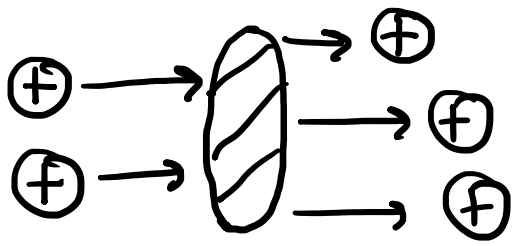
[Electric Current]

Electric Current – Electric current is defined as the rate of flow of charge through an area held perpendicular to the direction of flow of charge.

Average current – The amount of charge (ΔQ) passes in time interval (Δt).

$$i_{avg} = \frac{\Delta Q}{\Delta t} = \frac{Q_2 - Q_1}{t_2 - t_1} = \frac{\text{Total charge}}{\text{Total time}}$$



Instantaneous Current – small amount of charge (dq) passing in very small time interval (dt).

$$i_{inst} = \frac{dq}{dt}$$

Direction of electric current – a) Metallic Conductor – direction of current is taken as opposite to direction of flow of electron.

By – Sonu Kumar

b) Electrolytic Conductor – The direction of flow of current from anode to cathode. (electron flow from cathode to anode).

* Conventionally, we define the direction of electric current as the direction of flow of positive charge.

Electric Current – Scalar or vector quantity.

→ Electric current has direction, so it should be a vector quantity.

→ But, all vector quantities follow vector law law of addition but current obey scalar addition (junction rule).

* Electric current is a scalar quantity.

Q1. If 0.5 mol of electrons flow through a wire in 8 mins. Find the magnitude of electric current. (Take $N_A = 6 \times 10^{23}$)

a) 40 A b) 60 A c) 80 A d) 100 A

Sol. $i_{avg} = \frac{Q}{t} = \frac{ne}{t} = \frac{3 \times 10^{23} \times 1.6 \times 10^{-19}}{8 \times 60} = 100\,A$ $\left(\because 0.5\,mol = \frac{1}{2} N_A\right)$

Q2. A solution of copper sulphate furnishes 6×10^{16} Cu^{2+} ions and 4×10^{16} SO_4^{2-} ions in 2 seconds. Find the electric current passing through the solution.

a) 4 mA b) 8 mA c) 16 mA d) 32 mA

Sol. $Cu^{2+} \longrightarrow 2e \Rightarrow |q_1| = 6\times10^{16}\times 2e$

$SO_4^{2-} \longrightarrow -2e \Rightarrow |q_2| = 4\times10^{16}\times 2e$

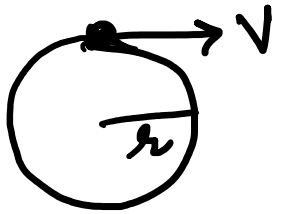
$$I = I_+ + I_- = \frac{q_1}{t} + \frac{q_2}{t}$$

$$\Rightarrow I = \frac{6\times10^{16}\times 2e + 4\times10^{16}\times 2e}{2} = 10\times10^{16}\times\frac{2e}{2} = 10^{17}\times1.6\times10^{-19} = 16\,mA$$

Q3. In a hydrogen atom, the electron makes about 0.6×10^{16} revolution per second around the nucleus. Determine the average current at any point on the orbit of the electron.

a) 0.36 mA b) 0.96 mA c) 0.60 mA d) 0.24 mA

Sol. $$i_{avg} = \frac{Q}{t} = \frac{ne}{t} = \frac{0.6\times10^{16}\times1.6\times10^{-19}}{1} = 0.96\,mA$$



$$T = \frac{dist}{speed} = \frac{2\pi r}{V} \Rightarrow i = \frac{Ve}{2\pi r} = ne$$ (n → frequency.)

By – Sonu Kumar

Q4. If $q = t^2 + 2t$. Find i) Current i at $t = 2s$
ii) Average current from 0–2s

Sol. i) $i_{inst} = \frac{dq}{dt} = 2t + 2 \Rightarrow i_{ins(t=2)} = 2(2) + 2 = 6A$

ii) $i_{avg} = \frac{\Delta Q}{\Delta t} = \frac{Q_f - Q_i}{t_f - t_i} = \frac{Q_{(2)} - Q_{(0)}}{t_2 - t_0} = \frac{((2)^2 + 2(2)) - 0}{2 - 0} = 4A$

#Note: $Q = i \times t$ (if i = constant)

$Q = \int i\,dt$ (if t = variable)

Q5. If $i = 3t^2 + 2t$. Calculate quantity of charge that passes through a cross-section of wire during the time $t = 0s$ to $t = 3s$.

a) 12C b) 24C c) 36C d) 48C

Sol. $i = \frac{dq}{dt} \Rightarrow q = \int dq = \int i\,dt = \int_0^3 i\,dt = \int_0^3 (3t^2 + 2t)\,dt = \left[\frac{3t^3}{3} + \frac{2t^2}{2}\right]_0^3$

$= [t^3 + t^2]_0^3 = [27 + 9] = 36\,C$

Current Density ($\vec{J}$) - Current density at a point is defined as the amount of current flowing per unit area around that point, provided the area is in the direction of current.

→ vector quantity. ($\vec{J}$ is in direction of $\hat{i}$)

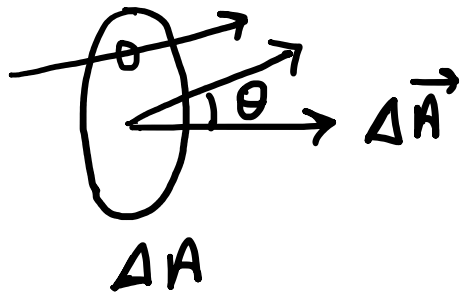
→ $\vec{J} = \frac{i}{A}\hat{i}$ (Unit - Ampere m^{-2})

