Unit II: Current Electricity **20 Periods**

Chapter–3: Current Electricity

Electric current, flow of electric charges in a metallic conductor, drift velocity, mobility and their relation with electric current; Ohm's law, electrical resistance, V-I characteristics (linear and non-linear), electrical energy and power, electrical resistivity and conductivity, Carbon resistors, colour code for carbon resistors; series and parallel combinations of resistors; temperature dependence of resistance.

Internal resistance of a cell, potential difference and emf of a cell, combination of cells in series and in parallel, Kirchhoff's laws and simple applications, Wheatstone bridge, metre bridge.

Potentiometer - principle and its applications to measure potential difference and for comparing EMF of two cells; measurement of internal resistance of a cell.

201. Define current density. Write its S.I. unit. Is it a scalar or vector quantity ? **CBSE(AIC)-2010**

[Ans. Current density : Electric current flowing normally per unit area of cross section is called current density

$\vec{J} = \frac{\vec{I}}{A}$,Its S.I. unit is A/m^2. It is a vector quantity

202. (a) Define resistance of a conductor. Write its S.I. unit.
(b) What are the factors on which the resistance of a conductor depends ? **CBSE(AIC)-2015,2001**

[Ans. (a) Resistance : It is the ratio of potential difference applied across the ends of a conductor to the current flowing through it

i,e, $R = \frac{V}{I}$, Its S.I. unit is Ohm (Ω)

(b) Factors : (i) Length of the conductor $R \propto L$
(ii) Area of cross section of the conductor $R \propto 1/A$
(iii) nature of material & temperature

203. (a) Define resistivity of a conductor. Write its S.I. unit.
(b) On what factors does the resistivity of a conductor depend ? **CBSE (D)-2016,(AI)-2015,2012,2011**

[Ans. (a) Resistivity : Resistivity of the material of a conductor is defined as the resistance of conductor of that material of unit length and unit area of cross section

$\rho = \frac{R\,A}{L}$

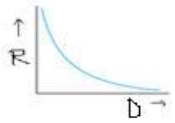
Its S.I. unit is Ohm metre ($\Omega\, m$)

(b) Factors : (i) relaxation time (i,e, temperature) and
(ii) number density of electrons

204.Draw a graph showing the variation of resistance of a metal wire as a function of its diameter keeping its length and material constant. **(Sample Paper)-2017**

[Ans. $R = \rho \frac{L}{\pi r^2} = \rho \frac{4l}{\pi D^2}$

⇨ $R \propto \frac{1}{D^2}$



205. Two wires, one of copper and the other of manganin, have same resistance and equal thickness. Which wire is longer? Justify your answer. **CBSE(AI)-2015**

[Ans. Copper wire will be longer

Reason : $\rho = \frac{R\,A}{L}$ but R and A are same ⇨ $\rho \propto 1/L$

Since $\rho_C < \rho_m$ ⇨ $L_c > L_m$

206. Two wires of equal length, one of copper and the other of manganin have the same resistance. Which wire is thicker ?

[Ans. Manganin wire is thicker **CBSE(AI)-2016,2012**

Reason : $\rho = \frac{R\,A}{L}$ but R and l are same ⇨ $\rho \propto A$

Since $\rho_m > \rho_C$ ⇨ $A_m > A_C$

207. Nichrome and copper wires of same length and same radius are connected in series. Current I is passed through them. Which wire gets heated up more ? Justify your answer. **CBSE(AI)-2017**

[Ans. Nichrome

Reason : $H = I^2Rt$ & $R_{Ni} > R_{Cu}$ (or Resistivity Ni > Resistivity Cu)

208. Define the term conductivity of a conductor. Write its S.I. unit. On what factors does it depend ?
CBSE (AIC)-2017,(AI)-2016,(D)-2014,2008

[Ans. Conductivity : It is defined as the current flowing per unit area per unit electric field

i,e, $\sigma = \frac{J}{E}$

It is also defined as the reciprocal of resistivity i,e, $\sigma = 1/\rho$

Its S.I. unit is $\Omega^{-1}m^{-1}$

Factors : (i) nature of material and (ii) temperature (relaxation time)

209. Resistance of a conductor increases with the rise in temperature. Why ? **CBSE(DC)-2001**

[Ans. Due to increase in frequency of collision of electrons with ions/atoms in the conductor.

210 . If a wire is stretched to double its original length without loss of mass, what will be its new- (a) resistivity (b) resistance ? **CBSE(AIC)-2001**

[Ans. (a) Resistivity will remain same

(b) Resistance will be 4 times the original resistance

$R' = (2)^2 R = 4R$

211. Two materials, Si and Cu, are cooled from 300K to 60K. What will be the effect on their resistivity ? **CBSE (F)-2013**

[Ans. For Si, resistivity will increase.

Reason : Semiconductors have negative temperature coefficient of resistivity.

For Cu, resistivity will decrease.

Reason : conductors have positive temperature coefficient of resistivity

212. Explain, why allows like constantan and manganin are used for making standard resistors ?

[Ans. Because they have **CBSE (D)-2016,(F)-2011,2004**

1. High resistivity 2. Very small temperature coefficient of resistivity

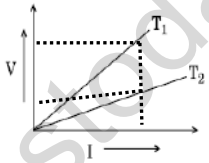
213. The I-V graph for a metallic wire at two different temperatures T_1 and T_2 is as shown in the figure. Which of the two temperatures is higher and why ? **CBSE(AI)-2015**

[Ans. T_1 is higher

Reason : for the same I, $V_1 > V_2$

⇨ $R_1 > R_2$ $[\because R = \frac{V}{I}]$

⇨ $T_1 > T_2$ as $R = R_0(1 + \alpha\, t)$



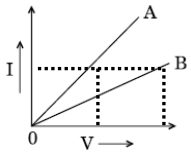
214. The I-V graph for two identical conductors of different materials A and B is shown in figure. Which one of the two has higher resistivity and why ? **CBSE(AI)-2015**

[Ans. B has higher Resistivity

Reason : As for the same I, $V_B > V_A$

⇨ $R_B > R_A$ $[\because R = \frac{V}{I}]$

⇨ $\rho_B > \rho_A$ $[\because \rho = \frac{R\,A}{L}]$

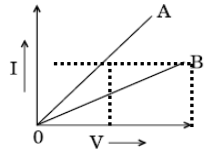


215. Two metallic resistors are connected first in series and then in parallel across a d.c. supply. Plot of I-V graph is shown for the two cases. Which one represents a parallel combination of the resistors and why ? **CBSE(AI)-2015,2004**

