Long Answer Questions

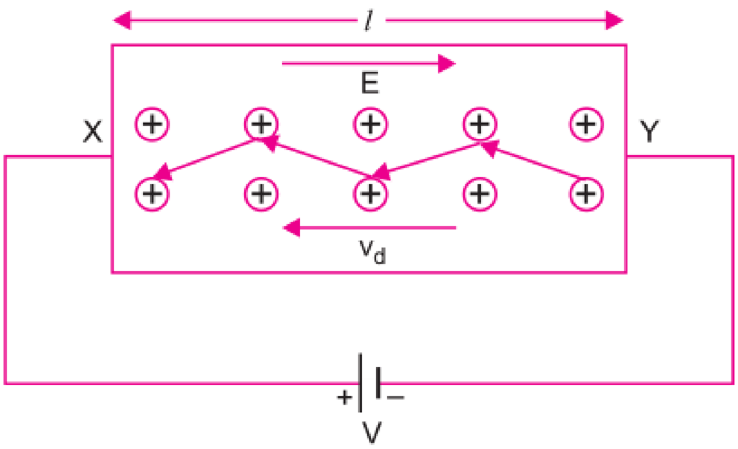
Q. 1. Derive an expression for drift velocity of free electrons in a conductor in terms of relaxation time of electrons. [CBSE Delhi 2009]

OR

Explain how the average velocity of free electrons in a metal at constant temperature, in an electric field, remains constant even though the electrons are being constantly accelerated by this electric field.

Ans. Consider a metallic conductor XY of length l and cross-sectional area A. A potential difference V is applied across the conductor XY. Due to this potential difference an electric field $\vec{E}$ is produced in the conductor. The magnitude of electric field strength $E = \frac{V}{l}$ and its direction is from Y to X.

This electric field exerts a force on free electrons; due to which electrons are accelerated.



The electric force on electron $\vec{F} = -e\vec{E}$ (where e = +1.6 × 10^{-10} coulomb).

If is the mass of electron, then its acceleration

$$\vec{a} = \frac{\vec{F}}{m} = -\frac{e\vec{E}}{m} \qquad \ldots(i)$$

This acceleration remains constant only for a very short duration, since there are random forces which deflect the electron in random manner. These deflections may arise as

(i) Ions of metallic crystal vibrate simple harmonically around their mean positions. Different ions vibrate in different directions and may be displaced by different amounts.

(ii) Direct collisions of electrons with atoms of metallic crystal lattice.

In any way after a short duration called relaxation time, the motion of electrons become random. Thus, we can imagine that the electrons are accelerated only for a short duration. As average velocity of random motion is zero, if we consider the average motion of an electron, then its initial velocity is zero, so the velocity of electron after time τ (i.e., drift velocity $\vec{V}$ d) is given by the relation $\vec{V} = \vec{U} + \vec{at}$

$$\left(\text{here } \vec{u} = 0,\ v = \vec{v}_d, t = \tau,\ \vec{a} = -\frac{e\vec{E}}{m} \right)$$

$$\vec{v}_d = 0 - \frac{e\vec{E}}{m}\tau \quad \Rightarrow \quad \vec{v}_d = -\frac{e\tau}{m}\vec{E}$$

At given temperature, the relaxation time τ remains constant, so drift velocity remains constant.

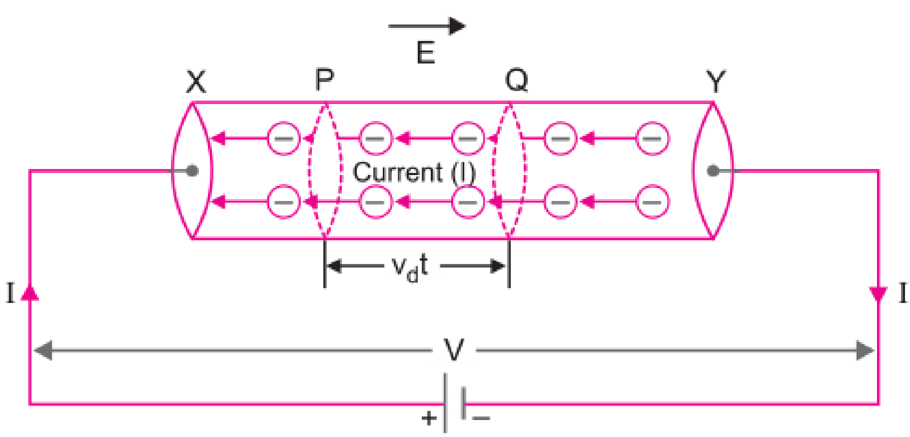
Q. 2. Establish a relation between electric current and drift velocity.
[CBSE (AI) 2013]

OR

Prove that the current density of a metallic conductor is directly proportional to the drift speed of electrons.