→ If current is not perpendicular to area -

Area in direction of current = $A\cos\theta$

$$\vec{J} = \frac{i}{A\cos\theta}\hat{i}$$

θ → angle between $\hat{i}$ and $\vec{A}$

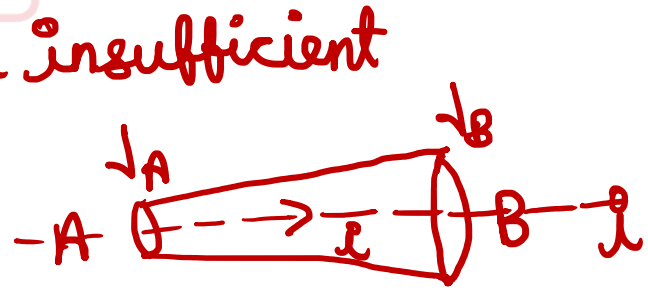


Q6. Under Steady State, which is correct

a) $v_A > v_B$ b) $v_A < v_B$ c) $v_A = v_B$ d) Data insufficient

Sol. In steady state, current = constant

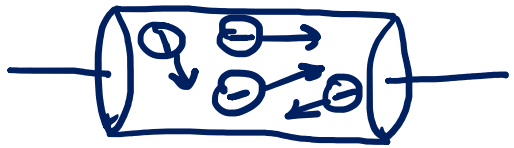
$$J = \frac{i}{A} \Rightarrow v \propto \frac{1}{A} \Rightarrow v_A > v_B$$



[Electron Gas Model / Structural Model for Metallic Conductor]

1. Metal have a large number of free electrons (10^{28} free electron per m^3 → free electron density)

   (No battery → No ΔV → No $\vec{E}$)



2. In the absence of any Electric field, the free electrons move 'Randomly' due to their thermal energies.

   (K.E $\propto T$ or $V \propto \sqrt{T}$) ⇒ $V \approx 10^5$ m/s

3. The average thermal velocity of all electrons is zero since different electron move in different direction.

$$u_{avg} = \frac{u_1 + u_2 + u_3 + _ _ _ _ + u_n}{n} = 0$$

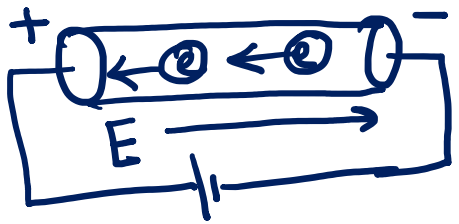
   Thus, there is no net motion of electron in any particular direction in the absence of an electric field.

4. On applying external electric field (by connecting a battery), each electron

experiences electric force in direction opposite to applied field.

$\vec{F} = q\vec{E} = -e\vec{E} \Rightarrow ma = -eE$

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



5. The acceleration occurs only for a short interval of time between two collisions and provides a small velocity to electron in a direction opposite to Electric field.

This velocity is called drift velocity. ($V_d \approx 10^{-4}$ m/s)

The electron moves randomly at high thermal velocities (10^5 m/s) between two collisions but also keeps on drifting opposite to Electric field at small velocity (10^{-4} m/s).

Calculation of drift velocity (V_d) – If an electron moving with random thermal velocity (u_1) accelerates for time τ_1 (relaxation time between two successive collisions and attains velocity v_1.

$\vec{v_1} = u_1 + a\tau_1$ and $a = -\frac{eE}{m}$

Similarly, another e^- moving with random thermal velocity u_2 accelerates for time τ_2 (relaxation time between two successive collisions) and attains velocity v_2,

$$\boxed{v_2 = u_2 + a\tau_2}$$

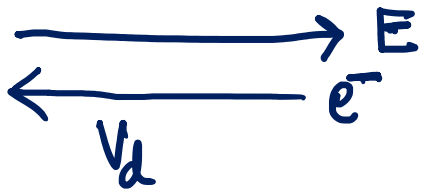
$$\text{drift velocity } (v_d) = \frac{(u_1 + a\tau_1) + (u_2 + a\tau_2) + \dots + (u_n + a\tau_n)}{n}$$

$$= \frac{u_1 + u_2 + \dots + u_n}{n} + \vec{a}\left(\frac{\tau_1 + \tau_2 + \dots + \tau_n}{n}\right)$$

(average thermal velocity) (average relaxation time)

$$\vec{v_d} = \vec{a}\,\tau_{avg} \Rightarrow \vec{v_d} = -\frac{eE}{m}\tau$$

where, v_d - drift velocity
e - charge on electron
E - Electric Field
τ - average relaxation time
m - mass of electron.

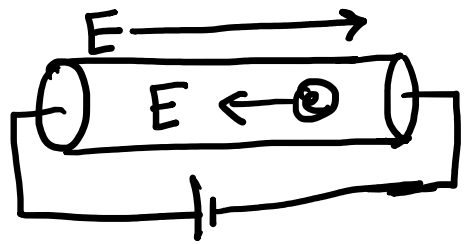


By - Sonu Kumar

Drift velocity in terms of potential difference (V) across conductor –

$$V_d = -\frac{eE}{m}\tau \Rightarrow |V_d| = \frac{eE}{m}\tau$$

$$|V| = E.l \Rightarrow |\vec{E}| = \frac{V}{l} \Rightarrow |V_d| = \frac{eV}{ml}\tau$$



(drift velocity is from lower to higher potential)

electron moves with very small constant velocity $\left(V_d = \frac{eV}{ml}\tau\right)$

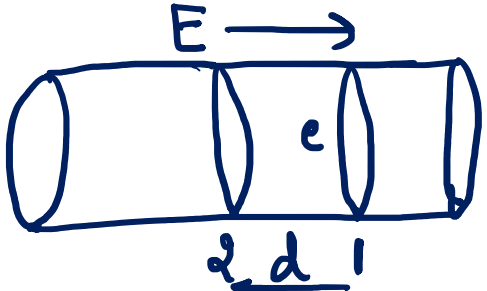
Relationship of (V_d) with current (I) –

Let there be 'n' free electron per m^3 of conductor (free electron density).

Let in time 'dt' all electron in cross-section ① reach cross section ②

$d = (V_d)\,dt \Rightarrow$ Volume $= A \times d = AV_d\,dt$

N = no. of e^- per unit volume × volume $= n(AV_d\,dt)$



By – Sonu Kumar

Number of electron passing through cross-section ① in time $dt = n(Av_d\,dt)$

Charge passing through cross section ① in time $dt = \frac{dq}{dt} = nAv_d e$

or $\boxed{I = neAv_d}$

and current density $= -v_d en$ or $\boxed{J = -v_d en}$

Q7. Drift speed of electrons, when 1.5A of current flows in a copper wire of cross-section $5mm^2$ is v. If the electron density in copper is $9\times10^{28}\ m^{-3}$, the value of v in mm/s is close to (Take, charge of electron to be $= 1.6\times10^{-19}C$)

a) 0.02 b) 0.2 c) 2 d) 3

Sol. $i = 1.5A$

$A = 5mm^2 = 5\times(10^{-3})^2 = 5\times10^{-6}\ m^2$

$n = 9\times10^{28}\ m^{-3}$

$i = v_d enA \Rightarrow v_d = \frac{i}{enA} = \frac{1.5}{1.6\times10^{-19}\times9\times10^{28}\times5\times10^{-6}} = \frac{1}{48}\times10^{-3}\ m/s = 0.02\ mm/s$

Adda247

Q8. How much time will be taken by an electron to move a distance $l = 1\,km$ in a copper wire of cross-section $A = 1\,mm^2$, if current $I = 0.8\,A$

Sol. $t = \frac{\text{distance}}{\text{speed}} = \frac{10^3 \times 1.6 \times 10^{-19} \times 1 \times 10^{-6}}{0.8} = 2 \times 10^6\,s \quad \left(V_d = \frac{I}{neA}\right)$

Mobility (μ) – electrical mobility is the ability of a charged particle to move in a medium.