[Ans. A represents parallel combination

Reason : for the same I, $V_A < V_B$

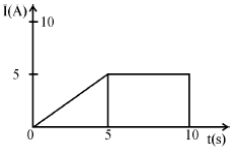
⇨ $R_A < R_B$ $[\because R = \frac{V}{I}]$



216. Figure shows a plot of current 'I' flowing through the cross section of a wire versus the time 't'. Use the plot to find the charge flowing in $10\ s$ through the wire. **CBSE(AIC)-2015**

[Ans. $q = I\,dt =$ area under I-t curve

$= \frac{1}{2}(5\ X\ 5) + (10 - 5)\ X\ 5 = 37.5\ C$



217. Show that the current density $\vec{j}$ is related to the applied electric field $\vec{E}$ by the relation **CBSE(AI)-2015, (F)-2014**

$$\vec{j} = \sigma\, \vec{E}$$

Where σ defines the conductivity of the material.

[Ans. $j = nev_d = ne\left(\frac{eE}{m}\tau\right) = \left(\frac{ne^2\tau}{m}\right)E$ $[\because v_d = \frac{eE}{m}\tau]$

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

⇨ $\boldsymbol{j = \frac{1}{\rho}E = \sigma E}$ ⇨ $\vec{j} = \sigma\, \vec{E}$

218. Define the term (a) Emf of a cell (b) Terminal voltage of a cell. **CBSE (DC)-2010**

[Ans. (a) Emf : Emf of a cell may be defined as the energy supplied by the cell in moving unit charge through the complete circuit (including the cell)

i,e, $E = W/q$

(b) Terminal voltage: It is the potential difference between the electrodes of a cell, when the cell is in closed circuit

$V = E - \mathrm{I}\, r$

219. Define internal resistance of a cell. Write any two factors on which it depends. **CBSE (AI)-2010**

[Ans. Internal resistance (r)**:** It is the resistance offered by the electrolyte of a cell to the flow of current between its electrodes

Factors :(i) nature of electrolyte

(ii) concentration of electrolyte

(iii) nature of electrodes & distance between them

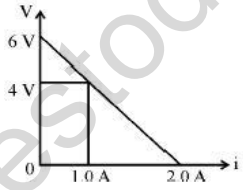
220. The emf of a cell is always greater than its terminal voltage. Give reason **CBSE (D)-2013**

[Ans. Because there is a potential drop across the internal resistance of the cell, when cell is in a closed circuit

221. Can the value of terminal potential difference be greater than the emf of a cell ? **CBSE (AI)-2013**

[Ans. yes. During the charging of the cell

222. The figure shows a plot of terminal voltage 'V' versus the current 'i' of a given cell. Calculate from the graph (a) emf of the cell and (b) internal resistance of the cell. **CBSE (AIC)-2017**



[Ans. (a) $V = E - \mathrm{I}\, r$

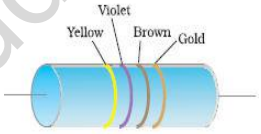
When $I = 0,\ V = E$

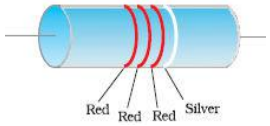
⇨ $E = 6\ V$

(b) $E = V + \mathrm{I}\, r$ ⇨ $6 = 4 + 1 \times r$

⇨ $r = 2\ \Omega$

223. Find the resistance of the following carbon resistors. **CBSE(AIC)-2010,NCERT-2017**





[Ans. (i) $R = 47 \times 10^1 \pm 5\ \%\ \Omega$

(ii) $R = 22 \times 10^2 \pm 10\ \%\ \Omega$

224. State Ohm's law. **CBSE(AI)-2013**

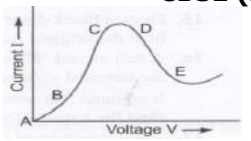
[Ans. Ohm's law : If the physical conditions of a conductor remains unchanged then the current flowing through it is directly proportional to the potential difference applied

i,e, $\mathrm{V} \propto \mathrm{I}$ ⇨ $\mathrm{V} = \mathrm{I}\,\mathrm{R}$

225. Graph showing the variation of current versus voltage for a material GaAs as shown in figure. Identify the region of

(i) negative resistance

(ii) where Ohm's law is obeyed. **CBSE (D)-2015**

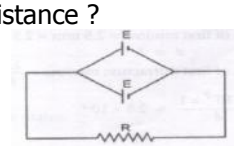


[Ans. (i) Region DE because current decreases on increasing voltage.

(ii) Region AB because current increases linearly on increasing voltage

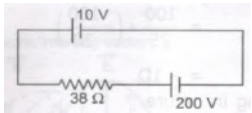
226. Two identical cells each of emf E,having negligible internal resistance, are connected in parallel with each other across an external resistance R. What is the current through the resistance ? **CBSE (D)-2013**

[Ans. $\mathrm{I} = \frac{\mathrm{E}}{\mathrm{R}}$



227. A 10 V battery of negligible internal resistance is connected across a 200 V battery and a resistance of 38 Ω as shown. Find the value of the current in the circuit. **CBSE (D)-2013**

[Ans. $\mathrm{I} = \frac{\mathrm{V}}{\mathrm{R}} = \frac{200-10}{38} = 5\ A$



228. Define the term drift velocity of charge carriers in a conductor and write its relation with the current flowing through it.

[Ans. Drift velocity (v_d) **:** **CBSE (AI)-2016,2014,(F)-2011**

The average velocity acquired by free electrons of a conductor in a direction opposite to the applied electric field is called drift velocity $(v_d \approx 10^{-4}\ m/s)$ **Relation :** $I = neAv_d$

229. How does the random motion of free electrons in a conductor gets affected when a potential difference is applied across its ends. **CBSE (AIC)-2014**

[Ans. Random motion is partially directed towards positive end of conductor

230. 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? **CBSE (AI)-2012, NCERT-2017**

[Ans. By no means. The drift velocity is superposed over the large random velocities of electrons.