Ans. Relation between electric current and drift velocity:

Consider a uniform metallic wire XY of length l and cross-sectional area A. A potential difference V is applied across the ends X and Y of the wire. This causes an electric field at each point of the wire of strength



$$E = \frac{V}{l}. \qquad \ldots(i)$$

Due to this electric field, the electrons gain a drift velocity v_d opposite to direction of electric field. If q be the charge passing through the cross-section of wire in t seconds, then

Current in wire $I = \frac{q}{t}$ ...(ii)

The distance traversed by each electron in time t = average velocity × time = v_d t

If we consider two planes P and Q at a distance v_d t in a conductor, then the total charge flowing in time t will be equal to the total charge on the electrons present within the cylinder PQ.

The volume of this cylinder = cross sectional area × height

= A v_d t

If n is the number of free electrons in the wire per unit volume, then the number of free electrons in the cylinder = n (Av_d t)

If charge on each electron is – e (e = 1.6 ×10^{-19}C), then the total charge flowing through a cross-section of the wire

q = (nA$_v$d t) (– e) =–neA$_v$d t ..(iii)

∴ Current flowing in the wire,

$$I = \frac{q}{t} = \frac{-v}{t}$$

i.e., current I = – neA$_v$d ...(iv)

This is the relation between electric current and drift velocity. Negative sign shows that the direction of current is opposite to the drift velocity.

Numerically I = – neA$_v$d ...(v)

∴ Current density, J = $\frac{I}{A}$ = d

⇒ J ∝ vd.

That is, current density of a metallic conductor is directly proportional to the drift velocity.

Q. 3. Deduce Ohm's law using the concept of drift velocity.

OR

Define the term 'drift velocity' of charge carriers in a conductor. Obtain the expression for the current density in terms of relaxation time. [CBSE (F) 2014]

OR

Define relaxation time of the free electrons drifting in a conductor. How is it related to the drift velocity of free electrons? Use this relation to deduce the expression for the electrical resistivity of the material. [CBSE (AI) 2012]

OR

(i) On the basis of electron drift, derive an expression for resistivity of a conductor in terms of number density of free electrons and relaxation time. On what factors does resistivity of a conductor depend?

(ii) Why alloys like constantan and manganin are used for making standard resistors? [CBSE Delhi 2016]

Ans. Relaxation time of free electrons drifting in a conductor is the average time elapsed between two successive collisions.

Deduction of Ohm's Law: Consider a conductor of length l and cross-sectional area A. When a potential difference V is applied across its ends, the current produced is I. If n is the number of electrons per unit volume in the conductor and vd the drift velocity of electrons, then the relation between current and drift velocity is

$$I = -neAv_d \qquad \ldots(i)$$

Where – e is the charge on electron ($e = 1.6 \times 10^{-19}$ C)

Electric field produced at each point of wire, $E = \frac{V}{l}$ (ii)

If τ is relaxation time and E is electric field strength, then drift velocity

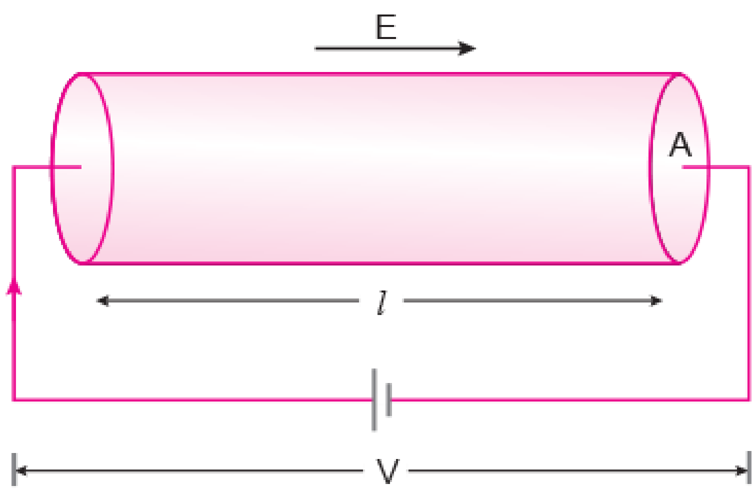
$$v_d = -\frac{e\tau E}{m} \qquad \text{(iii)}$$

Substituting this value in (i), we get

$$I = -neA\left(-\frac{e\tau}{m}E\right) \quad \text{or} \quad I = -\frac{ne^2\tau}{m}AE \qquad \ldots(iv)$$

As $E = \frac{V}{l}$ [From (ii)]

$$I = \frac{ne^2 tA}{m}\frac{V}{l} \quad \text{or} \quad \frac{V}{I} = \frac{m}{ne^2 t}\cdot\frac{l}{A} \qquad \ldots(v)$$



$$\text{Current density } J\left(=\frac{I}{A}\right) = \frac{ne^2\tau}{ml}V.$$

This is relation between current density J and applied potential difference V.

Under given physical conditions (temperature, pressure) for a given conductor

$$\frac{m}{ne^2\tau}\cdot\frac{l}{A} = \text{Constant}$$

∴ This constant is called the resistance of the conductor (i.e. R).

i.e. $$R = \frac{m}{ne^2\tau}\cdot\frac{l}{A} \qquad \text{(iv)}$$

From (v) and (vi); $\frac{V}{I} = R$

(vii)

This is Ohm's law. From equation (vi) it is clear that the resistance of a wire depends on its length (l), cross-sectional area (A), number of electrons per m^3 (n) and the relaxation time (τ)

Expression for resistivity:

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

$(viii)$

Comparing (vi) and (viii), we get

Resistivity of a conductor $$\rho = \frac{m}{ne^2\tau} \qquad ......\text{(ix)}$$

Clearly, resistivity of a conductor is inversely proportional to number density of electrons and relaxation time.

