3

Current Electricity

PREVIOUS YEARS' Questions

2007

SHORT ANSWER TYPE QUESTION[I] **[2 Marks]**

1. **A cylindrical metallic wire is stretched to increase its length by 5%. Calculate the percentage change in its resistance.** *[Delhi]*

Ans. Resistance, $R = \rho \frac{l}{A}$

$$\frac{l_f - l_i}{l_i} = \frac{5}{100}$$

$$\frac{l_f}{l_i} = \frac{21}{20}$$

On stretching volume remains same *i.e.,*

$$\frac{l_f}{l_i} = \frac{A_i}{A_f}.$$

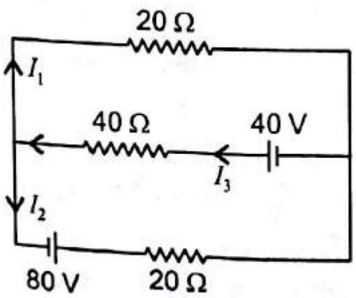
From the relation $R = \rho \frac{l}{A}$ we have

$$\frac{R_f}{R_i} = \frac{l_f}{l_i} \times \frac{A_i}{A_f} = \left(\frac{21}{20}\right)^2$$

$$\frac{R_f - R_i}{R_i} = \left(\frac{21}{20}\right)^2 - 1 = 0.1025$$

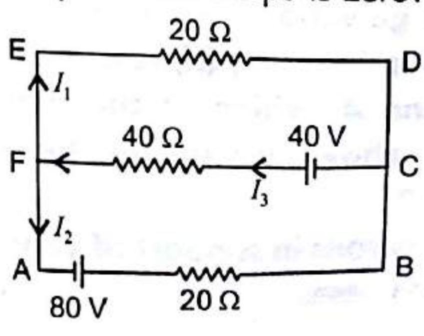
SHORT ANSWER TYPE QUESTIONS[II] **[3 Marks]**

2. **State Kirchhoff's rules of current distribution in an electrical network. Using these rules determine the value of the current I_1 in the electric circuit given below.** *[Delhi]*



Ans. **Kirchhoff's junction rule:** 'Algebraic sum of currents meeting at a junction in a closed circuit is zero.'

Kirchhoff's loop rule: 'In any closed path of an electric circuit the algebraic sum of all the potential drops is zero'.



According to junction rule :

$$I_3 = I_1 + I_2 \quad ...(i)$$

Taking loop FEDCF

$$20I_1 + 40I_3 = 40$$

$$\Rightarrow \quad I_1 + 2I_3 = 2$$

$$\Rightarrow \quad 2I_1 + 4I_3 = 4 \quad ...(ii)$$

Taking loop FCBAF

$$-40I_3 - 20I_2 = -40 - 80$$

$$\Rightarrow \quad 4I_3 + 2I_2 = 12$$

$$\Rightarrow \quad 2I_3 + I_2 = 6 \quad ...(iii)$$

Substituting value of I_2 from equation (*i*) in equation (*iii*)

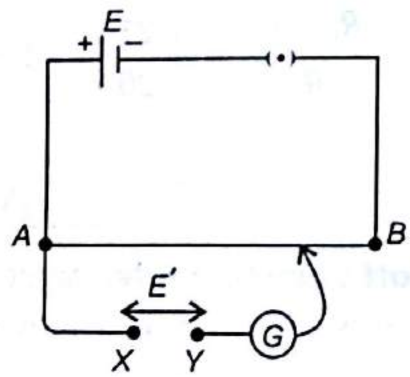
$$2I_3 + (I_3 - I_1) = 6$$

$$\Rightarrow \quad 3I_3 - I_1 = 6 \quad ...(iv)$$

On solving equations (*ii*) and (*iv*), we get

$$I_1 = -1.2 \text{ A}$$

3. For the potentiometer circuit shown in the given figure, points *X* and *Y* represent the two terminals of an unknown emf *E'*. A student observed that when the jockey is moved from the end *A* to the end *B* of the potentiometer wire, the deflection in the galvanometer remains in the same direction.



What may be the two possible faults in the circuit that could result in this observation?

If the galvanometer deflection at the end *B* is (*i*) more, (*ii*) less, than that at the end *A*, which of the two faults, listed above, would be there in the circuit?

Give reasons in support of your answer in each case. [*All India*]

Ans. (*a*) Two possible faults are

(*i*) e.m.f. (*E*) applied across *AB* is less than the unknown e.m.f. *E'*

(*ii*) –ve terminal of the source of unknown e.m.f. is joined with end *A* of the wire.

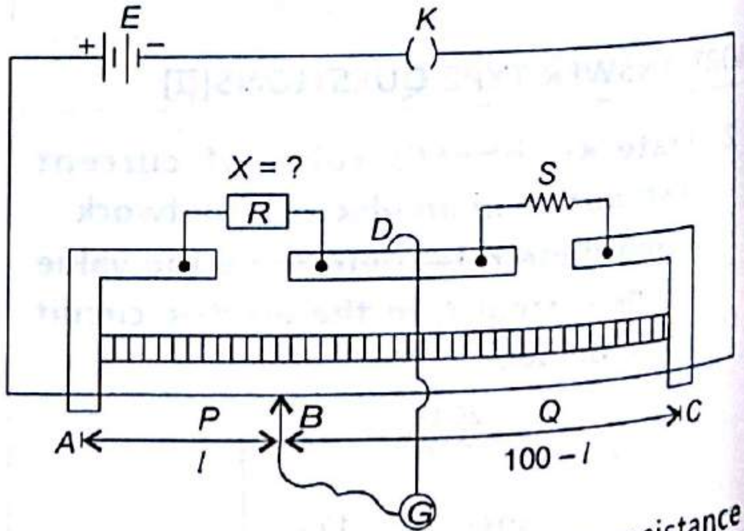
(*b*) The galvanometer deflection at the end *B* is more, means source of unknown e.m.f. have been joined with its –ve terminal to end *A*. Current gets divided at point *A* and combines at point *B*.

The galvanometer deflection at the end *B* is less than at the end *A*, means the e.m.f applied is less than the unknown e.m.f used. Currents get combined at end *A* and divided at end *B*.

4. On what principle does a metre bridge work? Draw a circuit diagram and explain how this device can be used for determination of an unknown resistance. [*Foreign*]

Ans. Working of meter bridge is based on the principle of the Wheatstone bridge. When bridge is balanced

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



First we connect unknown resistance either in left gap or right gap of the meter bridge. Then we attach a resistance of the known value in the second gap of the meter bridge. We find out the balance point. Let the balance point be at a distance 'l' from the point A of the bridge. Then

$$\frac{X}{S} = \frac{l}{100-l}$$

$$X = \left(\frac{l}{100-l}\right)S$$

Thus, unknown resistance is calculated.

5. Derive a mathematical expression for resistivity of a conductor in terms of number density of charge carries in the conductor and relaxation time. [*Foreign*]

Ans. Consider a conductor of length l and area of cross-section A. Let a potential V be applied across it. An electric field is developed across the conductor that derives the electrons in one direction and constitutes current I in it

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

We know that $I = neAv_d$ ...(*ii*)

where, n is number density of free electrons and v_d is drift velocity of free electrons.

Force experienced by an electron is

$$F = eE$$

$$ma = eE$$

$$m\frac{v_d}{\tau} = eE$$

$$v_d = \frac{eE\tau}{m} \quad ...(iii)$$

where, τ is relaxation time.

Substitute the value of v_d in equation (*ii*)

$$I = neA\left(\frac{eE}{m}\tau\right)$$

$$I = neA\frac{eV}{ml}\tau$$

$$\frac{V}{I} = \frac{ml}{ne^2A\tau} \quad ...(iv)$$

From Ohm's law

$$\frac{V}{I} = R \quad ...(v)$$

On comparing equations (*iv*) and (*v*), we get

$$R = \frac{ml}{ne^2A\tau}$$

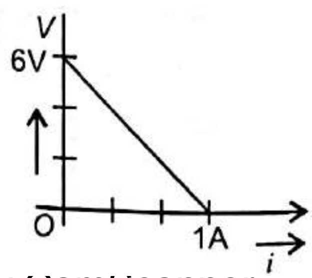
where, $\rho = \frac{m}{ne^2\tau}$

ρ is called resistivity of the conductor.