231. The electron drift speed is estimated to be only a few $mm\ s^{-1}$ for currents in the range of a few amperes ? How then is current established almost the instant a circuit is closed ? **NCERT-2017**

[Ans. When the circuit is closed, electric field is setup in the entire circuit instantly with the speed of em waves which causes electron drift at every portion of the circuit. A current starts flowing in the circuit almost instantly

232. If the electron drift speed is so small, and the electron's charge is small, how can we still obtain large amounts of current in a conductor ? **CBSE (AI)-2015,NCERT-2017**

[Ans. because the electron number density is very large $(\approx 10^{29}\ m^{-3})$

233. The electron drift arises due to the force experienced by electrons in the electric field inside the conductor. But force should cause acceleration. Why then do the electrons acquire a steady average drift speed ? **NCERT-2017**

[Ans. Each 'free' electron does accelerate, but due to frequent collisions with ions they acquire only an average speed known as drift speed

234. How does the drift velocity of electrons in a metallic conductor vary with increase in temperature ?

[Ans. Drift velocity will decrease on increasing the temperature **CBSE (AI)-2016,(F)-2011,(D)-2002**

Reason : $v_d = \frac{eE}{m}\tau$, when temperature is increased, relaxation time decreases or frequency of collision increases

235. If a potential difference V applied across a conductor is increased to $2V$, how will the drift velocity of electrons change ?

[Ans. drift velocity will be doubled as $v_d = \frac{e\ V}{m\ L}\tau \Rightarrow v_d \propto V$ **CBSE (AIC)-2001**

236. Define the term 'relaxation time' in a conductor. **CBSE(AI)-2016,2012,(F)-2014**

[Ans. Relaxation time : It is the average time between two successive collisions of electron with ions in a conductor

237. If the temperature of a good conductor increases, how does the relaxation time of electrons in the conductor change ?

[Ans. Relaxation time decreases **CBSE (AI)-2002**

Reason : with the increase in temperature, free electron collides more frequently with the ions/atoms of the conductor, resulting decrease in relaxation time

238. (i) How is the relaxation time related to the drift velocity of free electrons ?
(ii) Obtain an expression for the current density in terms of relaxation time. **CBSE(AI)-2016,2012,(F)-2014**

[Ans. $v_d = \frac{eE}{m}\tau$

Expression : $j = nev_d = ne\left(\frac{eE}{m}\tau\right) = \frac{ne^2\tau}{m}E$

239. (i) Define mobility of a charge carrier. Write its S.I. unit.
(ii) What is its relation with relaxation time ? **CBSE(AI)-2016,2015,(D)-2014**
(iii) How does the electron mobility change if
(a) temperature is increased , (b) potential difference in doubled ?

[Ans. (i) Mobility: It is defined as the drift velocity per unit electric field
i,e, $\mu_m = v_d/E$ Its S.I. unit is $ms^{-1}N^{-1}C$

(ii) Relation : $\mu_m = v_d/E = \frac{1}{E}\left(\frac{eE}{m}\tau\right) = \frac{e}{m}\tau$

(iii) (a) μ_m decreases because if temperature is increased, relaxation time τ decreases
(b) No effect because μ_m does not depend on potential difference

240. What happens if the galvanometer and cell are interchanged at the balanced point of the Wheatstone bridge? Would the galvanometer show any current ?

[Ans. balanced condition still remains satisfied hence galvanometer does not show any current

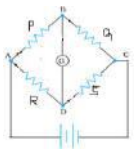
241. What is a meter bridge ? Write the principle of working meter bridge. **CBSE (AI)-2017,2016,(AIC)-2015**

[Ans. Meter bridge : It is the simplest practical application of Wheatstone bridge and is used to determine the unknown resistance

principle : It is based on the principle of Wheatstone bridge ,

i,e, in balanced condition of the bridge

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



242. Why are the connections between the resistors in a meter bridge made of thick metal (copper) strips ? **CBSE(AI)-2016,2014**

[Ans. Thick copper strips have negligible resistance due to low resistivity & large area of cross section. It helps to maintain continuity without adding resistance to the circuit and accurate balance point is obtained

243. Why is it generally preferred to obtain the balance point in the middle of the meter bridge wire? **CBSE (D)-2014**

[Ans. sensitivity of meter bridge is higher when balance point lies in the middle of the wire

244. State the principle of potentiometer. **CBSE (F)-2017,2009,(D)-2016,(DC)-2014,(AI)-2014,2006**

[Ans. When a constant current flows through a conductor of uniform area of cross section, the potential difference across any length of the conductor is directly proportional to that length

i,e, $V \propto l$

245. Of which material a metre bridge/potentiometer wire normally made and why ?**CBSE (AI) -2016,2014,(F)-2013**

[Ans. Nichrome or manganin

Reason : Such an alloy has high resistivity and very small temperature coefficient of resistance, hence its resistance does not change with rise in temperature due to flow of current

246. Why should the potentiometer wire be of uniform cross section and composition ? **CBSE (AIC)-2014**

[Ans. A wire of uniform cross section and composition has the uniform resistance per unit length and only then potential difference per unit length will be directly proportional to the length, as required by the principle of potentiometer

247. Why do we prefer a potentiometer with a longer wire ? **CBSE (AIC)-2014**

[Ans. Sensitivity $\propto \frac{1}{Potential\ gradient\ K}$ & $\mathrm{K} = \frac{V}{L}$

A longer bridge wire will have small potential gradient and hence it will be more sensitive, so it is preferred

248.. What is meant by sensitivity of a potentiometer ? **CBSE (AIC)-2014,(DC)-2011,(D)-2003**

[Ans. A potentiometer is said to be sensitive if

(i) It can measure very small potential differences, and

(ii) it shows a large change in balancing length ,for a small change in potential difference being measured,

249. How can a given potentiometer be made more sensitive ? **CBSE (F)-2017, (AIC)-2014,(DC)-2011,(D)-2003**

[Ans. It can be made more sensitive by

(i) decreasing current in the main circuit

(ii) decreasing potential gradient or increasing the length of potentiometer wire

(iii) increasing resistance put in series with the potentiometer wire

250. The emf of the driving cell used in the main circuit of the potentiometer should be more than the potential Difference to be measured. Why ? **CBSE (AIC)-2014, (DC)-2011, (D)-2003**

[Ans. If it is not so the balance point will not be obtained on the potentiometer wire

251. The variation of potential difference V with length l in case of two potentiometer wires P and Q is as shown.

(a) Which potentiometer is more sensitive ? **CBSE (F)-2017,(AI)-2016,2006**

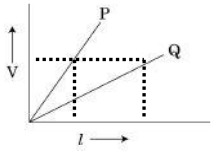
(b) Which of these will you prefer for comparing emfs of two primary cells and why ?