Resistivity of the material of a conductor depends upon the relaxation time, i.e., temperature and the number density of electrons.

This is because constantan and manganin show very weak dependence of resistivity on temperature.

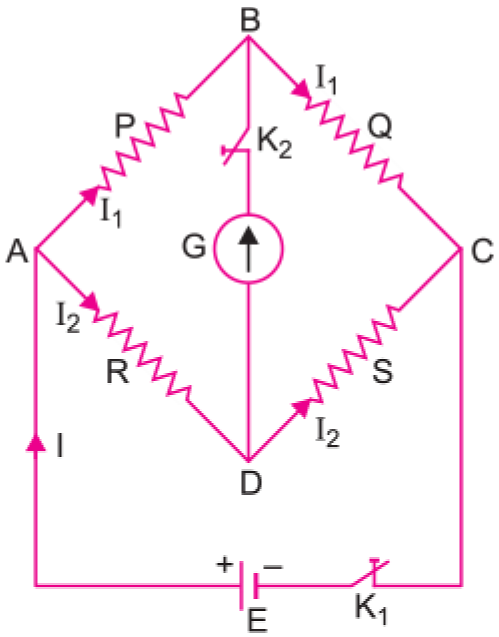
Q. 4. Derive condition of balance of a Wheatstone bridge.

OR

Draw a circuit diagram showing balancing of Wheatstone bridge. Use Kirchhoff's rules to obtain the balance condition in terms of the resistances of four arms of wheat stone Bridge. [CBSE Delhi 2013, 2015]

Ans. Condition of balance of a Wheatstone bridge:

The circuit diagram of Wheatstone bridge is shown in fig.



P, Q, R and S are four resistance forming a closed bridge, called Wheatstone bridge. A battery is connected across A and C, while a galvanometer is connected between B and D. When the bridge is balanced, there is no current in galvanometer.

Derivation of Formula: Let the current flowing in the circuit in the balanced condition be I. This current on reaching point A is divided into two parts I_1 and I_2. As there is no current in galvanometer in balanced condition, current in resistances P and Q is I_1 and in resistances R and S it is I_2.

Applying Kirchhoff's I law at point A

$$I - I_1 - I_2 = 0 \quad \text{or} \quad I = I_1 + I_2 \qquad ...(i)$$

Applying Kirchhoff's II law to closed mesh ABDA

Or $-I_1 P + I_2 R = 0 \quad \text{or} \quad I_1 P = I_2 R \qquad ...(ii)$

Applying Kirchhoff's II law to mesh BCDB

$$-I_1 Q + I_2 S = 0 \quad \text{or} \quad I_1 Q = I_2 S \qquad ...(iii)$$

Dividing equation (ii) by (iii), we get

$$\frac{I_1 P}{I_1 Q} = \frac{I_2 R}{I_2 S} \quad \text{or} \quad \frac{P}{Q} = \frac{R}{S} \qquad ...(iv)$$

This is the **condition of balance of Wheatstone bridge.**

Q. 5. Using the principle of Wheatstone Bridge, describe the method to determine the specific resistance of a wire in the laboratory. Draw the circuit diagram and write the formula used.

Write any two important precautions you would observe while performing the experiment.

OR

Draw a circuit diagram of a Metre Bridge and write the mathematical relation used to determine the value of an unknown resistance. Why cannot such an arrangement be used for measuring very low resistance? [CBSE East 2016]

OR

(a) State, with the help of a suitable diagram, the principle on which the working of a meter bridge is based.

(b) Answer the following:

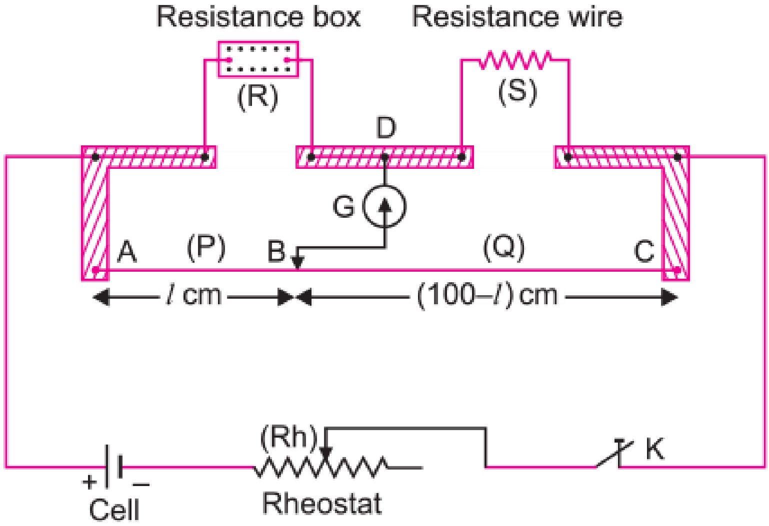
(i) Why are the connections between resistors in a meter bridge made of thick copper strips?