→ It is the drift velocity of a charged particle per unit electric field.

$$\mu = \frac{V_d}{E} \Rightarrow \mu \propto \frac{q}{m}$$

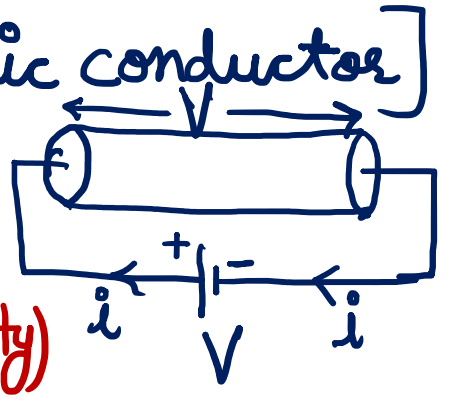
Q9. Consider a conductor of length 40 cm where a potential difference of 10V is maintained between the ends of the conductor. Find the mobility of the electrons provided the drift velocity of the electrons is 5×10^{-6} m/s.

Sol. $\mu = \frac{V_d}{E} = V_d\left(\frac{l}{V}\right) = \frac{5 \times 10^{-6} \times 40 \times 10^{-2}}{10} = 2 \times 10^{-7}\,\frac{m^2}{Vs}$

[Electric Resistance]

Resistance of a conductor is defined as the ratio of potential difference across the ends of conductor to the current flowing through the conductor.

$$R = \frac{\Delta V}{I} = \frac{V}{i}$$ [always true for ohmic or non-ohmic conductor]



Unit of resistance – $R = \frac{V}{i} = \frac{\text{Volt}}{\text{ampere}}$ or Ohm (Ω)

Resistance in terms of τ and n (relaxation time & electron density)

$$I = neAv_d = neA\left(\frac{eV}{ml}\right)\tau = \left(\frac{ne^2\tau A}{ml}\right)V \Rightarrow R = \frac{V}{i} = \frac{ml}{ne^2\tau A}$$

$$\therefore \boxed{R = \frac{ml}{ne^2\tau A}} \rightarrow \text{valid for metallic conductor.}$$

Factors on which resistance of a Conductor depends – $R = \frac{ml}{ne^2\tau A}$

m – mass of electron
e – charge on electron
n – number of electrons per unit volume
τ – average relaxation time between two collisions for conductor → Choice of material → temperature
l – length of conductor along which current flows
A – Cross-section area of conductor through which current flows.

Resistivity (ρ) – unit – Ohm meter $\left(\rho = R\frac{A}{l}\right)$

$$R = \frac{ml}{ne^2\tau A} = \left(\frac{m}{ne^2\tau}\right) \times \frac{l}{A} = \rho\frac{l}{A}$$

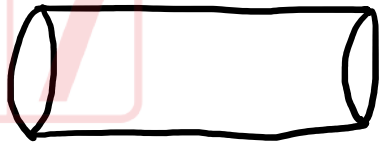
$\rho = \frac{m}{ne^2\tau}$ = remains constant if material is same, also temperature, pressure and other physical conditions remains same

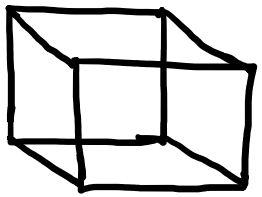
→ Resistivity of a conductor $\left(\frac{m}{ne^2\tau}\right)$ donot depends on shape and size of conductor

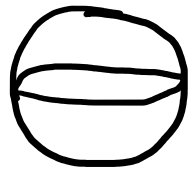
→ Resistivity depends on – choice (nature) of material, temperature, pressure and other physical conditions.

For example –

Resistivity of copper at 20°C is $1.68 \times 10^{-8}\ \Omega m$.







R_A, R_B, R_C, R_D are different.

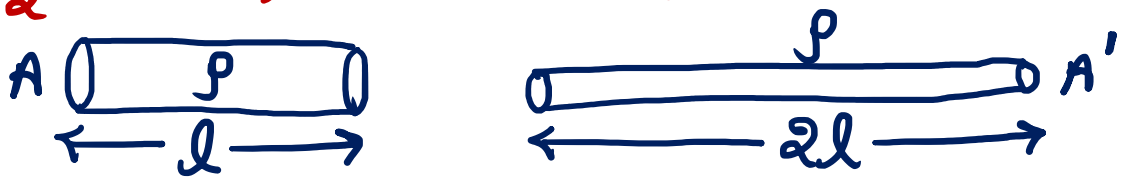
$\rho_A = \rho_B = \rho_C = \rho_D$ if temp. and material are same.

Q10. A wire of resistance R is stretched to double its length. Find the new resistance.

a) R b) $\frac{R}{2}$ c) 2R d) 4R

Sol.

$$\frac{R_i}{R_f} = \left(\frac{l_i}{l_f}\right)^2$$



Volume = Al = constant

$$R' = \frac{\rho(2l)}{A'} = \frac{\rho(2l)}{\frac{A}{2}}$$

$$R' = 4\left(\rho\frac{l}{A}\right) = 4R$$

(length become n times ⇒ R become n^2 times)
(stretching)

Q11. A wire of resistance 9 ohm is compressed to one-third of its length. Find the new resistance.

a) 1 ohm b) 3 ohm c) 9 ohm d) 27 ohm

Sol.

$$\frac{R_f}{R_i} = \left(\frac{\frac{l}{3}}{l}\right)^2 \Rightarrow \frac{R}{9} = \left(\frac{\frac{l^2}{9}}{l^2}\right) \Rightarrow R = \frac{9}{9} = 1 \text{ ohm}$$

Q12. If a wire is stretched to increase its length by 1%. Find the change in the resistance.

a) 1% b) 2% c) 0.5% d) 1.5%

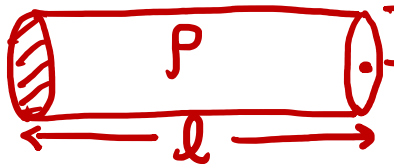
Sol. $R \propto l^2 \Rightarrow \frac{\Delta R}{R} \times 100\% = 2\left(\frac{\Delta l}{l} \times 100\%\right)$

$\therefore \frac{\Delta R}{R} \times 100\% = 2(1\%) = 2\%$.