[Ans. (a) Potentiometer Q is more sensitive

Reason : Sensitivity $\propto \frac{1}{Potential\ gradient\ K}$

& Q has less potential gradient $\left(\mathrm{K} = \frac{V}{L}\right)$

(b) Potentiometer Q as it is more sensitive



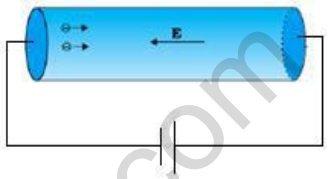
252. When a metallic conductor is subjected to a certain potential V across its ends, discuss briefly how the phenomenon of drift occurs. **CBSE (AI)-2015,(F)-2014**

[Ans. Drift : When a potential difference is applied to the ends of a conductor, electrons get accelerated due to electric field. After being accelerated for relaxation time (τ), each electron undergoes collisions with ions and their velocity again becomes random. The electrons move with an average velocity which is independent of time, although they are accelerated. This phenomenon is called drift and average velocity is called drift velocity.

253. Derive an expression for drift velocity of free electrons in a conductor in terms of relaxation time of electrons. **CBSE(AI)-2016,2015,2009**

[Ans. Expression for drift velocity :

Let a potential difference V is applied across the ends of a conductor, then each free electron will experience a force



$$\vec{F} = -e\,\vec{E} \quad \Rightarrow \quad \vec{a} = -\frac{e\,\vec{E}}{m}$$

Average of all random velocities under this acceleration is the drift velocity

$$\Rightarrow \quad \vec{v_d} = \frac{\vec{v_1} + \vec{v_2} + \text{----------} + \vec{v_N}}{N} = \frac{(\vec{u_1} + \vec{a}\,\tau_1) + (\vec{u_2} + \vec{a}\,\tau_2) + \text{----------} + (\vec{u_N} + \vec{a}\,\tau_N)}{N}$$

$$\Rightarrow \quad \vec{v_d} = \frac{\vec{u_1} + \vec{u_2} + \text{----------} + \vec{u_N}}{N} + \vec{a}\left(\frac{\tau_1 + \tau_2 + \text{--------} + \tau_N}{N}\right)$$

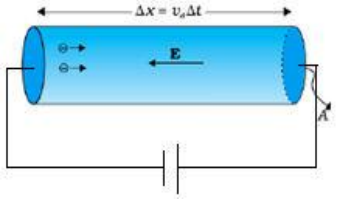
$$\Rightarrow \quad \vec{v_d} = 0 + \vec{a}\,\tau = \vec{a}\,\tau$$

$$\Rightarrow \quad \vec{v_d} = -\frac{e\,\vec{E}}{m}\tau$$

254. Deduce the relation between current I flowing through a conductor and drift velocity $\vec{v_d}$ of free electrons.

[Ans. Relation between current and drift velocity : **CBSE(AIC)-2015,(AI)-2013,(D)-2008**

Let a potential difference V is applied across the ends of a conductor as shown. If n be the number of free electrons per unit volume then charge crossing area A in time Δt



$$\Delta Q = \text{Ne} = (n\,A v_d\,\Delta\text{t})\,e$$

$$\Rightarrow \quad \text{I} = \frac{\Delta Q}{\Delta t} = \frac{n\,e\,A\,v_d\,\Delta\text{t}}{\Delta t}$$

$$\Rightarrow \quad \text{I} = neAv_d$$

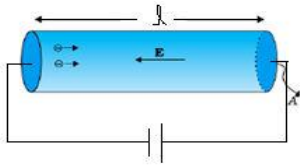
$$\& \quad \text{j} = \frac{\text{I}}{\text{A}} = \frac{n\,e\,A\,v_d}{A} \quad \Rightarrow \quad \text{j} = nev_d$$

255. Deduce Ohm's law using the concept of drift velocity. **CBSE(AI)-2013**

OR

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. **CBSE (D)-2016,(AI)-2012**

[Ans. Let a potential difference V is applied across the ends of a conductor as shown.



Electric field produced, $E = \frac{V}{l}$

$$\Rightarrow \quad v_d = \frac{eE}{ml}\tau = \frac{eV}{ml}\tau$$

$$\Rightarrow \quad \text{I} = neAv_d = neA\left(\frac{eV}{ml}\,\tau\right) = \frac{ne^2\tau}{m}\left(\frac{A}{l}\right)\text{V}$$

$$\Rightarrow \quad \frac{V}{I} = \frac{m}{ne^2\tau}\left(\frac{l}{A}\right) \qquad \text{---------(1)}$$

If the physical conditions of conductor such as temperature etc. remains constant then

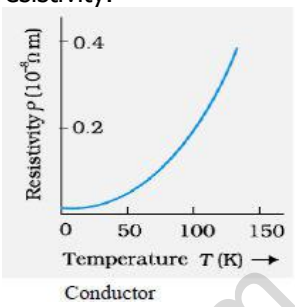
$$\frac{m}{ne^2\tau}\left(\frac{l}{A}\right) = constant = R \qquad \text{--------(2)}$$

$\Rightarrow$ from (1) $\boldsymbol{\frac{V}{I} = R}$ $\Rightarrow$ $\boldsymbol{V = IR}$, Now, $R = \frac{\rho l}{A}$ $\Rightarrow$ from (2) $\boldsymbol{\rho = \frac{m}{ne^2\tau}}$

PHYSICS CLASS-XII –CURRENT ELECTRICITY

256. (i) Plot a graph showing the variation of resistivity with temperature in the case of a conductor.
(ii) How does one explain such behaviour, using the mathematical expression of the resistivity.

[Ans. (i) Graph :



Conductor

(ii) explanation : $\boldsymbol{\rho = \frac{m}{ne^2\tau}}$

In conductors, with increase in temperature, number density (n) does not change but the average speed of electrons and hence frequency of collision increases due to which relaxation time (τ) decreases. Hence resistivity ρ increases.

Over limited range of temperature

$\rho_T = \rho_0 \left(1 + \alpha\,(T - T_0)\right)$

Where α is called temperature coefficient of resistivity.

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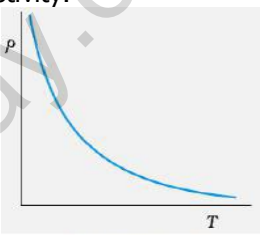
257. (i) Plot a graph showing the variation of resistivity with temperature in the case of a semiconductor.
(ii) How does one explain such behaviour, using the mathematical expression of the resistivity.