2008

VERY SHORT ANSWER TYPE QUESTION [1 Mark]

6. The plot of the variation of potential difference across a combination of three identical cells in series, versus current is as shown here. What is the emf of each cell? [*Delhi*]



Ans. 2 volts

When $I = 0$,

$E = V$

Thus, e.m.f. of each cell $= \frac{6}{3}$

$= 2$ volts.

7. Using the mathematical expression for the conductivity of a material, explain how it varies with temperature for (*i*) semiconductors, (*ii*) good conductors. *[All India]*

Ans. Conductivity, $\sigma = \frac{ne^2\tau}{m}$

(*i*) **Semiconductors:** With increase in temperature, conductivity of semiconductors increases. It is due to increase in 'n'. It dominates the effect caused by decrease in 'τ'.

(*ii*) **Good conductors:** With increase in temperature, conductivity of good conductors decreases. It is due to decrease in the value of relaxation time. The effect of increased value of 'n' is negligible.

8. Derive an expression for the resistivity of a good conductor, in terms of the relaxation time of electrons. *[All India]*

Ans. Drift speed gained by an electron under the effect of electric field 'E' in a conductor is

$$v_d = \frac{eE}{m}\tau$$

$$v_d = \frac{eV}{ml}\tau \quad (\therefore E = \frac{V}{l})$$

We have relation

$$I = enA\, v_d$$

$$I = enA\left(\frac{eV}{ml}\tau\right)$$

$$\frac{V}{I} = \frac{ml}{ne^2\tau A}$$

In case, l = 1m and A = 1m^2,

$$\frac{V}{I} = \frac{m}{ne^2\tau}$$

Here, $\frac{m}{ne^2\tau}$ is called resistivity of the conductor (ρ).

Thus, $\rho = \frac{m}{ne^2\tau}$

where, 'τ' is relaxation time.

9. Two metallic wires of the same material have the same length but cross-sectional area is in the ratio 1 : 2. They are connected (*i*) in series and (*ii*) in parallel. Compare the drift velocities of electrons in the two wires in both the cases (*i*) and (*ii*). *[All India]*

Ans. Given : $l_1 = l_2 = l$

$$\frac{A_1}{A_2} = \frac{1}{2}$$

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

We have, $\frac{R_1}{R_2} = \frac{A_2}{A_1} = \frac{2}{1}$

(*i*) In series current is same. So, from $v_d = \frac{I}{enA}$

we get $\frac{v_{d_1}}{v_{d_2}} = \frac{A_2}{A_1} = \frac{2}{1}$

(*ii*) In parallel current get divided in inverse ratio of resistances. So,

$$\frac{I_1}{I_2} = \frac{R_2}{R_1} = \frac{1}{2}$$

As $v_{d_1} = \frac{I_1}{enA_1}, v_{d_2} = \frac{I_2}{enA_2}$

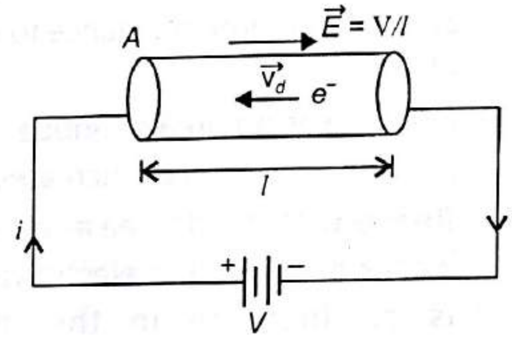
We have,

$$\frac{v_{d_1}}{v_{d_2}} = \frac{I_1}{I_2} \times \frac{A_2}{A_1}$$

$$= \frac{1}{2} \times \frac{2}{1} = \frac{1}{1}$$

10. Prove that the current density of a metallic conductor is directly proportional to the drift speed of electrons. *[Delhi]*

Ans. Consider a conductor of length 'l' and area of cross-section 'A' having number density of free electrons 'n'. Suppose on applying a potential drop across this conductor electrons begin to move with a drift velocity 'v_d' in a direction opposite to the direction of the electric field established across the conductor.



Total number of free electrons

$$N = nAl$$

Total charge $\quad Q = eAnl$

Time taken by an electron to move across the conductor.

$$t = \frac{l}{v_d}$$

As $\quad I = \frac{Q}{t}$

$$I = \frac{eAnl}{l/v_d} = nAev_d$$

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

$$J = nev_d$$

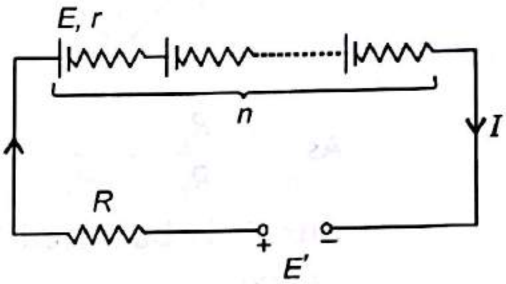
Hence, $\quad J \propto v_d$

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

(i) Draw the circuit arrangement.

(ii) Deduce the expressions for (a) the charging current and (b) the potential difference across the combination of the cells. *[Delhi]*

Ans. (i)



(ii) (a) Expression for charging current

Net resistance of the circuit,

$$R_{eq} = R + nr$$

Total emf of the cells, $E_t = nE$

Effective emf $= E' - nE$

Charging current, $I = \dfrac{E' - nE}{R + nr}$

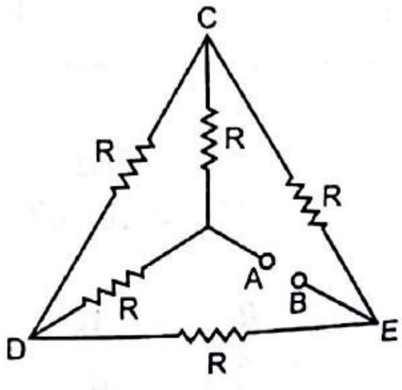
(b) Potential difference across the combination of cell,

$$V = nE - I\,(nr)$$

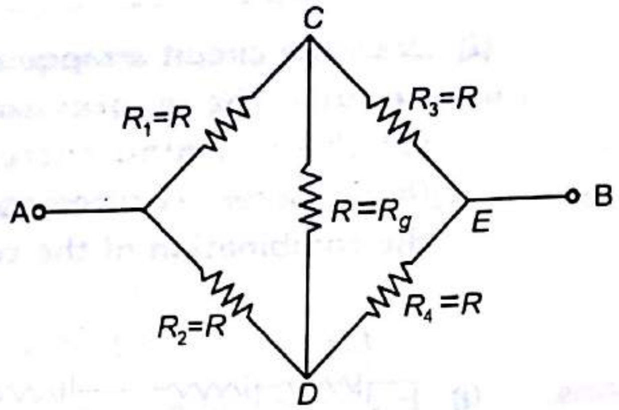
$$V = n(E - Ir)$$

12. (i) Calculate the equivalent resistance of the given electrical network between points A and B.