(ii) Why is it generally preferred to obtain the balance point near the middle of the bridge wire in meter bridge experiments? [CBSE (F) 2013]

Ans. Metre Bridge: Special Case of Wheatstone Bridge

It is a practical device based on the principle of Wheatstone bridge to determine the unknown resistance of a wire.

If ratio of arms resistors in Wheatstone bridge is constant, then no current flows through the galvanometer (or bridge wire).



Construction: It consists of a uniform 1 metre long wire AC of constantan or manganin fixed along a scale on a wooden base (fig.) The ends A and C of wire are joined to two L-shaped copper strips carrying connecting screws as shown. In between these copper strips, there is a third straight copper strip having three connecting screws. The middle screw D is connected to a sensitive galvanometer. The other terminal of galvanometer is connected to a sliding jockey B. The jockey can be made to move anywhere parallel to wire AC.

Circuit: To find the unknown resistance S, the circuit is complete as shown in fig. The unknown resistance wire of resistance S is connected across the gap between points C and D and a resistance box is connected across the gap between the points A and D. A cell, a rheostat and a key (K) is connected between the points A and C by means of connecting screws. In the experiment when the sliding jockey touches the wire AC at any point, then the wire is divided into two parts. These two parts AB and BC act as the resistances P and Q of the Wheatstone bridge. In this way the resistances of arms AB, BC, AD and DC form the resistances P, Q, R and S of Wheatstone bridge. Thus the circuit of metre bridge is the same as that of Wheatstone bridge.

Method: To determine the unknown resistance, first of all key K is closed and a resistance R is taken out from resistance box in such a way that on pressing jockey B at end points A and C, the deflection in galvanometer is on both the sides. Now jockey is slided on wire at such a position that on pressing the jockey on the wire at that point, there is no deflection in the galvanometer G. In this position, the points B and D are at the same potential; therefore the bridge is balanced. The point B is called the null point. The length of both parts AB and BC of the wire are read on the scale. The condition of balance of Wheatstone bridge is

$$\frac{P}{Q} = \frac{R}{S}$$

$\Rightarrow$ Unknown resistance,

$$S = \left(\frac{Q}{P}\right) R \quad \ldots(i)$$

To Determine Specific Resistance:

If r is the resistance per cm length of wire AC and l cm is the length of wire AB, then length of wire BC will be (100 – l) cm

$\therefore$ P = resistance of wire AB = lr

Q = resistance of wire BC = (100 – l)r

Substituting these values in equation (i), we get

$$S = \frac{(100-l)\,r}{l\,r} \times R \quad \text{or} \quad S = \frac{100-l}{l} R \quad \ldots(ii)$$

As the resistance (R) of wire (AB) is known, the resistance S may be calculated.

A number of observations are taken for different resistances taken in resistance box and S is calculated each time and the mean value of S is found.

$$\text{Specific resistance } \rho = \frac{SA}{l} = \frac{S\pi r^2}{L}$$

Knowing resistance S, radius r by screw gauge and length of wire L by metre scale, the value of ρ may be calculated.

If a small resistance is to be measured, all other resistances used in the circuit, including the galvanometer, should be low to ensure sensitivity of the bridge. Also the resistance of thick copper strips and connecting wires (end resistences) become comparable to the resistance to be measured. This results in large error in measurement.

Precautions:

(i) In this experiment the resistances of the copper strips and connecting screws have not been taken into account. These resistances are called end-resistances. Therefore very small resistances cannot be found accurately by Metre Bridge. The resistance S should not be very small.

(ii) The current should not flow in the metre bridge wire for a long time, otherwise the wire will become hot and its resistance will be changed.

(iii) The resistivity of copper is several times less than the resistivity of the experimental alloy wire. As such area of thick copper strips is more, so copper strips almost offer zero resistance in the circuit.

(iv) If any one resistance in wheat stone bridge is either very small (or very large) in respect of other, then balance point might be very close to terminal A or terminal B. So generally balance point is taken in the middle of the bridge wire.

Q. 6. Answer the following questions:

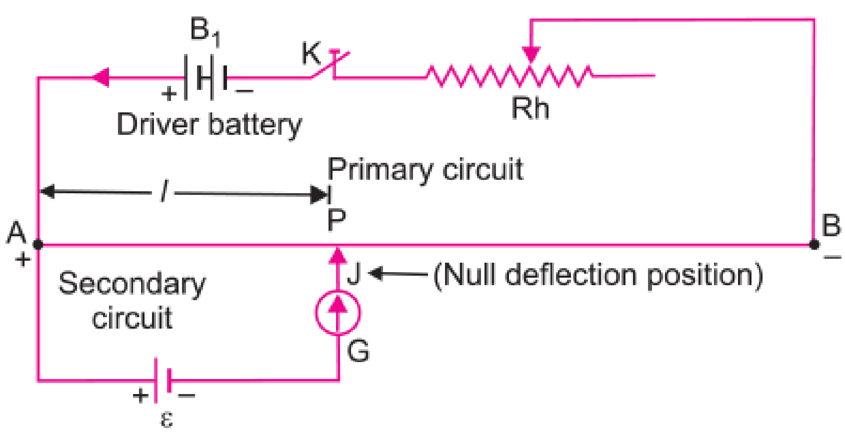
(i) State the principle of working a potentiometer. [CBSE Delhi 2010, 2016]

(ii) Draw a circuit diagram to compare the emf of two primary cells. Write the formula used. How can the sensitivity of a potentiometer be increased?