[Ans. (i) Graph :



Semiconductor

(ii) explanation : $\rho = \frac{m}{ne^2\tau} \Rightarrow \rho \propto \frac{1}{n}$

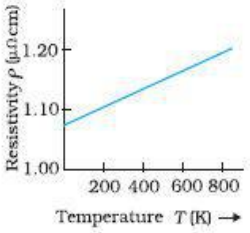
& for semiconductors $n(T) = n_0\, e^{-E_g/K_BT} \Rightarrow \rho(T) = \rho_0\, e^{E_g/K_BT}$

In semiconductors, with increase in temperature, number density (n) increases exponentially and dominates the decrease in relaxation time (τ) Hence resistivity ρ decreases exponentially

==========

258. Explain by plotting a graph, variation of resistivity with temperature for an allow such as Nichrome (Constantan or manganin). **CBSE (D)-2016, (F)-2011,2004**

[Ans. Graph & explanation :

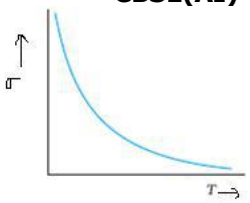


We have $\rho_T = \rho_0 \left(1 + \alpha\,(T - T_0)\right)$

For the allows such as Nichrome or constantan or manganin, coefficient of resistivity is negligible or very small hence these allows exhibit very weak dependence of resistivity with temperature as shown

259. Plot a graph showing the variation of conductivity with temperature for a metallic conductor. How does one explain such behaviour, using the mathematical expression of the conductivity of a material. **CBSE(AI)-2004**

[Ans. (i) Graph :



(ii) explanation : $\boldsymbol{\sigma = \frac{1}{\rho} = \frac{ne^2\tau}{m}}$

In conductors, with increase in temperature, number density (n) does not change but the average speed of electrons and hence frequency of collision increases due to which relaxation time (τ) decreases. Hence conductivity σ decreases

260. A wire whose cross sectional area is increasing linearly from it one end to another, is connected across a battery Of V volts. Which of following quantities remain constant in the wire ? **CBSE (D)-2017,(AIC)-2015**
(a) drift speed (b) current density (c) electric current (d) electric field. Justify your answer.
[Ans. Current Justification : all other quantities depends on area of cross section

261. 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 velocities of electrons in the two wires.

[Ans. $I = neAv_d$ & $\boldsymbol{I_X = I_Y}$ **CBSE (AI)-2010**

$\Rightarrow \quad (2n)\, eAv_X = n\, eAv_Y \quad \Rightarrow \quad 2v_X = v_Y \quad \Rightarrow \quad v_X/v_Y = 1/2$

262. Explain giving reasons, how the internal resistance of a cell changes in the following cases : **CBSE(F)-2008**

(i) When concentration of the electrolyte is increased

(ii) When area of the anode is decreased

(iii) When temperature of the electrolyte is increased

[Ans. (i) Internal resistance increases

Reason : inter ionic attractions increase and the movement of the ions become difficult

(ii) Internal resistance increases

Reason : lesser area of the anode decreases its tendency to attract its oppositely charged ions

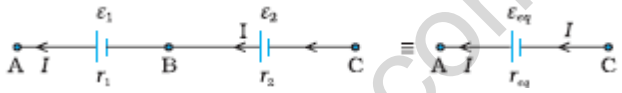
(iii) Internal resistance decreases

Reason : Both inter ionic attractions and viscous forces decrease at higher temperature

==========

263. Derive an expression for the equivalent resistance of combination of cells in series. **NCERT-2017**

[Ans. $V_{AC} = V_A - V_C = (V_A - V_B) + (V_B - V_C)$



$\Rightarrow \quad V_{AC} = (E_1 - Ir_1) + (E_2 - Ir_2)$

$\Rightarrow \quad V_{AC} = (E_1 + E_2) - I(r_1 + r_2)$ ----------(1)

Let E_{eq} be the equivalent emf and r_{eq} be the equivalent internal resistance of this series combination then we have

$V_{AC} = \mathrm{E_{eq}} - \mathrm{Ir_{eq}}$ ----------(2)

On comparing (1) & (2) we get

$E_{eq} = E_1 + E_2 \quad \& \quad r_{eq} = r_1 + r_2$

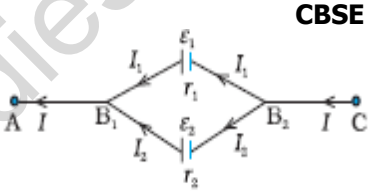
==========

264. Two cells of emfs E_1 and E_2 and internal resistances r_1 and r_2 are connected in parallel as shown in the figure. Deduce an expression for the **CBSE (AI)-2015, (F)-2012**

(i) equivalent emf of the combination

(ii) equivalent internal resistance of the combination

(iii) potential difference between the points A and C



[Ans. We have

$V = V_{B_1} - V_{B_2} = E_1 - I_1 r_1 \quad \Rightarrow \quad I_1 = \frac{E_1 - V}{r_1}$

& $V = V_{B_1} - V_{B_2} = E_2 - I_2 r_2 \quad \Rightarrow \quad I_2 = \frac{E_2 - V}{r_2}$

$\Rightarrow \quad \mathrm{I} = \mathrm{I}_1 + \mathrm{I}_2 = \left(\frac{E_1 - V}{r_1}\right) + \left(\frac{E_2 - V}{r_2}\right) = \left(\frac{E_1}{r_1} + \frac{E_2}{r_2}\right) - V\left(\frac{1}{r_1} + \frac{1}{r_2}\right) = \left(\frac{E_1 r_2 + E_2 r_1}{r_1 r_2}\right) - V\left(\frac{r_1 + r_2}{r_1 r_2}\right)$

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

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

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

On comparing with, $\mathrm{V = E_{eq} - Ir_{eq}}$

(i) $E_{eq} = \left(\frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}\right)$

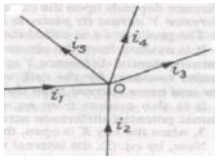
(ii) $r_{eq} = \left(\frac{r_1 r_2}{r_1 + r_2}\right)$ (iii) $V_{AC} = V = \left(\frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}\right) - \mathrm{I}\left(\frac{r_1 r_2}{r_1 + r_2}\right)$

265. State Kirchhoff's rules in electrostatics and explain on what basis they are justified ? **CBSE(AI)-2017,2015**

[Ans. Kirchhoff's Rules :

(i) Junction rule :The algebraic sum of all the currents meeting at any junction in an electric circuit is zero.

i,e, $\sum i = 0$

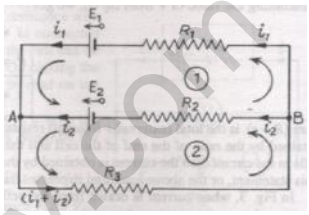


⇨ $i_1 + i_2 = i_3 + i_4 + i_5$

This rule is based on the conservation of charge.