(ii) Also calculate the current through CD and ACB, if a 10V d.c. source is connected between A and B, and the value of R is assumed as 2 Ω. *[All India]*



Ans. (*i*) Given circuit can be redrawn as

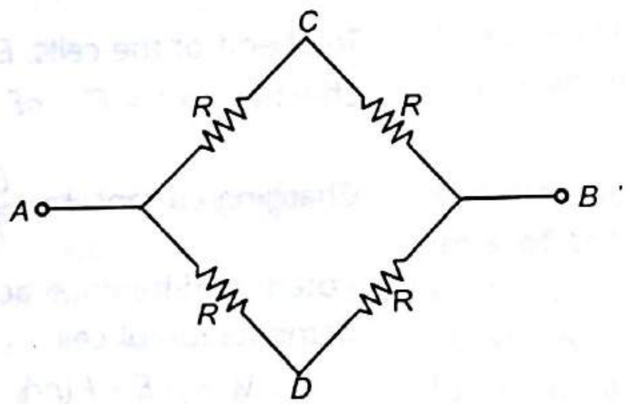


As $\quad \dfrac{R_1}{R_2} = \dfrac{R_3}{R_4}$

Circuit is balanced Wheatstone bridge.

$$V_C = V_D \text{ and } I_{CD} = 0$$

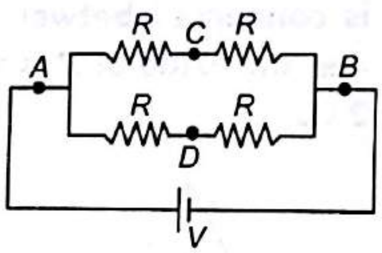
Equivalent circuit is



Thus $\quad R_{AB} = \dfrac{(2R)(2R)}{4R} = R\ \Omega$

(*ii*) Being a balanced Wheatstone bridge

$$I_{CD} = 0$$
$$V = 10 \text{ volt}$$



$$R = 2\ \Omega$$
$$V_{AB} = 10 \text{ volt}$$
$$R_{ACB} = 4\ \Omega$$
$$I_{ACB} = \frac{10}{4} = 2.5 \text{ A}$$

13. Explain, giving reasons, how the internal resistance of a cell changes in the following cases :

(*a*) When concentration of electrolyte is increased.

(*b*) When area of the anode is decreased.

(*c*) When temperature of the electrolyte is increased. [*Foreign*]

Ans. (*a*) On increasing concentration of electrolyte internal resistance of the cell increases.

Reason: On increasing concentration electrolyte become more saturated. So, it offers more resistance to motion of ions.

(*b*) On decreasing area of anode internal resistance of the cell increases.

Reason: With decrease in area of electrode dipped in electrolyte there is an increase in the internal resistance.

(*c*) On increasing temperature of electrolyte internal resistance of the cell decreases.

Reason: With increase in temperature viscosity decreases. So ions gain more mobility.

14. Derive the relation connecting drift speed of electrons and the electric current. Hence, prove that current density is directly proportional to the relaxation time. [*Foreign*]

Ans. (*i*) Electrons experience a force under the effect of an electric field developed across the conductor having certain value of potential difference at its two ends.

$$\vec{F} = -e\vec{E}$$

$$\vec{a} = -\frac{e\vec{E}}{m}$$

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

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

where 'v_d' is drift velocity of electron and τ is average relaxation time.

or $$v_d = \frac{eE}{m}\tau \quad ...(i)$$

Time taken by an electron to move across the conductor having length 'l' is

$$t = \frac{l}{v_d} \quad ...(ii)$$

$$t = \frac{lm}{eE\tau} \quad ...(iii)$$

If 'n' is number density of free electrons. 'A' is area of cross-section and 'l' is length of the conductor, total free charge in it is

$$Q = eAnl \quad ...(iv)$$

As $$I = \frac{Q}{t}$$

Substituting value of Q and τ from equations (i) and (ii)

We get

$$I = enAv_d$$

(ii) Current density is

$$J = \frac{I}{A}$$

$$J = \frac{enAv_d}{A}$$

$$J = env_d$$

Substituting value of 'v_d' from equation (i), we get

$$J = en\left(\frac{eE\tau}{m}\right) = \frac{ne^2E}{m}\tau$$

Thus,

$$J \propto \tau$$

2009

VERY SHORT ANSWER TYPE QUESTION [1 Mark]

15. A steady current flows in a metallic conductor of non-uniform cross-section. Which of these quantities is constant along the conductor : Current, Current density, Drift speed, Electric field? [*Foreign*]

Ans. Current.

SHORT ANSWER TYPE QUESTIONS[I] [2 Marks]

16. Derive an expression for drift velocity of free electrons in a conductor in terms of relaxation time. [*Delhi*]

Ans. In the absence of electric field, the motion of electron is random and the net velocity is zero. In the presence of electric field, they tend to flow opposite to that of the electric field in the conductor. If an electric field 'E' is applied across a length l of the conductor, the electrons will experience an acceleration $a = -\frac{eE}{m}$. If the time average for the acceleration is t then, the velocity acquired is,

$$\vec{v}_d = \vec{u} + \vec{a}\tau = \vec{a}\tau$$

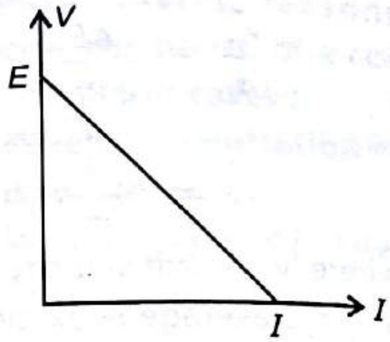
$$\therefore \quad v_d = -\frac{e\vec{E}}{m}\tau, \; |\vec{v}_d|$$

$$= \frac{eE\tau}{m}$$

17. 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 R.

Predict from the graph, the condition under which 'V' becomes equal to 'E'. [*Delhi*]

Ans. $V = E - Ir$ gives the terminal voltage and can be plotted as shown.



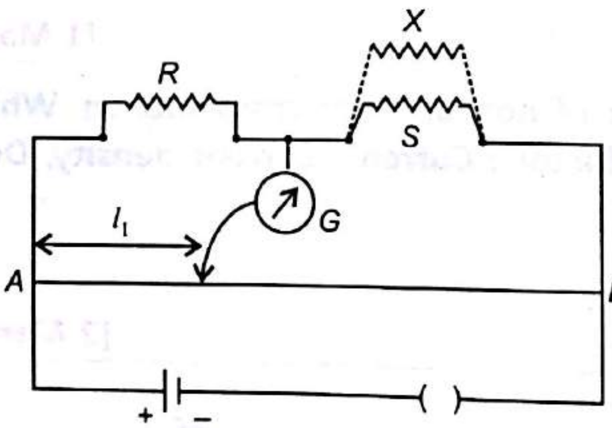
V becomes E when no current is drawn from the cell.

SHORT ANSWER TYPE QUESTIONS[II] [3 Marks]

18. (i) State the principle of working of a meter bridge.

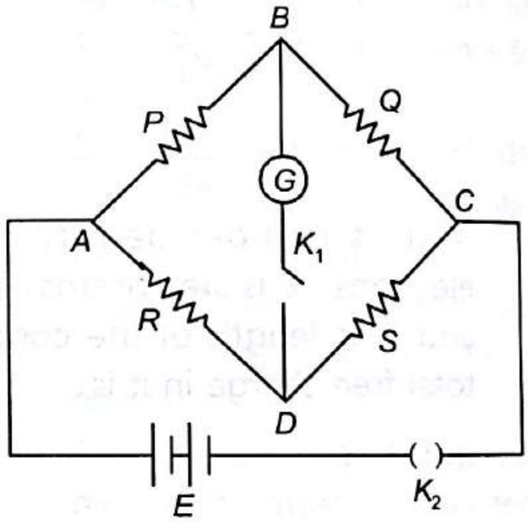
(ii) In a meter bridge balance point is found at a distance l_1 with resistances R and S as shown in the figure.

When an unknown resistance X is connected in parallel with the resistance S, the balance point shifts to a distance l_2. Find the expression for X in terms of l_1, l_2 and S. [*All India*]



Ans. (*i*) **Wheatstone Bridge:** Arrangement of four resistances, say P, Q, R and S as shown in figure is known as Wheatstone's bridge. The null point condition is given by

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



At the balance condition, no current flows through the galvanometer arm.

By using the balance condition of wheatstone bridge, the value of unknown resistance can be determined, knowing the other three resistance.