Adda247

Q13. A wire of resistance R is stretched such that its radius is halved. Find the new resistance.

a) 2R b) 4R c) 8R d) 16R



Sol. Volume (Al) = constant

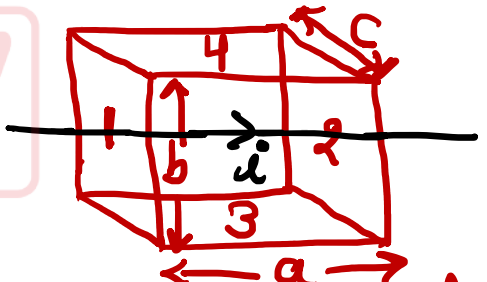
$R = \rho \frac{l}{\pi r^2}$, on stretching or compression, $\frac{R_i}{R_f} = \left(\frac{r_f}{r_i}\right)^4 = \left(\frac{d_f}{d_i}\right)^4$ (Radius, diameter)

$$\Rightarrow \frac{R}{R'} = \left(\frac{\frac{r}{2}}{r}\right)^4 = \frac{1}{16} \Rightarrow R' = 16R$$

Q14. If the resistivity of material of cube is ρ. Find the resistance across the face i) 1 and 2 ii) 3 and 4

Sol. i) 1 and 2 $l = a$, $A = bc \Rightarrow R = \rho\left(\frac{a}{bc}\right)$

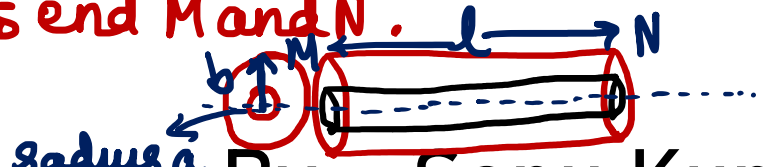
ii) 3 and 4 $l = b$, $A = ac \Rightarrow R = \rho\left(\frac{b}{ac}\right)$



Q15. A hollow cylindrical tube of length l has inner radius a while outer radius b. What is the resistance of the tube between its end M and N.

Sol. length = l, Area = $\pi(b^2 - a^2)$

$$R = \rho\frac{l}{A} = \rho\frac{l}{\pi(b^2 - a^2)}$$



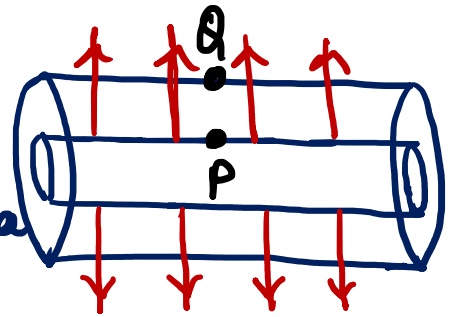
By – Sonu Kumar

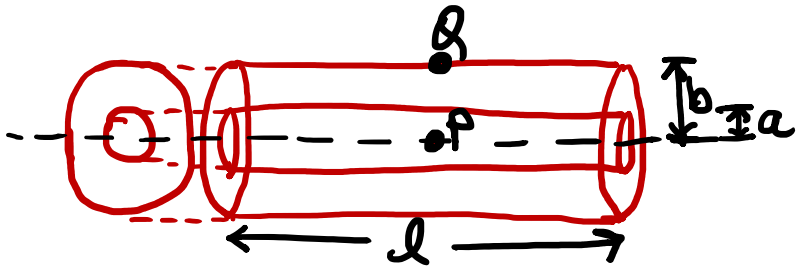
Q16. A hollow cylindrical tube of length l has inner radius a while outer radius b. What is the resistance of the tube between its end P and Q.

Sol.

$l = b - a$

A = changing elemental area





Elemental cylinder

$l = dr$

$A = 2\pi rl$

$$dR = \rho \frac{dr}{2\pi rl} \Rightarrow R = \int_{r=a}^{r=b} dR = \int_a^b \rho \left(\frac{dr}{2\pi rl}\right) = \frac{\rho}{2\pi rl} \int_a^b \frac{dr}{r}$$

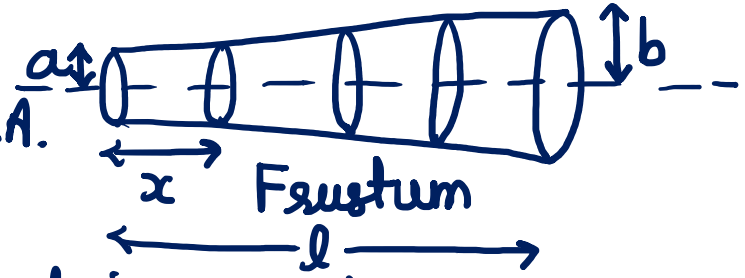
$$\therefore R = \frac{\rho}{2\pi rl} [\log_e r]_a^b = \frac{\rho}{2\pi rl} (\log_e b - \log_e a) = \frac{\rho}{2\pi rl} \log_e \left(\frac{b}{a}\right)$$

Q17. Show a conductor of length l having a circular cross-section. The radius of cross-section varies linearly from $a \to b$. The resistivity of material is ρ. Assuming that $(b-a) << l$, find the resistance of the conductor.

By – Sonu Kumar

Sol. length = l, Area of cross-section - variable

We will take elemental disc at distance x from end A.