(iii) Write two possible causes for one sided deflection in the potentiometer experiment. [CBSE Delhi 2013]

Ans. (i) Principle of Potentiometer: When a constant current flows through a wire of uniform area of cross-section, the potential drop across any length of the wire is directly proportional to the length.

Circuit Diagram. It consists of a long resistance wire AB of uniform cross-section. Its one end A is connected to the positive terminal of battery B1 whose negative terminal is connected to the other end B of the wire through key K and a rheostat (Rh). The battery B1 connected in circuit is called the driver battery and this circuit is called the **primary circuit.** By the help of this circuit a definite potential difference is applied across the wire AB; the potential falls continuously along the wire from A to B. **The fall of potential per unit length of wire is called the potential gradient.** It is denoted by 'k'. A cell is connected such that its positive terminal is connected to end A and the negative terminal to a jockey J through the galvanometer G. This circuit is called the **secondary circuit.**



In primary circuit the rheostat (Rh) is so adjusted that the deflection in galvanometer is on one side when jockey is touched on wire at point A and on the other side when jockey is touched on wire at point B.

The jockey is moved and touched to the potentiometer wire and the position is found where galvanometer gives no deflection. Such a point P is called null deflection point.

VAB is the potential difference between points A and B and L metre be the length of wire, then the potential gradient

$$k = \frac{V_{AB}}{L}$$

If the length of wire AP in the null deflection position be l, then the potential difference between points A and P,

$$V_{AP} = kl$$

∴ The emf of cell, $\varepsilon = V_{AP} = kl$

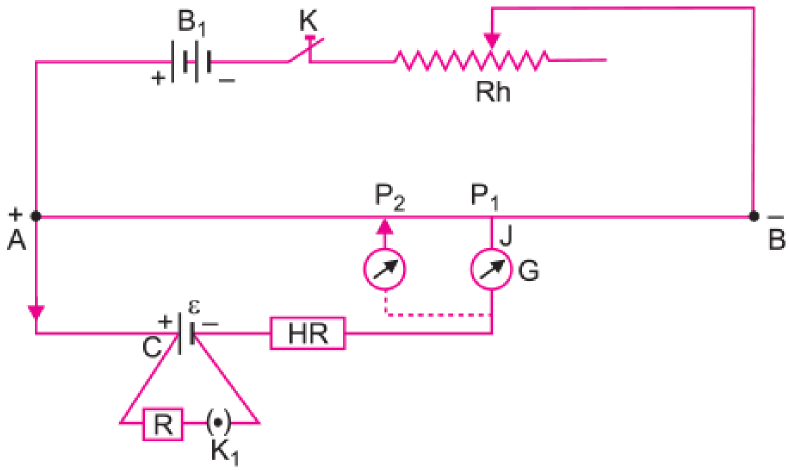
In this way the emf of a cell may be determined by a potentiometer.

Q. 7. Draw the circuit diagram of a potentiometer which can be used to determine the internal resistance (E) of a given cell of emf. Describe a method to find the internal resistance of a primary cell. [CBSE (AI) 2013; (F) 2011, 2016]

Ans. Determination of Internal Resistance of Potentiometer.

Circuit: A battery B_1 a rheostat (Rh) and a key K is connected across the ends A and B of the potentiometer wire such that positive terminal of battery is connected to point A. This completes the primary circuit.

Now the given cell C is connected such that its positive terminal is connected to A and negative terminal to jockey J through a galvanometer. A resistance box (R) and a key K_1 are connected across the cell. This completes the secondary circuit.



Method:

Initially key K is closed and a potential difference is applied across the wire AB. Now rheostat Rh is so adjusted that on touching the jockey J at ends A and B of potentiometer wire, the deflection in the galvanometer is on both sides. Suppose that in this position the potential gradient on the wire is k.

Now key K_1 is kept open and the position of null deflection is obtained by sliding and pressing the jockey on the wire. Let this position be P_1 and $AP_1 = l_1$

In this situation the cell is in open circuit, therefore the terminal potential difference will be equal to the emf of cell, i.e.,

emf $\varepsilon = kl_1$ ...(i)

Now a suitable resistance R is taken in the resistance box and key K_1 is closed. Again, the position of null point is obtained on the wire by using jockey J. Let this position on wire be P_2 and $AP_2 = l_2$.

In this situation the cell is in closed circuit, therefore the terminal potential difference (V) of cell will be equal to the potential difference across external resistance R, i.e.,

$V = kl_2$ ...(ii)

Dividing (i) by (ii), we get $\frac{\varepsilon}{V} = \frac{l_1}{l_2}$

$\therefore$ Internal resistance of cell, $r = \left(\frac{\varepsilon}{V} - 1\right) R = \left(\frac{l_1}{l_2} - 1\right) R$

From this formula r may be calculated.