(*ii*) With R and S alone, we have

$$\frac{R}{S} = \frac{l_1}{(100 - l_1)}$$

$$\Rightarrow \quad R(100 - l_1) = Sl_1$$

With S and X in parallel with R on the left gap,

$$\frac{R}{\left(\frac{SX}{S+X}\right)} = \frac{l_2}{(100 - l_2)}$$

$$\Rightarrow \quad R(100 - l_2) = \frac{SXl_2}{(S+X)}$$

Dividing the two equations, we get

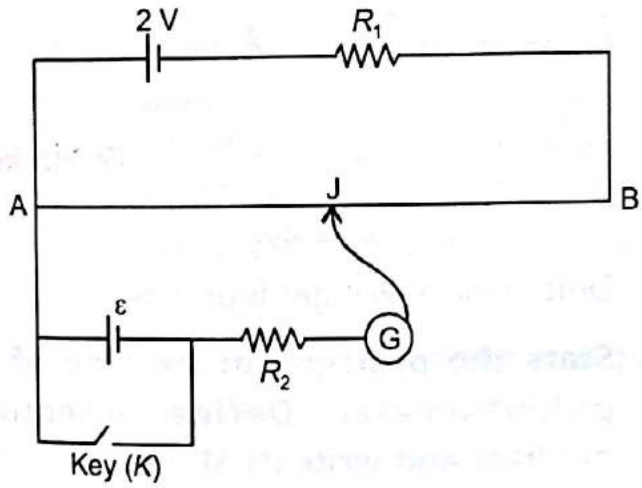
$$\frac{100 - l_1}{100 - l_2} = \frac{l_1(S+X)}{Xl_2}$$

$$\Rightarrow 100\,Xl_2 - l_1l_2X = 100\,l_1S + 100\,l_1X - l_2l_1S - l_2l_1X$$

$$\therefore \quad X = \frac{100l_1S - l_1l_2S}{100(l_2 - l_1)}$$

19. (a) State the principle of working of a potentiometer.

(b) Figure shows the circuit diagram of a potentiometer for determining the emf 'ε' of a cell of negligible internal resistance.



(i) What is the purpose of using high resistance R_2?

(ii) How does the position of balance point (J) change when the resistance R_1 is decreased?

(iii) Why cannot the balance point be obtained (1) When the emf ε is greater than 2V, and (2) When the key (K) is closed?

[*Foreign*]

Ans. (a) **Principle of Potentiometer:** When a constant current is passed through a wire of uniform area of cross-section, then fall of potential V across any portion of the wire is directly proportional to the length of that portion, *i.e.*,

$$V \propto l \quad \text{or} \quad V = kl$$

where, k is called potential gradient. Its SI unit is V m^{-1}. It is constant for a given current but varies with current in potentiometer circuit.

(b) (i) High resistance R_2 will only reduce the current as long as it flows and so the galvanometer will not over-shoot.

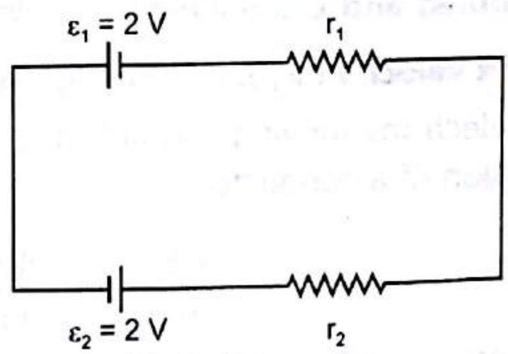
(ii) Change in R_1 will not alter the balancing point but the deflection will increase as more current will flow on lesser resistance.

(iii) (1) When ε is greater than 2V, it will drive current in the potentiometer wire and so no balance point will be obtained.

(2) When the key K is closed, the cell of emf ε is short-circuited so there will be no balancing point.

20. State Kirchhoff's rules. Use Kirchhoff's rules to show that no current flows in the given circuit when any one of the cells is connected with reverse polarity.

[*Foreign*]



Ans. Kirchhoff's Rules:

(i) *Junction Rule-Conservation of Charge* : At any junction in a circuit, the sum of currents entering the junction must be equal to the sum of the currents leaving it.

(ii) *Closed Mesh Rule-Conservation of Energy* : In any closed loop of an electric circuit, the sum of the potential change across all the circuit elements is zero.

Using the Kirchhoff's rule in the loop we get,

$$\varepsilon_1 + \varepsilon_2 - I(r_1 + r_2) = 0$$

$$I = \frac{\varepsilon_1 + \varepsilon_2}{r_1 + r_2} = \frac{2+2}{r_1 + r_2} \neq 0$$

For no current, the sources should bring a net potential of zero. It is possible only when any one of the cell is connected in reverse.

2010

VERY SHORT ANSWER TYPE QUESTIONS [1 Mark]

21. Two conducting wires *X* and *Y* of same diameter but different materials are joined in series across a battery. If the number density of electrons in *X* is twice that in *Y*, find the ratio of drift velocity of electrons in the two wires. *[All India]*

Ans. $I = v_d enA.$

$$\therefore \quad \frac{v_{dx}}{v_{dy}} = \frac{n_y}{n_x}$$

$$\text{As} \quad n_x = 2n_y$$

$$\therefore \quad \frac{v_{dx}}{v_{dy}} = \frac{1}{2}$$

SHORT ANSWER TYPE QUESTIONS[I] [2 Marks]

22. Define drift velocity. Write its relationship with relaxation time in terms of the electric field $\vec{E}$ applied to a conductor.

A potential difference *V* is applied to a conductor of length *L*. How is the drift velocity affected when *V* is doubled and *L* is halved? *[Foreign]*

Ans. **Drift velocity ($\vec{v}_d$):** It is average velocity of electrons moving through any cross-section of a conductor.

$$\vec{v}_d = -\frac{e\vec{E}}{m}\tau = -\frac{eV\tau}{mL}$$

where, τ is relaxation time.

V is doubled and *L* is halved

$$v_d' = \frac{e(2V)\,\tau}{m\frac{L}{2}}$$

$$v_d' = 4v_d$$

Drift velocity will get four times.

23. State the principle of working of a potentiometer. Define potential gradient and write its SI unit. *[Foreign]*

Ans. **Principle of working of potentiometer:** Potential difference across any section of a conducting wire is directly proportional to its length provided current through the wire, its area of cross-section composition and temperature are kept constant.

$$V \propto l$$

$$V = kl$$

Here, *k* is a constant called potential gradient. Potential gradient is the fall of potential per unit length of the wire carrying current.

$$k = \frac{V}{l}$$

SI unit is Vm^{-1}.

24. **State the principle on which the working of a meter bridge is based. Under what condition is the error in determining the unknown resistance minimized?** *[Foreign]*

Ans. Meter bridge is based on the principle of Wheatstone bridge.

Error in determination of resistance can be minimised by adjusting the balance point near the middle of the meter bridge.

2011

VERY SHORT ANSWER TYPE QUESTIONS [1 Mark]

25. **A resistance R is connected across a cell of emf ε and internal resistance r. A potentiometer now measures the potential difference between the terminals of the cells as V. Write the expression for 'r' in terms of ε, V and R.** *[Delhi]*

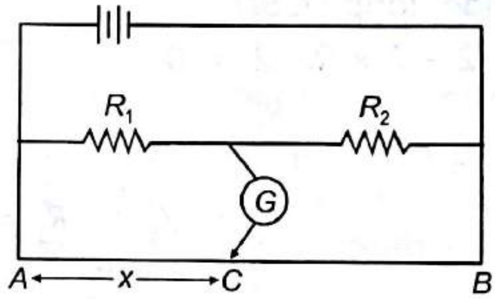
Ans. $r = \left(\dfrac{\varepsilon}{V} - 1\right)R$

26. **Define resistivity of a conductor. Write its SI unit.** *[All India]*

Ans. Resistivity of a conductor is defined as the resistance of a conductor of unit length and having a unit cross-section area. Its SI unit is ohm-m.

27. **In an experiment on meter bridge, if the balancing length AC is 'x', what would be its value, when the radius of the meter bridge wire AB is doubled? Justify your answer.** *[All India]*

Ans.