Find resistance of elemental disc dR

Then, there are infinite discs in series (as current is same)

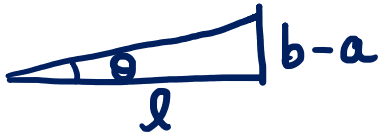
($r=a$ to $r=b$)

$R_{net} = R_1 + R_2 + R_3 + \dots$

$= \int dR$

Resistance of elemental disc (dR)

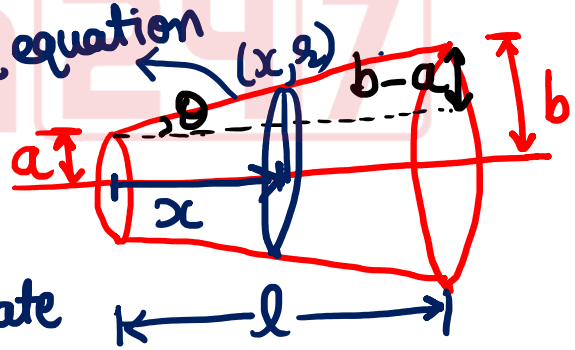
$l = dx$, $A = \pi r^2$ $\Rightarrow dR = \rho \frac{dx}{\pi r^2}$ $\Rightarrow R = \int dR = \int \rho \frac{dx}{\pi r^2}$



$\tan\theta = \frac{b-a}{l}$

Straight line, $y = mx + c$ (slope, intercept)

line equation



variable $\leftarrow r = \left(\frac{b-a}{l}\right)x + a$ $\rightarrow$ differentiate

x: variable

Adda247

$$dr = \left(\frac{b-a}{l}\right)dx + 0 \quad \Rightarrow \left(\frac{l}{b-a}\right)dr = dx$$

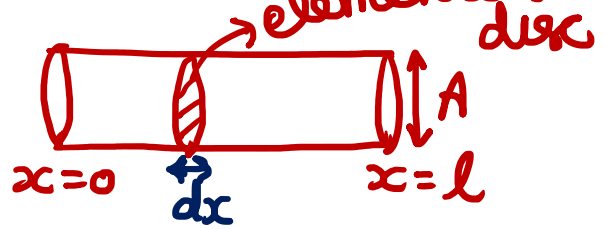
$$R = \int dR = \int \frac{\rho\, dx}{\pi r^2} = \int \rho\left(\frac{l}{b-a}\right)\frac{dr}{\pi r^2} \quad \Rightarrow \quad R = \int_{r=a}^{r=b} \frac{\rho l}{(b-a)}\frac{dr}{\pi r^2} = \frac{\rho l}{(b-a)\pi}\,\frac{(b-a)}{ab}$$

$$\therefore \boxed{R = \frac{\rho l}{\pi ab}}$$

Q18. A cylindrical wire has length l and area of cross-section A. The resistivity of wires changes as $\rho = \rho_0 x$. Find the resistance of wire.

Sol. Resistance of element disc (dR), thickness $= dx$

$l = dx$, Area $= A$ $\Rightarrow dR = \rho\frac{l}{A} = \rho_0\frac{x\,dx}{A}$



(these are infinite elemental discs from $x=0$ to $x=l$) in series (current is same)

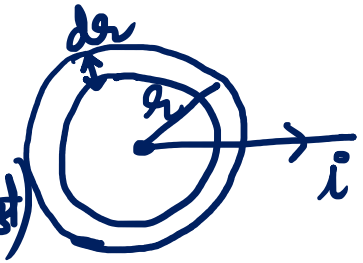
$$R_{net} = R_1 + R_2 + R_3 + \cdots = \int dR = \int_{x=0}^{x=l} \left(\rho_0\frac{x\,dx}{A}\right) = \frac{\rho_0}{A}\int_0^l x\,dx = \frac{\rho_0}{A}\left(\frac{x^2}{2}\right)_0^l$$

$$R = \frac{\rho_0}{A}\left(\frac{l^2}{2} - \frac{0^2}{2}\right) = \frac{\rho_0 l^2}{2A} \quad \Rightarrow \quad \boxed{R = \frac{\rho_0 l^2}{2A}}$$

Q19. Space between two concentric conducting spheres of radii a and b (b>a) is filled with a medium of resistivity ρ. The resistance between the two spheres will be - a) $\frac{\rho}{2\pi}\left(\frac{1}{a}+\frac{1}{b}\right)$ b) $\frac{\rho}{4\pi}\left(\frac{1}{a}-\frac{1}{b}\right)$ c) $\frac{\rho}{2\pi}\left(\frac{1}{a}-\frac{1}{b}\right)$ d) $\frac{\rho}{4\pi}\left(\frac{1}{a}+\frac{1}{b}\right)$

Sol. Elemental shell → small elemental resistance (dR)

$l = dr$, $A = 4\pi r^2$ $\Rightarrow dR = \rho\frac{l}{A} = \rho\left(\frac{dr}{4\pi r^2}\right)$



∴ total resistance of all sphere are in series (current = const)

$R = dR + dR + dR + \dots\dots$

$$= \int_a^b dR = \int_a^b \frac{\rho}{4\pi r^2}\,dr = \frac{\rho}{4\pi}\int_a^b \frac{dr}{r^2} = \frac{\rho}{4\pi}\left[-\frac{1}{r}\right]_a^b$$

$$\Rightarrow R = \frac{\rho}{4\pi}\left[\frac{1}{a}-\frac{1}{b}\right]$$

Adda247

[Effect of Temperature on Resistivity and Resistance]

Effect of Temperature on 'n' (free electron density) and 'τ' (average relaxation time)

On increasing temperature
- → more ionisation of electron
- → number of free electron increase
- → electron density (n) - increase

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

On increasing temperature -
- → internal energy / thermal energy (kinetic energy of electron) - increase
- → Thermal speed of free electron increase.
- → Free electron collides more frequently.
- → Relaxation time (τ) - decrease

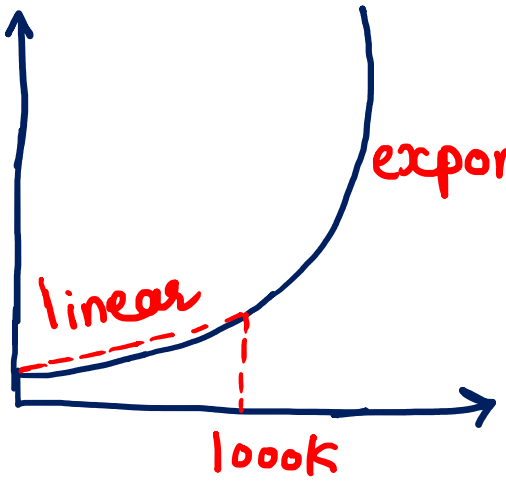
For metallic conductors / Conductors -
- → For metals, the number of free electrons per unit volume (n) is very large, about 10^{28} - 10^{29} per m^3 at room temperature.
- → On increasing temperature, the increase in n is not significant.
- → So, on increasing temperature -

