2013]

Ans.(i) **Working principle of potentiometer** 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.

The required circuit diagram is shown in the figure below.



The main circuit comprises of battery of emf E, key (K) and rheostat (R_h). The auxiliary circuit comprises of two primary cells of emfs E_1 and E_2, galvanometer, jockey and resistance box (RB) to prevent large current flowing through the galvanometer.

When key K_1 is closed and K_2 kept open, the cell, E_1 comes into action. The jockey J is moved on the wire AB till null point is obtained in galvanometer. Let null point is obtained at length l_1 then emf of first cell is given by

$$E_1 = kl_1 \qquad \ldots(i)$$

(1)

where, k is the potential gradient along the wire AB due to battery E.

Now, key K_2 is closed and K_1 kept open and null point is obtained at length l_2, then

$$E_2 = kl_2 \qquad \ldots(ii) \quad \textbf{(1)}$$

Therefore, $\dfrac{E_1}{E_2} = \dfrac{kl_1}{kl_2} = \dfrac{l_1}{l_2} \Rightarrow \dfrac{E_1}{E_2} = \dfrac{l_1}{l_2}$ **(1)**

NOTE The null point is obtained only when

(*i*) emf of battery E must be greater than emfs of two primary cells E_1 and E_2 each.

(*ii*) all the positive terminals of cells and battery must be connected at the same point.

(ii) (a) The emf of the cell connected in main circuit may not be more than the emf of the primary cells whose emfs are to be compared.

(b) The positive ends of all cells are not connected to the same end of the wire

36.State the working principle of a potentiometer. Draw a circuit diagram to compare emf of two primary cells. Derive the formula used.

(i)Which material is used for potentiometer wire and why?

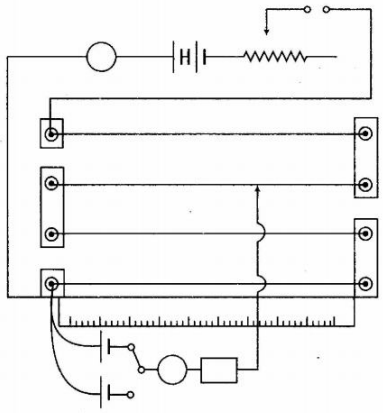
(ii)How can the sensitivity of a potentiometer be increased? [Delhi 2011]

Ans.(i) **For working principle of potentiometer**

We use a long wire to have a lower value of potential gradient (i.e a lower "least count" or greater sensitivity of the potentiometer.

For circuit diagram to compare emf of two cells

The required circuit diagram is shown in the figure below.



The main circuit comprises of battery of emf E, key (K) and rheostat (R_h). The auxiliary circuit comprises of two primary cells of emfs E_1 and E_2, galvanometer, jockey and resistance box (RB) to prevent large current flowing through the galvanometer.

When key K_1 is closed and K_2 kept open, the cell, E_1 comes into action. The jockey J is moved on the wire AB till null point is obtained in galvanometer. Let null point is obtained at length l_1 then emf of first cell is given by

$$E_1 = kl_1 \qquad \text{...(i)}$$

(1)

where, k is the potential gradient along the wire AB due to battery E.

Now, key K_2 is closed and K_1 kept open and null point is obtained at length l_2, then

$$E_2 = kl_2 \qquad \text{...(ii)} \quad \textbf{(1)}$$

Therefore, $\frac{E_1}{E_2} = \frac{kl_1}{kl_2} = \frac{l_1}{l_2} \Rightarrow \frac{E_1}{E_2} = \frac{l_1}{l_2}$ **(1)**

NOTE The null point is obtained only when

(*i*) emf of battery E must be greater than emfs of two primary cells E_1 and E_2 each.

(*ii*) all the positive terminals of cells and battery must be connected at the same point.

(ii) Constantan or manganin (alloy) as they have low temperature coefficient of resistance.

(iii) The sensitivity of potentiometer can be increased by increasing the number of wires of potentiometer and hence, decreasing the value of potential gradient