Q. 8. Answer the following questions:

A cell of emf E and internal resistance r is connected to two external resistances R_1 and R_2 and a perfect ammeter. The current in the circuit is measured in four different situations:

(i) Without any external resistance in the circuit.

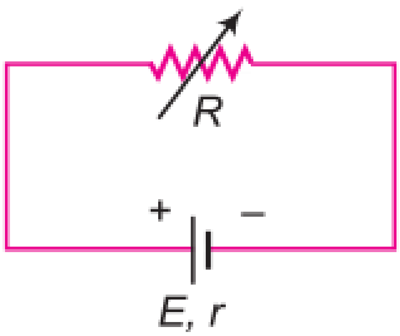
(ii) With resistance R_1 only

(iii) With R_1 and R_2 in series combination

(iv) With R_1 and R_2 in parallel combination.

The currents measured in the four cases are 0.42 A, 1.05 A, 1.4 A and 4.2 A, but not necessarily in that order. Identify the currents corresponding to the four cases mentioned above.

(ii) A variable resistor R is connected across a cell of emf E and internal resistance 'r' as shown in the figure.

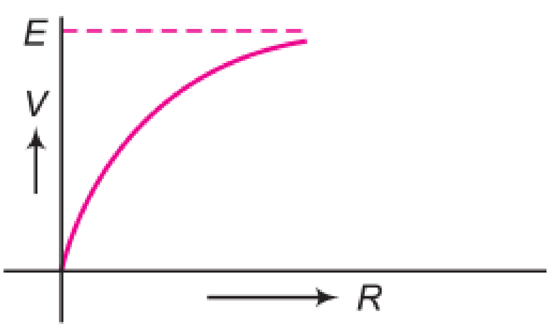


Plot a graph showing the variation of

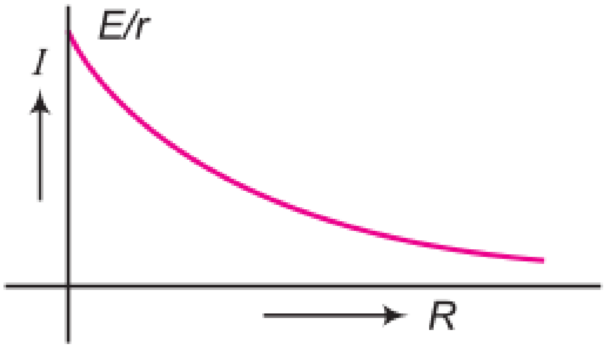
(i) Terminal voltage V and
(ii) The current I, as a function of R. [CBSE Delhi 2012] [HOTS]

Ans. $V = E - Ir = E - \frac{E}{R+r}r$

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



ii. $I = \frac{E}{R+r}$

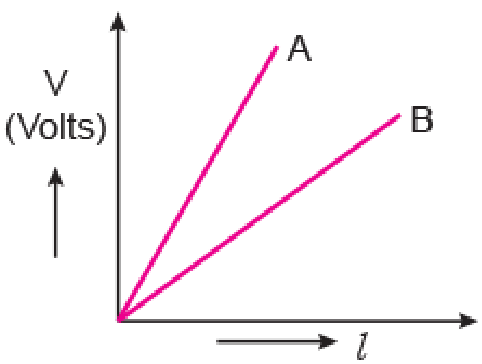


r = Internal resistance

Q. 9. Answer the following questions:

(1) (i) State the principle on which a potentiometer works. How can a given potentiometer be made more sensitive?

(ii) In the graph shown below for two potentiometers, state with reason which of the two potentiometer, A or B, is more sensitive.



(2) Two metallic wires, P1 and P2 of the same material and same length but different cross-sectional areas, A1 and A2 are joined together and connected to a source of emf. Find the ratio of the drift velocities of free electrons in the two wires when they are connected (i) in series, and (ii) in parallel. [CBSE (A) 2017]

Ans. (1) Principle: When a constant current flows through a wire of uniform area of cross section, the potential drop across any length of the wire is directly proportional to the length.

To make it more sensitive, the value of potential gradient K is kept least possible. Smaller the value of K, greater is the length (l) for the null deflection, and so greater will be the accuracy of measurement.

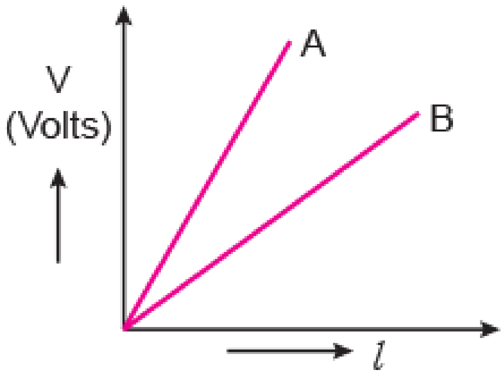
Potential gradient = v/l

∴ Potential gradient of wire A is more than wire B

So, wire B is more sensitive then A.