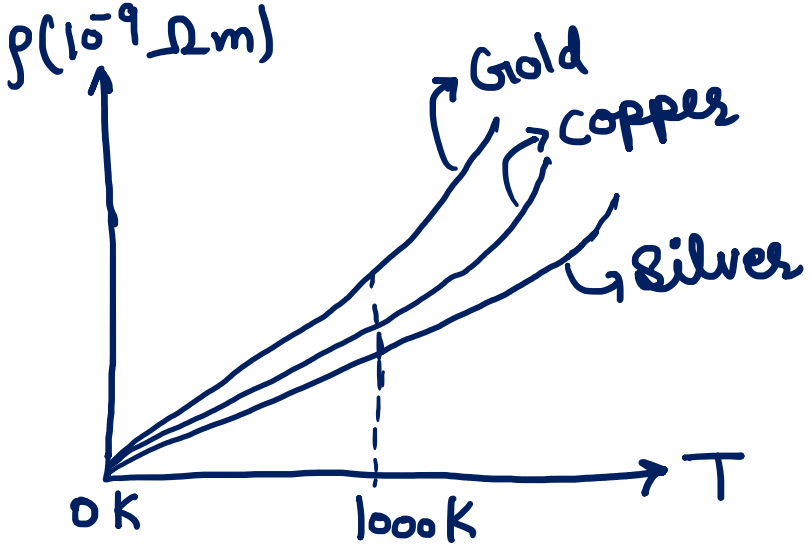
(temp ↑ τ ↓ R ↑ ρ ↑)

n increases (insignificant) and τ decrease (significant)

By - Sonu Kumar

Graph for ρ (or R) with temperature (T) for metallic conductor –





Resistance increase linearly with temp.

For Semi-Conductors and insulators –

→ For semiconductors like Silicon and Germanium (sometimes Carbon) and insulators, the relaxation time τ does not vary (change) so much with temperature.

→ The free electron density (actually charge carriers) depends on temperature as

$$n = n_0 e^{-\frac{E_g}{kT}}$$

E_g – energy gap , k – Boltzman constant

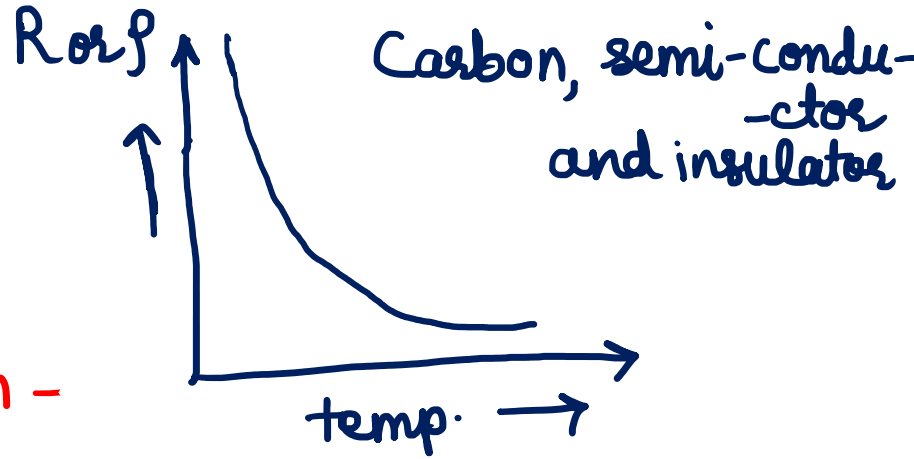
(temp-↑ ⇒ n-↑ ⇒ charge carrier-↑ ⇒ conductivity-↑

∴ temp-↑ ⇒ Resistivity-↓)

By – Sonu Kumar

Graph for ρ (or R) with T → For semiconductors or insulators.

Temp - increase ⇒ n - ↑ ⇒ conductivity - ↑
⇒ resistivity - ↓



Carbon, semi-conductor and insulator

For Alloys like Nichrome, manganin and constantan -

→ On increasing temperature -

n ↑ and T ↓

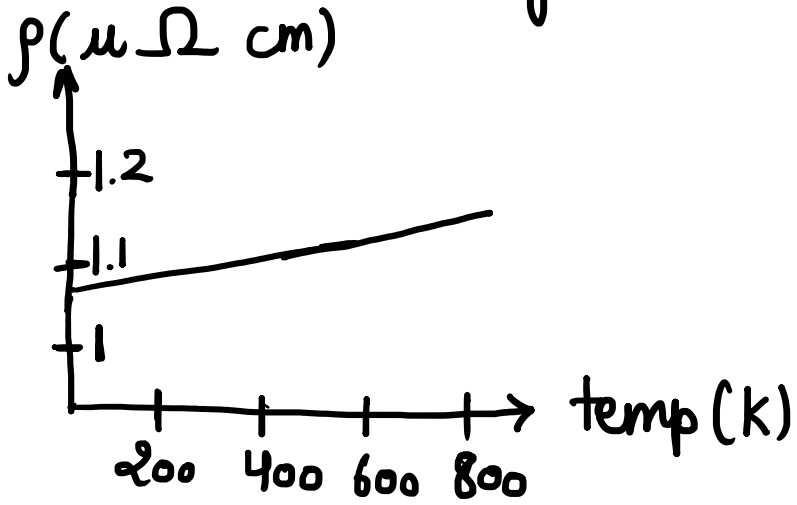
(ionisation of e^- ↑) ⇒ R - ↓ (collisions occur frequently) ⇒ R - ↑

Note – The overall effect is neutralized and there is no significant change in ρ or R i.e. resistance or resistivity is independent of temperature for alloys.