(ii) Loop rule : In any closed mesh of an electric circuit, the algebraic sum of the products of the currents and the resistance in each part of the mesh is equal to the algebraic sum of emf's in that mesh.

i,e, $\sum iR = \sum E$



In mesh (1),

$i_1 R_1 - i_2 R_2 = E_1 - E_2$

Similarly, in mesh (2)

$i_2 R_2 + (i_1 + i_2) R_3 = E_2$

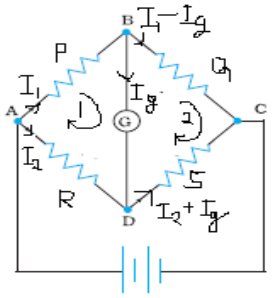
This rule is based on the conservation of energy

266. What is Wheatstone bridge ? When is the bridge said to be balanced ? Use Kirchhoff's rules to obtain conditions for the balanced condition in a Wheatstone bridge. **CBSE(D)-2015**

[Ans. Wheatstone bridge : It is an arrangement of four resistances which is used to determine one of these resistance in terms of the remaining three resistances

Balanced condition : If the resistances in the Wheatstone bridge are so arranged that current in the galvanometer (I_g) is zero then the bridge is said to be balanced and in this balanced condition

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



Proof : In the balanced condition, $I_g = 0$

Applying Kirchhoff's loop rule to ABDA

$I_1 P + 0 - I_2 R = 0$

⇨ $I_1 P = I_2 R$ -------(1)

Again applying Kirchhoff's loop rule to BCDB

$I_1 Q - I_2 S - 0 = 0$

⇨ $I_1 Q = I_2 S$ -------(2)

⇨ from (1) & (2), $\frac{I_1 P}{I_1 Q} = \frac{I_2 R}{I_2 S}$ ⇨ $\frac{P}{Q} = \frac{R}{S}$

267. How a metre bridge is used to determine the unknown resistance of a given wire ? Write the necessary precautions to minimize the error in the result. **CBSE (AI)-2016, (AIC)-2015**

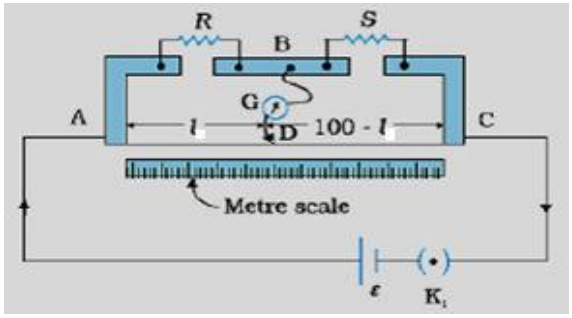
[Ans. Determination of unknown resistance (S)

Let l be the balancing length for unknown resistance S as shown then

$$\frac{P}{Q} = \frac{\rho l/A}{\rho(100-l)/A} = \frac{l}{(100-l)}$$

⇨ $\frac{R}{S} = \frac{l}{(100-l)}$

⇨ $S = R\left(\frac{100-l}{l}\right) = R\left(\frac{100}{l} - 1\right)$



By choosing three different values of R, we calculate S each time. Average of these values of S gives the value of unknown resistance

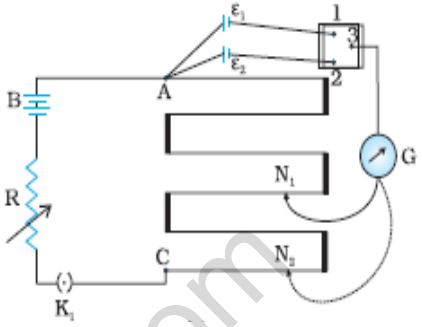
Precautions : (i) Make all the connections neat, clean and in tight manner

(ii) select those values of R for which the balancing length l is closed to the middle point of the wire

268. (i) With the help of a 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. **CBSE (D)-2013, (AIC)-2008**

(ii) Write two possible causes for one sided deflection in a potentiometer experiment. **CBSE (D)-2013**

[Ans. (i) Comparison of emf's of two primary cells :



If l is the balancing length the by the principle of potentiometer

$$\varepsilon = K\, l \qquad \text{----------(1)}$$

Where K is the potential gradient.

Let l_1 be the balancing length for cell of emf ε_1 then as per (1)

$$\varepsilon_1 = K\, l_1$$

Similarly, if l_2 be the balancing length for cell of emf ε_2 then

$$\varepsilon_2 = K\, l_2$$

⇨ from (1) & (2)

$$\frac{\varepsilon_1}{\varepsilon_2} = \frac{K\, l_1}{K\, l_2} = \frac{l_1}{l_2}$$

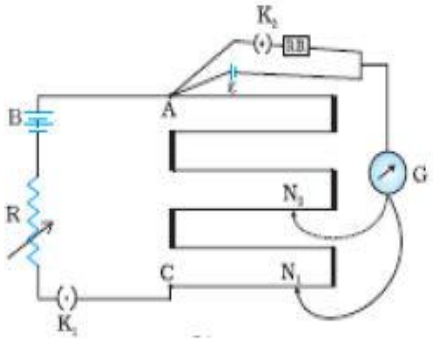
(ii) Possible causes :

(a) The emf ε_1 or ε_2 is more than the emf of driver cell

(b) Positive terminals of driver cell and the cell whose emf is to be measured may not be connected to the zero end of the potentiometer

269. With the help of a circuit diagram, explain how a potentiometer is used to determine the internal resistance of a cell. tain the required expression used. **CBSE (F)-2016,2011,(AI)-2013**

[Ans. Determination of internal resistance of a cell :



Let l_1 is the balancing length when key K_2 is open then by the principle of potentiometer

$$\varepsilon = K\, l_1 \qquad \text{----------(1)}$$

Where K is the potential gradient.