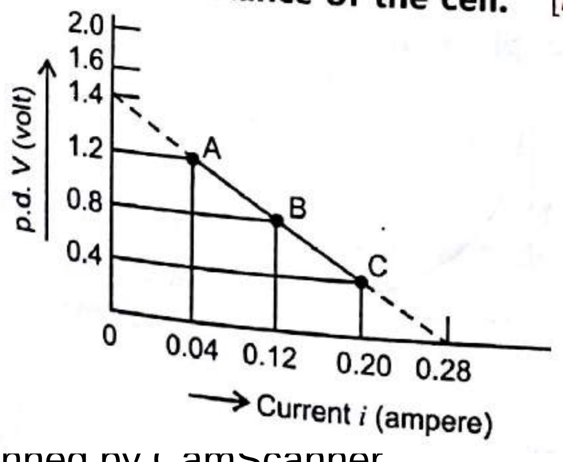
At the balance point,

we have $\dfrac{R_1}{R_2} = \dfrac{x}{100 - x}$

As R_1 and R_2 remain the same, then x will also remain the same. It will not depend upon the diameter of the wire.

SHORT ANSWER TYPE QUESTIONS[I] [2 Marks]

28. **A straight line plot showing the terminal potential difference (V) of a cell as a function of current (I) drawn from it is shown in the figure. Using this plot, determine (*i*) the emf and (*ii*) internal resistance of the cell.** *[Delhi]*



Ans. We know that

$$E - V = Ir$$

(*i*) Clearly, where $I = 0$, $E = V = 1.4$ V (from the graph)

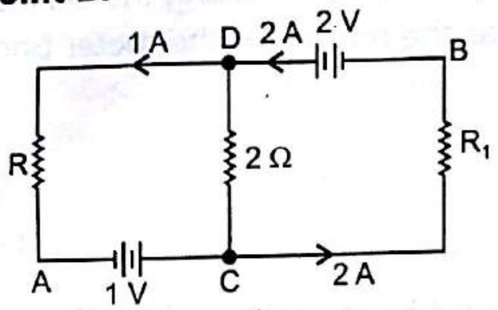
(*ii*) Also, when $V = 1.2$ V, $I = 0.04$ amp.

$$\therefore \quad r = \frac{E - V}{I}$$

$$= \frac{1.4 - 1.2}{0.04} = \frac{0.20}{0.04}$$

$$= 5\ \Omega$$

29. In the given circuit, assuming point *A* to be at zero potential, use Kirchhoff's rules to determine the potential at point *B*. [*All India*]



Ans. Consider loop *DACD*

$$1 \times R - 1 - 1 \times 2 = 0$$
$$R = 3$$

Consider loop *DCBD*

$$1 \times 2 + 2 \times R_1 - 2 = 0$$
$$R_1 = 0$$

As $V_A = 0$, $V_C = 1$ volt.

$$V_C = V_B \quad (\because R_1 = 0\ \Omega)$$

Thus, $V_B = 1$ volt

30. In the meter bridge experiment, balance point was observed at *J* with *AJ* = *l*.

(*i*) The values of *R* and *X* were doubled and then interchanged. What would be the new position of balance point?

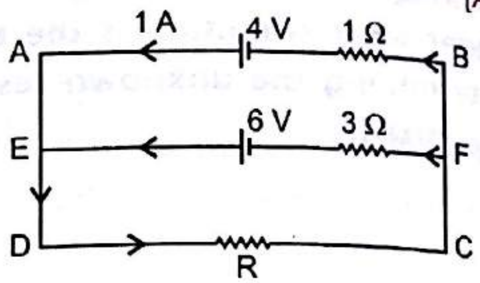
(*ii*) If the galvanometer and battery are interchanged at the balance position, how will the balance point get affected? [*All India*]

Ans. (*i*) Here, $\frac{R}{X} = \frac{l}{100 - l}$

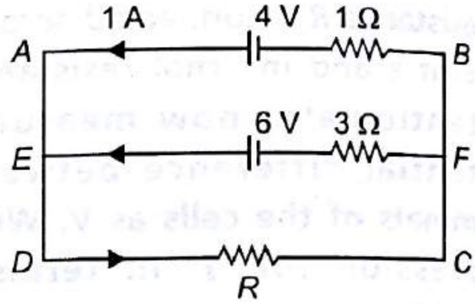
As on doubling the values of *R* and *X* ratio does not change, the balance point remains same.

(*ii*) As the ratio of resistors does not change, the balance point again remains same.

31. Using Kirchhoff's rules, determine (*i*) the voltage drop across the unknown resistor *R* and (*ii*) the current flowing in the arm EF in the circuit as shown. [*All India*]



Ans. The distribution of current is as shown in the fig.



(*i*) Applying Kirchhoff's law, we get

$V_B - V_A = -1 + 4 = 3$, where V_A and V_B are potential at *A* and *B*

$$V_B - V_A = 3$$

Now, *A* is directly connected to *B* and is connected to *C*

$$\therefore \quad V_A = V_D \text{ and } V_B = V_C$$
$$\therefore \quad V_D - V_C = 3 = V_F - V_E$$

$\therefore$ Potential difference across *R* is 3 volt.

(*ii*) Also, $V_F - V_E = -3I + 6$

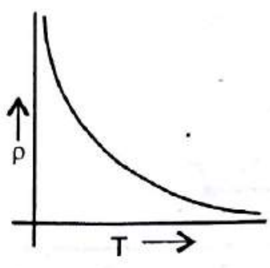
or $3 = -3I + 6$

$$3I = 3$$
$$I = 1\text{ A}$$

$\therefore$ Current through *EF* is 1 A.

32. Plot a graph showing temperature dependence of resistivity for a typical semiconductor. How is this behaviour explained? [*Foreign*]

Ans.



In case of semiconductors, n (no. density of free electrons) increases with temperature. The change in resistivity due to increase in 'n' dominates the change in resistivity due to decrease in 'τ'. So according to the relation,

$$\rho = \frac{m}{ne^2\tau}$$

Resistivity decreases with increase in temperature.

33. **(a) You are required to select a carbon resistor of resistance 47 kW ± 10% from a large collection. What should be the sequence of colour bands used to code it?**

(b) Write two characteristics of manganin which make it suitable for making standard resistances.

[Foreign]

Ans. (a) Sequence of colour bands is yellow, violet orange, silver.

(b) (i) High resistivity.

(ii) Low temperature coefficient of resistivity.

SHORT ANSWER TYPE QUESTIONS[II] [3 Marks]

34. **Define the terms (i) drift velocity, (ii) relaxation time.**

A conductor of length L is connected to a dc source of emf ε. If this conductor is replaced by another conductor of same material and same area of cross-section but of length $3L$, how will the drift velocity change?

[Delhi]

Ans. (i) It is the average of velocities of the electrons crossing any cross-section of a conductor at any instant of time under the effect of a given electric field.

(ii) It is duration of time between two successive collisions.

As, $$v_d = \frac{V}{en\rho L}$$

n = no. of density of free electron,

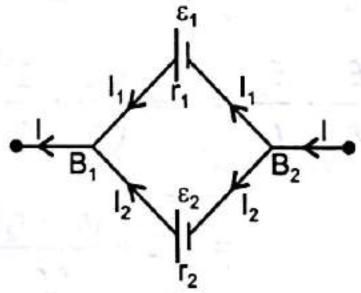
ρ = resistivity

L = Length of conductor.

On increasing length by a factor of three drift velocity decreases by a factor of three.