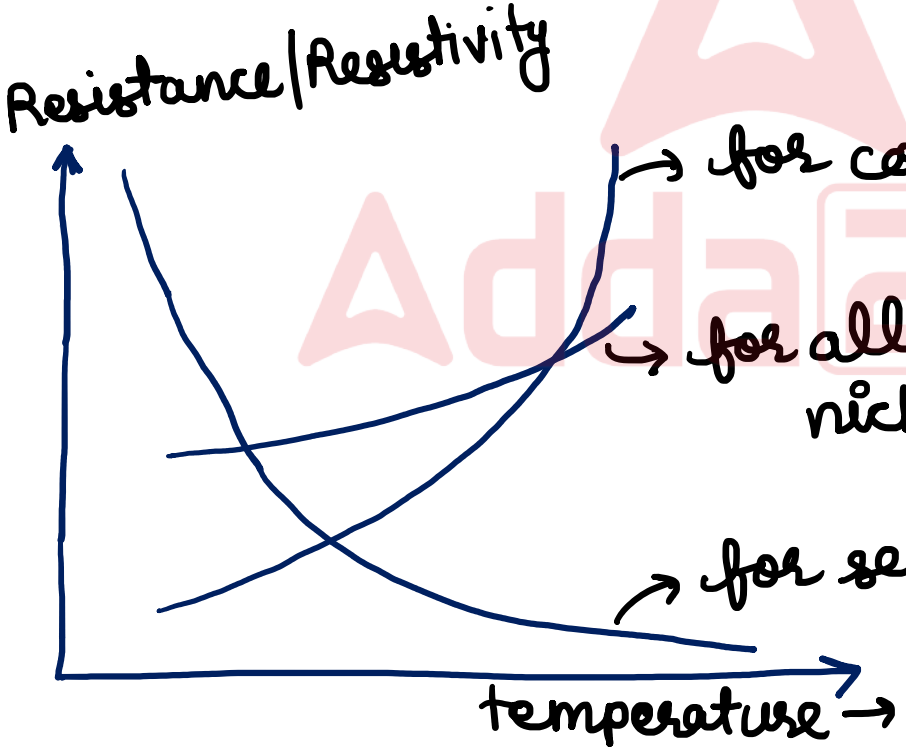
Adda247

Graph for ρ (or R) with T for alloys like nichrome, manganin and constantan

Resistivity is nearly constant with temperature.



Comparison –



→ for conductors

→ for alloys, such as manganin, constantan, nichrome, eureka

→ for semiconductors, carbon, insulators and electrolytes.

Adda247

Temperature Coefficient of resistance (or resistivity) -

For some material, the resistance is R_0 at temperature T.

On increasing temperature, $T \longrightarrow T+dT$

resistance change, $R_0 \longrightarrow R_0+dR$

experimentally, $dR \propto dT$ and $dR \propto R_0$

$\Rightarrow dR \propto R_0 dT \Rightarrow \boxed{dR = \alpha R_0 dT}$

where, α is temperature coefficient of resistance (or resistivity).

Suppose at temp T_i, Resistance is R_0

and at temp T_f, Resistance is R_f $\Rightarrow \int_{R_0}^{R_f} dR = \int_{T_i}^{T_f} \alpha R_0 dT \Rightarrow [R]_{R_0}^{R_f} = \alpha R_0 [T]_{T_i}^{T_f}$

$\Rightarrow R_f - R_0 = \alpha R_0 [T_f - T_i] \Rightarrow R_f = R_0 + \alpha R_0 (T_f - T_i)$ and $T_f - T_i = \Delta t$

$\therefore R_f = R_0 (1+\alpha \Delta T)$ and ΔT is same for °C and Kelvin.

Adda247

Qᴇᴏ. A copper coil has a resistance of 20Ω at 0°C and a resistance of 26.4Ω at 80°C. Find the temperature coefficient of resistance of copper.

a) $2\times10^{-3}\ °C^{-1}$ b) $4\times10^{-3}\ °C^{-1}$ c) $6\times10^{-3}\ °C^{-1}$ d) $8\times10^{-3}\ °C^{-1}$

Sol. $R_f - R_0 = R_0\alpha\Delta t \Rightarrow \alpha = \frac{R_f - R_0}{R_0\Delta t} = \frac{26.4-20}{20\times80} = \frac{6.4}{1600} = 4\times10^{-3}\ °C^{-1}$

Value of 'α' for conductors, semiconductor (& insulators) and Alloys –

Conductors

$R_f = R_0(1+\alpha\Delta t)$

$(\alpha = +ve)$

temp - increase ⇒ Resistance - increase

e.g. -

$\alpha_{copper} = +4\times10^{-3}\ °C^{-1}$

Semiconductors

$R_f = R_0(1+\alpha\Delta t)$

$(\alpha = -ve)$

temp - increase ⇒ Resistance - decrease

e.g. -

$\alpha_{silicon} = -7\times10^{-2}\ °C^{-1}$

Alloys

$R_f = R_0(1+\alpha\Delta t)$

(α = extremely small)

(temp - increase ⇒ R = constant)

e.g. -

$\alpha_{manganin} = 2\times10^{-6}\ °C^{-1}$

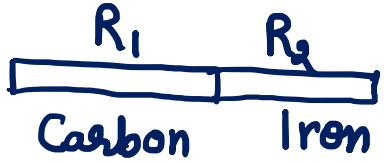
Q21. The resistance of a platinum wire is 5Ω at ice point and 5.5Ω at steam point. When the wire is inserted in a hot bath, resistance of wire is 5.8Ω. Calculate the temperature of bath.

a) 120°C b) 160°C c) 200°C d) 240°C

Sol. $\frac{R_f - R_i}{R_i \Delta t} = \alpha \Rightarrow \frac{5.5 - 5}{5 \times 100} = \frac{5.8 - 5}{5(t-0)} \Rightarrow t = 160°C$

Q22. It is desired to make a 20Ω coil of wire, which has a zero thermal coefficient of resistance. To do this, a carbon resistor of resistance R_1 is placed in series with an iron resistor of resistance R_2. The proportions of iron and carbon are so chosen that $R_1 + R_2 = 20\Omega$ for all temperatures near 20°C. Find the values of R_1 and R_2. ($\alpha_{carbon} = -0.5 \times 10^{-3}\ °C^{-1}$, $\alpha_{iron} = 5 \times 10^{-3}\ °C^{-1}$).

Sol.



$\alpha_{combination} = 0 \Rightarrow R_{combination}$ will not change with temperature.

$R_1 + R_2 = 20\Omega$

$[R_1 + R_2)_{initial} = R_{1(t)} + R_{2(t)}]$

$\therefore 20 = R_1(1+\alpha_1 \Delta t) + R_2(1+\alpha_2 \Delta t) = R_1 + R_2 + R_1\alpha_1 \Delta t + R_2\alpha_2 \Delta t \Rightarrow R_1\alpha_1 \Delta t + R_2\alpha_2 \Delta t = 0$

$\Rightarrow R_1(-0.5 \times 10^{-3}) + R_2(5 \times 10^{-3}) = 0 \Rightarrow \boxed{R_1 = 10R_2} \Rightarrow R_2 = \frac{20}{11}\Omega$