Similarly, if l_2 be the balancing length when key K_2 is closed then

$$V = K\, l_2 \qquad \text{---------(2)}$$

⇨ from (1) & (2)

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

⇨ $\frac{I(R+r)}{IR} = \frac{l_1}{l_2}$ ⇨ $\left(1 + \frac{r}{R}\right) = \frac{l_1}{l_2}$

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

270. Why is potentiometer preferred over a voltmeter for comparison of emf. of cells ? **CBSE(D)-2016,(AI)-2014**

[Ans. because a potentiometer does not draw current for any measurement unlike a voltmeter

271. (i) Define potential gradient. Write its S.I. unit. Obtain an expression for potential gradient in terms of the resistivity of the potentiometer wire. **CBSE (D)-2016,(AI)-2014,2006,(F)-2009**

(ii) In a potentiometer experiment, if the area of cross section of the wire increases uniformly from one end to another, draw a graph showing how potential gradient would vary as the length of the wire increases from one end ? **CBSE (AIC)-2014**

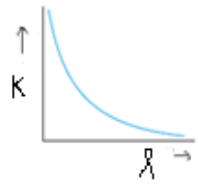
[Ans. Potential gradient :

Potential drop per unit length of the wire carrying current is called potential gradient

i,e, $\mathrm{K} = \frac{V}{L} = \frac{\mathrm{I}\,R}{L} = \frac{\mathrm{I}\,\rho\,\mathrm{L}/A}{L} = \frac{\mathrm{I}\,\rho}{\mathrm{A}}$

⇨ $\mathrm{K} \propto 1/A$

S.I. unit of potential gradient is V/m



272. A conductor of length 'l' is connected to a d.c. source of potential 'V'. If the length of the conductor is tripled by gradually stretching it, keeping 'V' constant, how will (i) drift speed of electrons and (ii) resistance of the conductor be affected ? Justify your answer. **CBSE (F)-2012**

[Ans. **(i)** $v_d = \frac{eV}{ml}\tau$ ⇨ $v_d \propto 1/l$ drift velocity will become one third when length of the conductor is tripled

(ii) Now when the wire is stretched $A\ X\ l = constant$

As $R = \rho\frac{l}{A}$ ⇨ $R_2 = \rho\frac{l_2}{A_2} = \rho\frac{3l_1}{A_1/3} = 9\,\rho\frac{l_1}{A_1} = 9R_1$ Hence resistance will become 9 times

273. Two wires X and Y have the same resistivity but their cross sectional areas are in the ratio 2:3 and lengths in the ratio 1:2. They are first connected in series and then in parallel to a d.c. source. Find out the ratio of the drift speeds of the electrons in the two wires for the two cases. **CBSE (AI)-2008**

[Ans. **Given** : $A_X : A_Y = 2{:}3$ & $l_X : l_Y = 1{:}2$

(i) in series, $I_X = I_Y$ ⇨ $neA_X(v_d)_X = neA_Y(v_d)_Y$

⇨ $\frac{(v_d)_X}{(v_d)_Y} = \frac{A_Y}{A_X} = 3/2$

(ii) in parallel, $V_X = V_Y$ ⇨ $I_XR_X = I_YR_Y$

⇨ $neA_X(v_d)_X\,(\rho\,\frac{l_X}{A_X}) = neA_Y(v_d)_Y\,(\rho\,\frac{l_Y}{A_Y})$

⇨ $\frac{(v_d)_X}{(v_d)_Y} = \frac{l_Y}{l_X} = 2/1$

274. A potential difference V is applied across a conductor of length L and diameter D. How is the drift velocity v_d, of charge carriers in the conductor is affected when (i) V is halved (ii) L is doubled and (iii) D is halved ? Justify your answer in each case. **CBSE(AI)-2015**

[Ans. $v_d = \frac{eV}{ml}\tau$ **(i)** v_d will become half as $v_d \propto V$ **(ii)** v_d will become half as $v_d \propto 1/L$

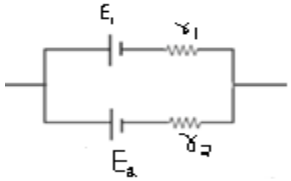
(iii) v_d will remain same as it does not depend on diameter

275. Two cells of emf $1.5\ V$ and $2.0\ V$ having internal resistances 0.2Ω and 0.3Ω respectively are connected in parallel. Calculate the emf and internal resistance of the equivalent cell. **CBSE(D)-2016,(AI)-2013**

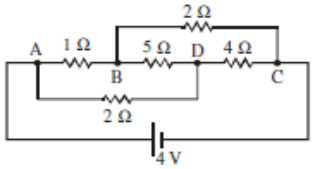
[Ans. **Given** : $E_1 = 1.5\ V, E_2 = 2.0\ V, r_1 = 0.2\Omega, r_2 = 0.3\Omega, E_{eq} = ?$ & $r_{eq} = ?$

$$E_{eq} = \frac{E_1r_2 + E_2r_1}{r_1 + r_2} = \frac{1.5\ X\ 0.3 + 2.0\ X\ 0.2}{0.2+0.3} = \frac{0.85}{0.5} = 1.7\ V$$

$$r_{eq} = \frac{r_1\,r_2}{r_1 + r_2} = \frac{0.2\ X\ 0.3}{0.2+0.3} = \frac{0.06}{0.5} = 0.12\ \Omega\ ]$$



276. Calculate the current drawn from the battery by the network of the resistors shown in figure. **CBSE(AIC)-2015**



[Ans. given network is a balanced Wheatstone bridge, $\frac{1}{R} = \frac{1}{1+2} + \frac{1}{2+4} = \frac{1}{2}$ ⇨ $R = 2\ \Omega$ ⇨ $I = \frac{V}{R} = \frac{4}{2} = 2\ A$

277. In a meter bridge with R and S in the gaps, the null point is found at 40 cm from A. If the resistance of 30 Ω is connected in parallel with S, the null point occurs at 50 cm from A. Determine the value of R and S.