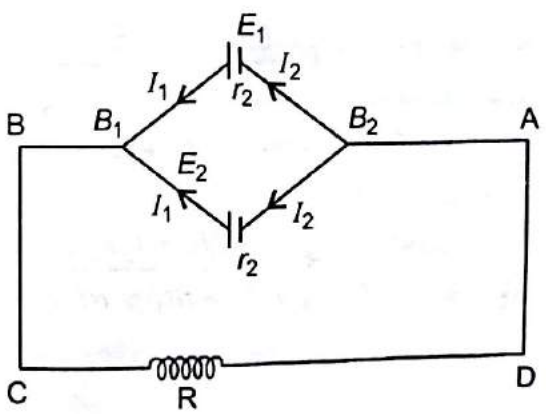
35. **Two cells of emf ε_1 and ε_2 having internal resistances r_1 and r_2 respectively are connected in parallel as shown. Deduce the expressions for the equivalent emf and equivalent internal resistance of a cell which can replace the combination between the points B_1 and B_2.**

[All India]



Ans. Let a resistance R be connected between B_1 and B_2. Let I_1 and I_2 be the currents through the two cells and I the current through R. Since, the two cells are in parallel, then equivalent internal resistance is

$$r = \frac{r_1 r_2}{r_1 + r_2}$$



The circuit contains three current loops. Applying loop rule to $AB_2\,E_1$ BCDA

$$E_1 - I_1r_1 - IR = 0 \quad ...(i)$$

and for the loop $AB_2\,E_2$ BCDA

$$E_2 - I_2r_3 - IR = 0 \quad ...(ii)$$

and for the loop $B_2E_1B_1E_2B_2$

$$E_1 - I_1r_1 - E_2 + I_2r_2 = 0 \quad ...(iii)$$

The equations (*i*) and (*ii*) can be written as

$$E_1 = I_1r_1 + IR$$

or

$$\frac{E_1}{r_1} = I_1 + \frac{IR}{r_1} \quad ...(iv)$$

and equation (*ii*) as

$$\frac{E_2}{r_2} = I_2 + \frac{IR}{r_2} \quad ...(v)$$

Adding equations (*iv*) and (*v*), we have

$$\frac{E_1}{r_1} + \frac{E_2}{r_2} = I_1 + I_2 + I\left(\frac{1}{r_1} + \frac{1}{r_2}\right)R$$

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

$$= I\left[1 + \frac{(r_1 + r_2)}{r_1r_2}R\right]$$

$$\frac{E_1r_2 + E_2r_1}{r_1r_2} = I\frac{[r_1r_2 + (r_1 + r_2)R]}{r_1r_2}$$

$$I = \frac{E_1r_2 + E_2r_1}{r_1r_2 + (r_1 + r_2)R} \quad ...(vi)$$

If E is the equivalent emf of the combination

$$I = \frac{E}{R_T} = \frac{E}{\frac{r_1r_2}{r_1 + r_2} + R}$$

$$= \frac{E(r_1 + r_2)}{r_1r_2 + Rr_1 + Rr_2} \quad ...(vii)$$

Comparing equations (*vi*) and (*vii*), we have

$$\frac{E_1r_2 + E_2r_1}{r_1r_2 + r_1R + r_2R} = \frac{E(r_1 + r_2)}{r_1r_2 + Rr_1 + Rr_2}$$

$$\therefore \quad E = \frac{E_1r_2 + E_2r_1}{r_1 + r_2}$$

Internal resistance of the equivalent cell is

$r = \frac{r_1r_2}{r_1 + r_2}$, since the two cells are in parallel.

36. Two heating elements of resistances R_1 and R_2 when operated at a constant supply of voltage, V, consume powers P_1 and P_2 respectively. Deduce the expressions for the power of their combination when they are, in turn, connected in (*i*) series and (*ii*) parallel across the same voltage supply. [*All India*]

Ans. We know $P = \frac{V^2}{R}$

(*i*) When resistors are connected in series, equivalent resistance is

$$R_s = R_1 + R_2.$$

Power consumed is

$$P_s = \frac{V^2}{R_s} = \frac{V^2}{R_1 + R_2}$$

As $R_1 = \frac{V^2}{P_1}$ and $R_2 = \frac{V^2}{P_2}$

$$P_s = \frac{V^2P_1P_2}{V^2(P_1 + P_2)}$$

i.e., $$P_s = \frac{P_1P_2}{P_1 + P_2}$$

or $$\frac{1}{P_s} = \frac{1}{P_1} + \frac{1}{P_2}$$

(ii) When resistors are connected in parallel

$$P_p = \frac{V^2}{R_p} \quad \text{... (i)}$$

Here, $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$

$$= \frac{1}{V^2}(P_1 + P_2)$$

$$R_p = \frac{V^2}{P_1 + P_2}$$

Substituting in equation (i), we get

$$P_p = \frac{V^2}{\left(\frac{V^2}{P_1 + P_2}\right)}$$

$$= P_1 + P_2$$

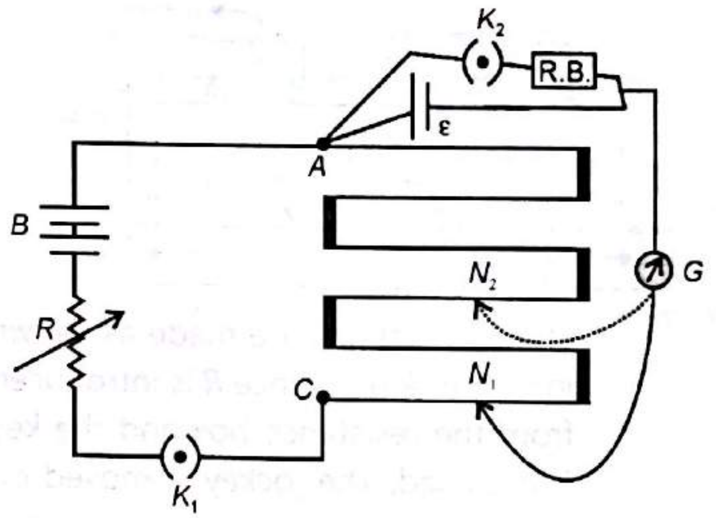
$$P_p = P_1 + P_2$$

37. 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]*

Ans. The Principle of working of a potentiometer: Potential difference across a wire is directly proportional to its length provided the current is constant and wire is of uniform area of cross section.

i.e., $V \propto l$



With key K_2 open, balancing length is obtained. Let it be length l_1. We have relation

$$\varepsilon = \phi l_1 \quad \text{...(i)}$$

where ϕ = Potential gradient

When key K_2 is closed, the cell passes a current I through the resistance box having resistance R.

If V is the terminal potential difference of the cell and l_2 is balancing length. We have relation

$$V = \phi l_2 \quad \text{...(ii)}$$

From equations (i) and (ii), we have

$$\frac{\varepsilon}{V} = \frac{l_1}{l_2}$$

We know that

$$r = \left(\frac{\varepsilon}{V} - 1\right)R$$

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

LONG ANSWER TYPE QUESTIONS [5 Marks]

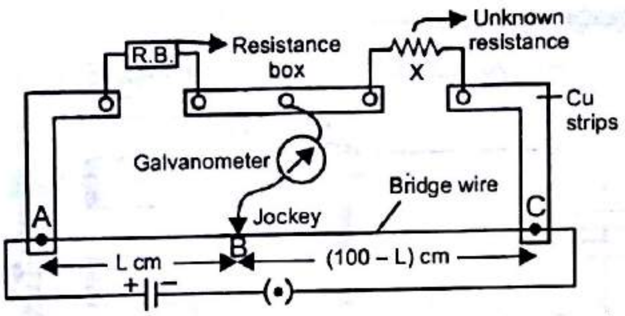
38. (a) State, with the help of circuit diagram, the working principle of a meter bridge. Obtain the expression used for determining the unknown resistance.

(b) What happens if the galvanometer and cell are interchanged at the balance point of the bridge?

(c) Why is it considered important to obtain the balance point near the mid-point of the wire? *[Delhi]*

Ans. (a) The metre bridge is based on Wheatstone bridge principle.

The circuit diagram is as shown below:



The connections are made as shown in figure. A resistance R is introduced from the resistance box and the key K is closed. The jockey is moved on the wire to the point where there is no deflection in the galvanometer. In such a case points B and D are at the same potential. The point B is called the "null" point.

Let in this position $AB = L$ cm and $BC = (100 - L)$ cm. Therefore, resistance of AB *i.e.*, $P \propto L$ and resistance of BC *i.e.*, $Q \propto (100 - L)$, hence

$$\frac{P}{Q} = \frac{L}{100 - L} \quad ...(i)$$

In the balanced state by the Wheatstone bridge Principle, we have

$$\frac{P}{Q} = \frac{R}{X} \quad ...(ii)$$

Substituting equation (*i*) in equation (*ii*), we have

$$\frac{R}{X} = \frac{L}{100 - L} \quad ...(iii)$$

Rewriting equation (*iii*), we have

$$X = \left(\frac{100 - L}{L}\right)R$$

(*b*) There is no change in the position of the balance point if the galvanometer and the cell are interchanged.