Q. 10. Explain with the help of a circuit diagram how the value of unknown resistance can be determined using a Wheatstone Bridge. Give the formula used.

Ans. Determination of Unknown resistance by Wheatstone Bridge. The circuit diagram is completed as shown in fig. P and Q are each 10Ω resistance, RB is a resistance box and X is unknown resistance to be measured. B is battery with key K_1 (in series, G is galvanometer with key K_2 in series.)



The battery key K_1 is pressed first and smallest resistance in RB is introduced by pressing galvanometer by K_2, the deflection in galvanometer is noted. Now resistance in RB is introduced, by pressing galvanometer key the deflection should be on other side. This is the main precaution before starting the experiment.

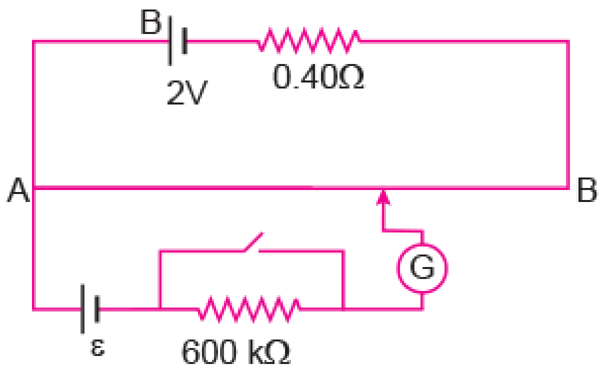
Now suitable value of resistance in RB is chosen so that on pressing the galvanometer key, there is no deflection in galvanometer. This resistance R is noted. Now formula used is

$$\frac{P}{Q} = \frac{R}{X}$$

⇒ Unknown resistance

$X = \frac{Q}{P} R$ can be calculated.

Q. 11. Figure shows a potentiometer with a cell of 2.0 V and internal resistance of 0.40Ω maintaining a potential drop across the resistor wire AB. A standard cell which maintains a constant emf of 1.02 V (for very moderate currents upto a few mA) gives a balance point at 67.3 cm length of the wire. To ensure very low currents drawn from the standard cell, a very high resistance of 600 kΩ is put in series with it, which is shorted close to the balance point. The standard cell is then replaced by a cell of unknown emf and the balance point found similarly, turns out to be at 82.3 cm length of the wire.



(a) What is the value of ε?

(b) What purpose does the high resistance of 600 kΩ have?

(c) Is the balance point affected by this high resistance?

(d) Is the balance point affected by the internal resistance of the driver cell?

(e) Would the method work in the above situation if the driver cell of the potentiometer had an emf of 1.0 V instead of 2.0 V?

(f) Would the circuit work well for determining extremely small emf, say of the order of few mV (such as the typical emf of a thermo couple)? If not, how would you modify the circuit?

Ans. (a) For same potential gradient of potentiometer wire, the formula for comparison of emfs of cells is

$$\frac{\varepsilon_2}{\varepsilon_1} = \frac{l_2}{l_1} \quad \Rightarrow \quad \frac{\varepsilon}{\varepsilon_s} = \frac{l}{l_s}$$

$$\varepsilon = \frac{l}{l_s}\varepsilon_s$$

ε_S = emf of standard cell = 1.02 V

l_S = balancing with length standard cell = 67.3 cm

l = balancing length with cell of unknown emf = 82.3 cm

$$\therefore \text{ Unknown emf } \varepsilon = \frac{(82.3 \text{ cm})}{(67.3 \text{ cm})} \times 1.02\ V = 1.25\ V$$

(b) The purpose of high resistance is to reduce the current through the galvanometer. When jockey is far from the balance point, this saves the standard cell from being damaged.

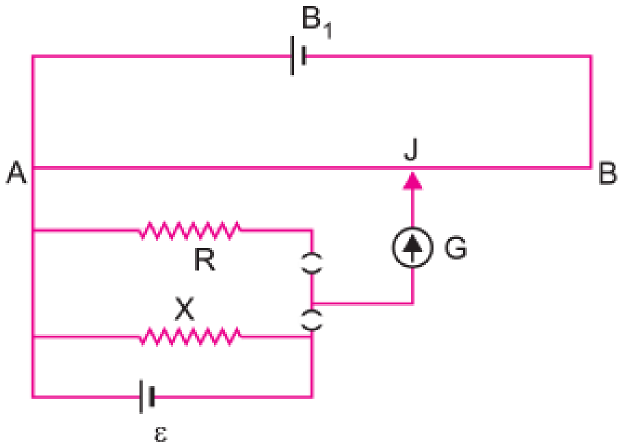
(c) The balance point is not affected by the presence of high resistance because in balanced-position there is no current in cell-circuit (secondary circuit).

(d) No, the balance point is not affected by the internal resistance of driver cell, because we have already set the constant potential gradient of wire.

(e) No, since for the working of potentiometer the emf of driver cell must be greater than emf of secondary circuit.

(f) No, the circuit will have to be modified by putting variable resistance (R) in series with the driver cell the value of R is so adjusted that potential drop across wire is slightly greater than emf of secondary cell, so that the balance point may be obtained at a longer length. This will reduce the error and increase the accuracy of measurement.