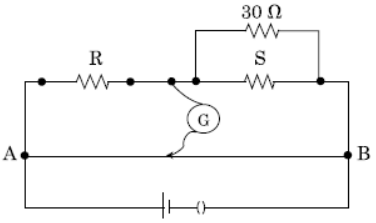
[Ans. $S = R\left(\frac{100-l}{l}\right)$ **CBSE(AI)-2016, (D)-2010**

In I^{st} case, $S = R\left(\frac{100-40}{40}\right) = \frac{3}{2}R$ ⇨ $R = \frac{2}{3}S$

In II^{nd} case, $\frac{30\,S}{30+S} = R\left(\frac{100-50}{50}\right) = R$

⇨ $\frac{30\,S}{30+S} = R = \frac{2}{3}S$ ⇨ $60 + 2S = 90$ ⇨ $S = 15\ \Omega$

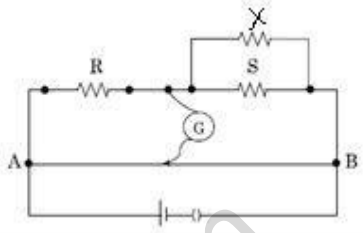
⇨ $R = \frac{2}{}S = \frac{2}{}$ X 15 = 10 Ω



278. In a meter bridge, the null point is found at a distance of l_1 cm from A. If now a resistance of X is connected in parallel with S, the null point occurs at l_2 cm from A. Obtain a formula for X in terms of l_1, l_2 *and* S.

CBSE (AI)-2017,2009,(D)-2010

[Ans. $S = R\left(\frac{100-l}{l}\right)$



In I^{st} case, $S = R\left(\frac{100-l_1}{l_1}\right)$ -------(1)

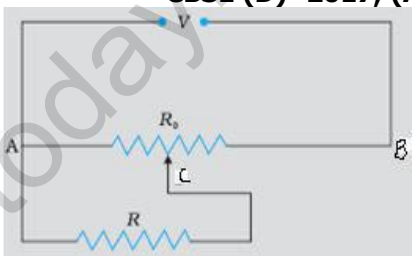
In II^{nd} case, $\frac{XS}{X+S} = R\left(\frac{100-l_2}{l_2}\right)$ -------(2)

Dividing (1) by (2), $\frac{S}{\frac{XS}{X+S}} = \frac{R\left(\frac{100-l_1}{l_1}\right)}{R\left(\frac{100-l_2}{l_2}\right)} \Rightarrow \frac{X+S}{X} = \frac{l_2}{l_1}\left[\frac{100-l_1}{100-l_2}\right]$

$\Rightarrow 1+\frac{S}{X} = \frac{l_2}{l_1}\left[\frac{100-l_1}{100-l_2}\right] \Rightarrow \frac{S}{X} = \frac{l_2}{l_1}\left[\frac{100-l_1}{100-l_2}\right]-1 \Rightarrow X = \frac{S}{\frac{l_2}{l_1}\left[\frac{100-l_1}{100-l_2}\right]-1}$

279. A resistance of R Ω draws current from a potentiometer. The potentiometer wire AB, has a total resistance of 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 wire.

CBSE (D) -2017, (AI)-2014



[Ans. Resistance between A and C

$$R_1 = \frac{R\left(\frac{R_0}{2}\right)}{R+\frac{R_0}{2}} = \frac{R_0R}{R_0+2R}$$

⇨ Effective resistance of the circuit

$$R_2 = R_1 + \frac{R_0}{2}$$

current through potentiometer wire

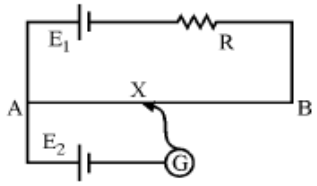
$$\mathrm{I} = \frac{V}{R_2} = \frac{V}{R_1+\frac{R_0}{2}} = \frac{2V}{2R_1+R_0}$$

Required voltage,

$$\mathrm{V_1} = \mathrm{I}\,R_1 = \left(\frac{2V}{2R_1+R_0}\right)R_1 = \frac{2V}{2\left(\frac{R_0R}{R_0+2R}\right)+R_0}\,\mathrm{X}\left(\frac{R_0R}{R_0+2R}\right) = \frac{2V}{\frac{R_0[2R+R_0+2R]}{(R_0+2R)}}\,\mathrm{X}\left(\frac{R_0R}{R_0+2R}\right) = \frac{2VR}{R_0+4R}$$

280. In the circuit diagram given below, AB is a uniform wire of resistance 15 Ω and length 1 m. It is connected to a cell E_1 of emf 2V and negligible internal resistance and a resistance R. The balance point with another cell E_2 of emf 75 mV is found at 30 cm from end A. Calculate the value of R. **[Ans** 105 Ω] **CBSE (F) -2016, (AI)-2015**

[Ans. $\varepsilon = K\,l$



⇨ $E_2 = (IR')\,l = \left(\frac{E_1}{R+R_{AB}}\right)R'\,l$

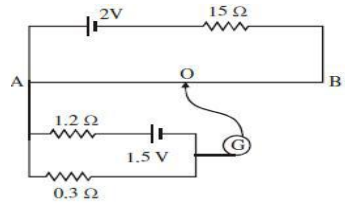
$75\ X\ 10^{-3} = \left(\frac{2}{R+15}\right)15\ X\ 30X\ 10^{-2}$

⇨ $\boldsymbol{R+15} = \frac{2\ X\ 15\ X\ 30\ X\ 10^{-2}}{75\ X\ 10^{-3}} = 120$

⇨ $\boldsymbol{R} = 120-15 = 105\ \Omega$

281. In the following potentiometer circuit AB is a uniform wire of length 1 m and resistance 10 Ω. Calculate the
(i) potential gradient along the wire, and
(ii) balance length AO (= *l*).

[Ans 0.8 V/m, 37.5 cm] **CBSE (D) -2016**



[Ans. **(i)** $K = \frac{V_{AB}}{l_{AB}} = \frac{I\,R_{AB}}{l_{AB}} = \left(\frac{\boldsymbol{E}}{\boldsymbol{R_{total}}}\right)\left(\frac{R_{AB}}{l_{AB}}\right) = \left(\frac{2}{\mathbf{15+10}}\right)\left(\frac{10}{1}\right)$

⇨ $K = \left(\frac{\mathbf{20}}{\mathbf{25}}\right) = 0.8\ V/m$

(ii) Current flowing in the circuit containing cell

$$\mathrm{I} = \frac{1.5}{1.2+0.3} = 1\ A \qquad \Rightarrow \boldsymbol{V_{AO}} = 0.3\ \mathrm{X}\ 1 = 0.3\ V$$

Now, $K = \frac{V_{AO}}{}$ ⇨ $l_{AO} = \frac{V_{AO}}{} = \frac{0.3}{} = 0.375$ m $= 37.5\ cm$

K 0.8