(*c*) It is important to get the balance point near the mid-point of the wire because then the resistances in the four arms of the bridge are of the same order. The sensitivity of the bridge is maximum and the resistance is determined more accurately.

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

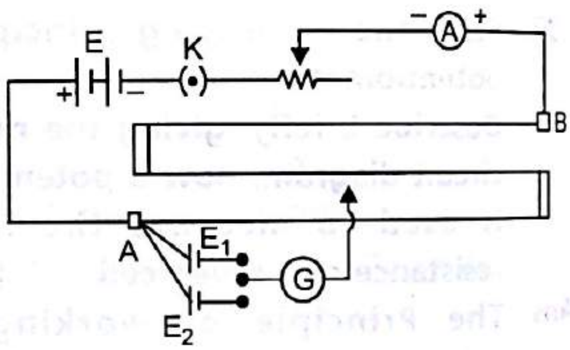
(*b*) Which material is used for potentiometer wire and why?

(*c*) How can the sensitivity of a potentiometer be increased?

[*Delhi*]

Ans. (*a*) A potentiometer works on the principle that fall of potential across a wire of uniform area of cross-section through which is a constant current is flowing is proportional to the length. If V is the fall of potential a cross a length l then $V \propto l$ or $\frac{V}{l}$ = constant.

The circuit diagram for comparing the emf's of two cell is given below :



First, the key K_1 is inserted. This brings the cell of emf E_1 in the circuit. The jockey is moved on the wire to obtain a balance point *i.e.*, a point on the wire where the galvanometer gives zero deflection. Let the balancing length be L_1. Therefore, by the potentiometer principle, we have

$$E_1 \propto L_1 \quad ...(i)$$

Now, the key K_2 is inserted. This brings the cell of emf E_2 in the circuit. The jockey is again moved on the wire to obtain the balance point. Let the balancing length be L_2. Then by potentiometer principle, we have

$$E_2 \propto L_2 \quad ...(ii)$$

Dividing equations (*i*) by (*ii*), we have

$$\frac{E_1}{E_2} = \frac{L_1}{L_2} \quad ...(iii)$$

Knowing the values of L_1 and L_2 the emf's can be compared.

(*b*) The potentiometer wire is usually of constantan or manganin. The material of the wire should have (*i*) high specific resistance (*ii*) low temperature coefficient of resistance.

(*c*) For greater sensitivity of measurement the fall of potential per cm should be small. Smaller the value of K greater will be balancing length and greater will be the accuracy of measurement. For this wire of longer length should be taken or the current in the wire should be less.

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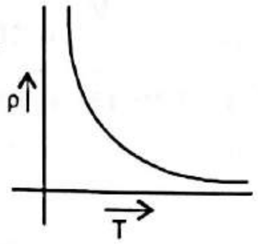
VERY SHORT ANSWER TYPE QUESTIONS [1 Mark]

40. When electrons drift in a metal from lower to higher potential, does it mean that all the free electrons of the metal are moving in the same direction? [*Delhi*]

Ans. No.

41. Show on a graph, the variation of resistivity with temperature for a typical semiconductor. [*Delhi*]

Ans.



42. Two wires of equal length, one of copper and the other of manganin have the same resistance. Which wire is thicker? [*All India*]

Ans. $R = \rho_1 \frac{l}{A_1}, S = \rho_2 \frac{l}{A_2}, \frac{A_1}{A_2} = \frac{\rho_1}{\rho_2}$

As, the resistivity of manganin (ρ_2) > resistivity of copper (ρ_1). So, manganin wire is thicker.

SHORT ANSWER TYPE QUESTIONS[I] [2 Marks]

43. A cell on 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. but not necessarily in that order. Identify the currents corresponding to the four cases mentioned above. [*Delhi*]

Ans. (*i*) Without any external resistance, Current will have maximum value.

$$i = 4.2 \text{ A} \qquad \left(\because i = \frac{\varepsilon}{r}\right)$$

(*ii*) When only resistance R_1 is joined in the circuit, current further get reduced.

$i = 1.05$ A

$$\left(\because i = \frac{\varepsilon}{r + R_1}\right)$$

(*iii*) In series combination, equivalent resistance (R_1 and R_2) is maximum. So current in the circuit is least.

$i = 0.42$ A

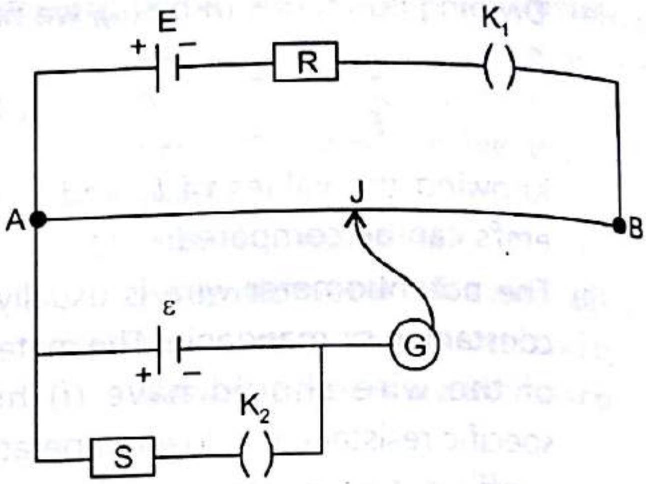
$$\left(\because i = \frac{\varepsilon}{r + R_1 + R_2}\right)$$

(*iv*) In parallel combination equivalent resistance (R_1 and R_2) is lesser than the least resistance of the combination. So current will have lesser value.

$i = 1.4$ A

$$\left(\because i = \frac{\varepsilon}{r + \frac{R_1 R_2}{R_1 + R_2}}\right)$$

44. 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* is the set-up by keeping the key K_1 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 the key K_1 closed. *[Foreign]*

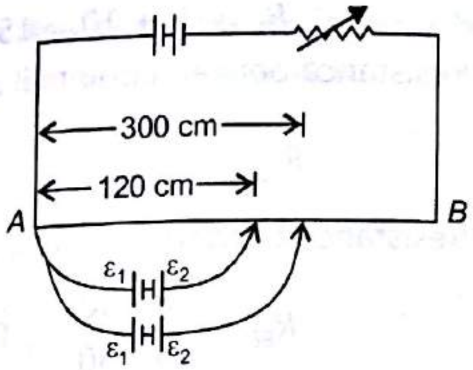
Ans. (*i*) Current through potentiometer wire decreases. Thus, potential gradient decreases. As $K = \frac{V}{l}$ with the decrease in potential gradient balancing length increases *i.e.*, null point will shift towards '*B*'.

(*ii*) Current through potentiometer wire remains same *i.e.*, potential gradient does not change. As a result null point remains same.

SHORT ANSWER TYPE QUESTIONS[II] [3 Marks]

45. 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 ε_1 and ε_2 connected in the manner shown are obtained at a distance of 120 cm and 300 cm from the end *A*. Find (*i*) $\varepsilon_1/\varepsilon_2$ and (*ii*) position of null point for the cell ε_1.

How is the sensitivity of a potentiometer increased? *[Delhi]*



Ans. (*i*) $\varepsilon_1 + \varepsilon_2 = k\,(300)$

$\varepsilon_1 - \varepsilon_2 = k\,(120)$

On solving, we get $\dfrac{\varepsilon_1}{\varepsilon_2} = \dfrac{7}{3}$

(*ii*) $\varepsilon_1 + \varepsilon_2 = 300\,k$

From above relation $\varepsilon_2 = \dfrac{3}{7}\varepsilon_1$

$$\varepsilon_1 + \frac{3}{7}\varepsilon_1 = 300\,k$$

$$\varepsilon_1 = 210\,k$$

So, balancing length for cell of ε_1 is 210 cm.