Q. 12. Figure shows a potentiometer circuit for comparison of two resistances. The balance point with a standard resistance R = 10.0Ω is found to be 58.3 cm, while that with the unknown resistance X is 68.5 cm. Determine the value of X. What might you do if you failed to find a balance point with the given cell ε.



Ans. In first case, resistance R is in parallel with cell ε, so p.d. across R = ε

i.e., $\varepsilon = RI$ ...(i)

In second case, X is in parallel with cell so p.d. across X = ε

i.e., $\varepsilon = XI$ ...(ii)

Let k be the potential gradient of potentiometer wire. If l1 and l2 are the balancing length corresponding to resistance respectively, then

$$\varepsilon = kl_1 \quad \text{...(iii)}$$

$$\varepsilon = kl_2 \quad \text{...(iv)}$$

From (i) and (iii) $RI = kl_1$ ...(v)

From (ii) and (iv) $XI = kl_2$ ...(vi)

Dividing (vi) by (v), we get

$$\frac{X}{R} = \frac{l_2}{l_1} \Rightarrow X = \frac{l_2}{l_1} R$$

Here, R = 10.0 Ω, l_1 = 58.3 cm, l_2 = 68.5 cm

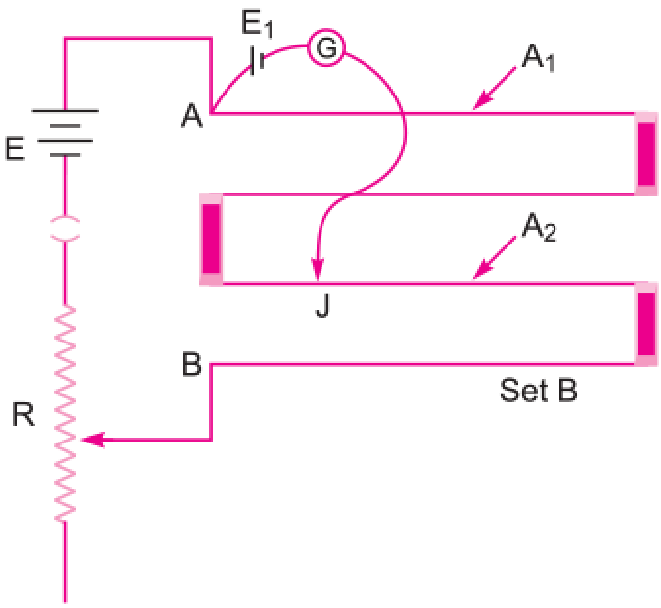
$$\therefore \qquad X = \frac{68.5}{58.3} \times 10.0 = 11.75\Omega$$

If we fail to find the balance point with the given cell ε, then we shall take the driver battery (B_1) of higher emf than given emf (ε).

Q. 13. You are given two sets of potentiometer circuits to measure the emf E_1 of a cell.

Set A: consists of a potentiometer wire of a material of resistivity ρ_1, area of cross-section A_1 and length l.

Set B: consists of a potentiometer of two composite wire of equal lengths l/2 each, of resistivity ρ_1, ρ_2 and area of cross-section A_1, A_2 respectively.



Find the relation between resistivity of the two wires with respect to their area of cross section, if the current flowing in the two sets is same.

Compare the balancing length obtained in the two sets. [CBSE Sample Paper 2016]

Ans.

(i) $I = \frac{\varepsilon}{R+\frac{\rho_1 l}{A_1}}$ for set A and $I = \frac{\varepsilon}{R+\frac{\rho_1 l}{2A_1}+\frac{\rho_2 l}{2A_2}}$ for set B

Equating the above two expressions, we have

$$\frac{\varepsilon}{R+\frac{\rho_1 l}{2A_1}} = \frac{\varepsilon}{R+\frac{\rho_1 l}{2A_1}+\frac{\rho_2 l}{2A_2}}$$

$$\Rightarrow \qquad R+\frac{\rho_1 l}{A_1} = R+\frac{\rho_1 l}{2A_1}+\frac{\rho_2 l}{2A_2} \qquad \Rightarrow \frac{\rho_1 l}{A_1} - \frac{\rho_1 l}{2A_1} = \frac{\rho_2 l}{2A_2}$$

...(i)

$$\Rightarrow \qquad \frac{\rho_1}{A_1} = \frac{\rho_2}{A_2}$$

(ii) Potential gradient of the potentiometer wire for set A, $K = I\frac{\rho_1}{A_1}$

Potential drop across the potentiometer wire in set B

$$V = I\left(\frac{\rho_1 l}{2A_1}+\frac{\rho_2 l}{2A_2}\right) \qquad \Rightarrow \qquad V = \frac{1}{2}\left(\frac{\rho_1}{A_1}+\frac{\rho_2}{A_2}\right) I$$

$$K' = \frac{I}{2}\left(\frac{r_1}{A_1}+\frac{r_2}{A_2}\right),$$

using the condition (i), we get

$K' = I\frac{\rho_1}{A_1}$, which is equal to K.

Therefore, balancing length obtained in the two sets is same.