$k = \dfrac{V}{l}$ (where k is potential gradient)

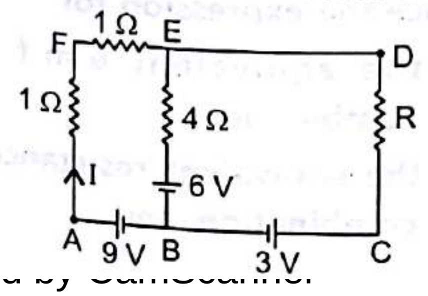
Lesser is the value of potential gradient more sensitive is the potentiometer.

Thus, sensitivity of potentiometer can be increased by

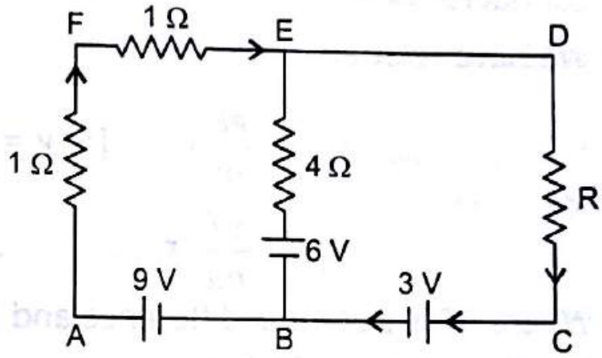
(*a*) increasing length of potentiometer wire

(*b*) reducing potential difference across the wire.

46. Using Kirchoff's rules determine the value of unkown resistance *R* in the circuit so that no current flows through 4 Ω resistance. Also find the potential difference between *A* and *D*. [*Delhi*]



Ans. On applying Kirchhoff's voltage rule for loop *FABEF*



$$+\,2I - 9 + 6 + 4 \times 0 = 0$$

$$2I = 3$$

$$I = 1.5\text{A}$$

For loop *BCDEB*

$$3 + IR + 4 \times 0 - 6 = 0$$

$$IR = 3$$

Substituting value of current I = 1.5A in the above equation, we get

$$R = \frac{3}{1.5}$$

$$R = 2\ \Omega$$

Potential difference between *A* and *D*.

We take path *AFED*

$$V_{AD} = V_{AF} + V_{FE}$$

$= 1 \times 1.5 + 1 \times 1.5 = 3$ volt

47. 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. [*All India*]

Ans. **Relaxation time:** It is duration for which an electron drifting through a conductor does not suffer any collision.

Relation between drift velocity of free electrons and relaxation time.

$$\vec{v}_d = \frac{e\vec{E}}{m}\tau$$

where $\vec{E}$ is the electric field across the conductor drifting the electrons.

We have relation

$$v_d = \frac{eE}{m}\tau \qquad [\because v = El]$$

$$v_d = \frac{eV}{ml}\tau \qquad ...(i)$$

Where 'V' is potential difference and 'l' is length of the conductor.

As $\qquad I = v_d enA.$

$$v_d = \frac{I}{enA} \qquad ...(ii)$$

Substituting value of v_d from equation (*ii*) in equation (*i*), we get

$$\frac{I}{enA} = \frac{eV}{ml}\tau$$

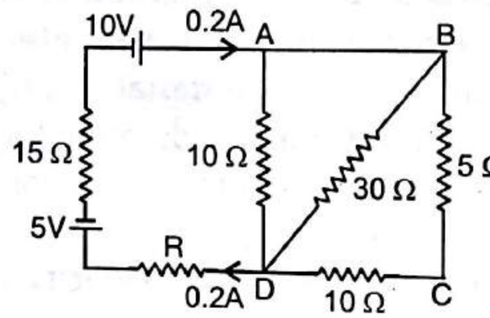
$$V = \left(\frac{ml}{ne^2\tau A}\right)I$$

where $\qquad z = \frac{ml}{ne^2\tau A} = R$

and $\qquad \frac{m}{ne^2\tau} = \rho$

ρ is called resistivity of the material of the conductor.

48. Calculate the value of the resistance *R* in the circuit shown in the figure so that the current in the circuit is 0.2 A. What would be the potential difference between points *A* and *D*? [*All India*]



Ans. • Resistance in the arm *BCD* of the circuit.

$$R_1 = 5 + 10 = 15\ \Omega$$

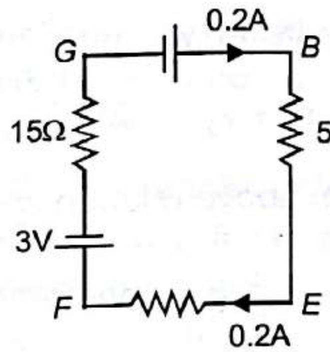
Resistance between points B and D is

$$R_{BD} = \frac{10 \times 15}{25} = 6\ \Omega$$

Resistance between points B and E is

$$R_{BE} = \frac{6 \times 30}{6 + 30} = 5\ \Omega$$

Now, circuit reduces to the form shown



From the loop *EFGBE*

$$5 \times 0.2 + R \times 0.2 + 15 \times 0.2 = 5$$

$$0.2R + 4 = 5$$

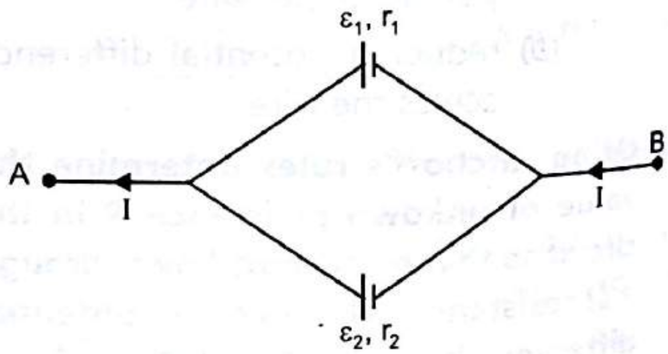
$$0.2R = 1$$

$$R = \frac{1}{0.2} = 5\ \Omega$$

• $V_{BE} = 5 \times 0.2$

$= 1$ volt.

49. Two cells of emfs ε_1, ε_2 and internal resistance r_1 and r_2 respectively are connected in parallel as shown in the figure.



Deduce the expression for

(*i*) the equivalent e.m.f. of the combination,

(*ii*) the equivalent resistance of the combination, and

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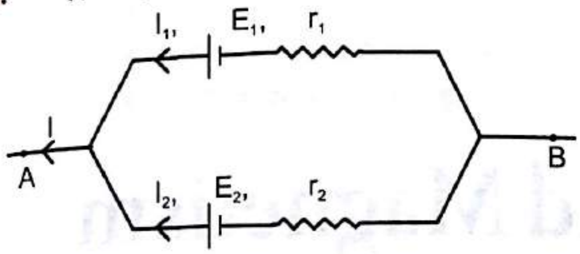
***(iii)* the potential difference between the points *A* and *B*.** [*Foreign*]

Ans. (*i*) Equivalent emf of the combination.



We know $V = \in_1 - I_1 r_1$

So, $$I_1 = \frac{\in_1 - V}{r_1}$$

Similarly $$I_2 = \frac{\in_2 - V}{r_2}$$

As the cells are in parallel, potential difference across the cells is same *i.e.,* $V_1 = V_2 = V$

Now, $I = I_1 + I_2$

$$= \left(\frac{\in_1 - V}{r_1}\right) + \left(\frac{\in_2 - V}{r_2}\right)$$

$$= \left(\frac{\in_1}{r_1} + \frac{\in_2}{r_2}\right) - V\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$$

(*ii*) Equivalent resistance of the combination.

On comparing with a cell of equivalent e.m.f. and internal resistance, we get

$$V = \in_{eq} - I\, r_{eq}$$

$$\in_{eq} = \frac{\in_1 r_2 + \in_2 r_1}{r_1 + r_2}$$

$$r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$$

(*iii*) On solving this, we get equivalent potential difference between the points *A* and *B*.

$$V = \frac{\in_1 r_2 + \in_2 r_1}{r_1 + r_2} - \left(\frac{r_1 r_2}{r_1 + r_2}\right) I$$