$R_1 = 18.18\Omega$

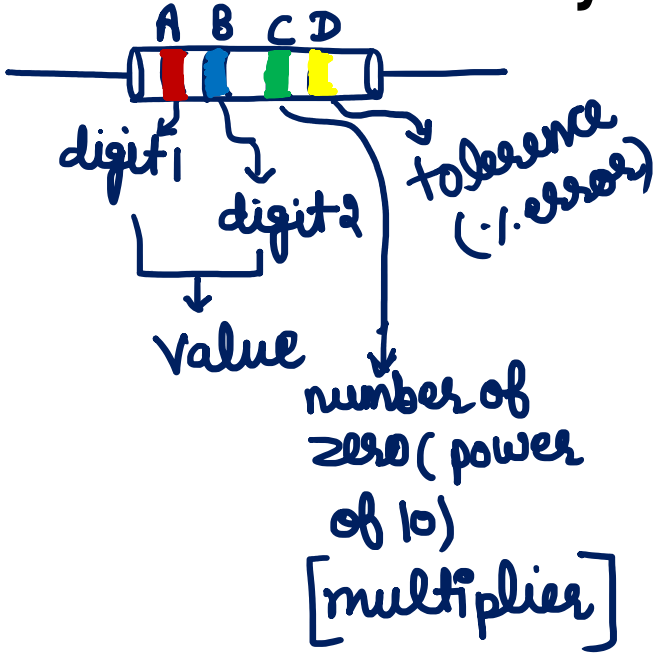
By – Sonu Kumar

KVS PGT PHYSICS

Current Electricity

[Colour Coding of Resistances]

$[R = AB \times 10^{C} \pm D]$

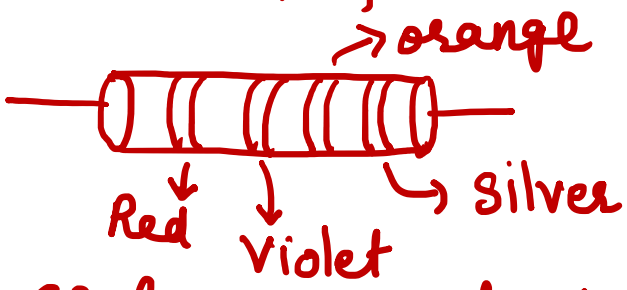


	Colour	Strip A	Strip B	Strip C	Strip D
B	Black	0	0	$\times 10^{0}$	
B	Brown	1	1	$\times 10^{1}$	
R	Red	2	2	$\times 10^{2}$	
O	Orange	3	3	$\times 10^{3}$	
Y	Yellow	4	4	$\times 10^{4}$	
G	Green	5	5	$\times 10^{5}$	
B	Blue	6	6	$\times 10^{6}$	
V	Violet	7	7	$\times 10^{7}$	
G	Grey	8	8	$\times 10^{8}$	
W	White	9	9	$\times 10^{9}$	
G	Gold			$\times 10^{-1}$	± 5
S	Silver			$\times 10^{-2}$	± 10
	None				± 20

Adda247

By – Sonu Kumar

Q23. A resistance is shown in the figure. Its value and tolerance are given respectively by - a) 270 Ω, 5% b) 27 kΩ, 20% c) 27 kΩ, 10%
d) 270 kΩ, 10%.



Sol. $27 \times 10^3 \pm 10\%$

Q24. A 200 Ω resistor has a certain colour code. If one replaces the red colour by Green in the code, the new resistance will be :
a) 100 Ω b) 400 Ω c) 300 Ω d) 500 Ω

Sol. $200\ \Omega = 20 \times 10^1\ \Omega$

Red	Black	Brown	→	Green	Black	Brown

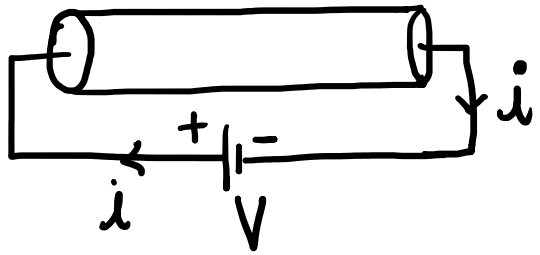
$50 \times 10^1 = 500\ \Omega$

Why colour coding is done, Why not directly writes values on Resistance?

→ Colour coding is done as the resistors are too small to print value of resistance. Moreover even after mounting resistors, colour bands are visible from any side as it is printed across the circumference.

[Ohm's Law]

→ The electric current in any conductor is directly proportional to the potential difference across the ends of the conductor provide temperature, pressure and all other physical conditions remain constant.



$$i \propto \Delta V$$

→ It is not a universal law.

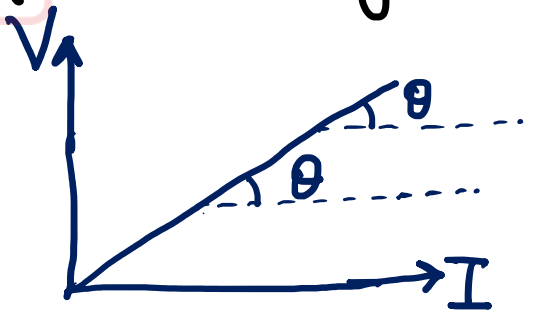
→ $\Delta V \propto i \Rightarrow \Delta V = iR$ where, R → constant at given temp, pressure.

$$R = \frac{\Delta V}{i}$$

Graph of ΔV v/s I or i for Ohmic Conductor (which obey Ohm's Law) -

$\Delta V \propto i \Rightarrow$ Slope $= \tan\theta = \frac{\Delta y}{\Delta x} = \frac{\Delta V}{\Delta I}$

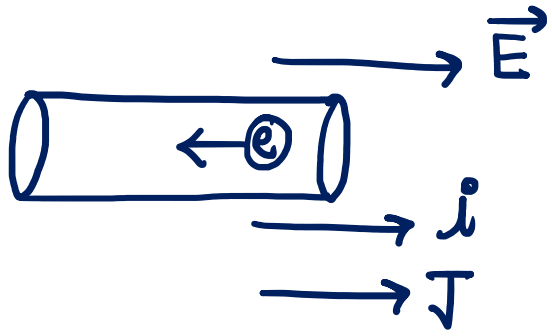
$$\therefore \frac{\Delta V}{\Delta I} = R$$



By - Sonu Kumar

[Ohm's Law in Vector Form]

$V \propto i$ or $V = iR$



$$V = iR = i\rho\frac{l}{A} \Rightarrow \frac{V}{l} = \rho\frac{i}{A}$$

$$\Rightarrow \boxed{\vec{E} = \rho\vec{J}}$$

$\vec{J}$ → current density

$\vec{E}$ → electric field

ρ → resistivity

$$\text{Conductivity}(k) = \frac{1}{\text{Resistivity}(\rho)}$$

$$\Rightarrow \vec{J} = k\vec{E}$$

→ unit of conductivity - $\text{Ohm}^{-1}\,m^{-1}$.

Validity and Failure of Ohm's Law –

a) Ohm's law is not a fundamental law of nature i.e. it is not a universal law that applies to all conductors under all conditions.

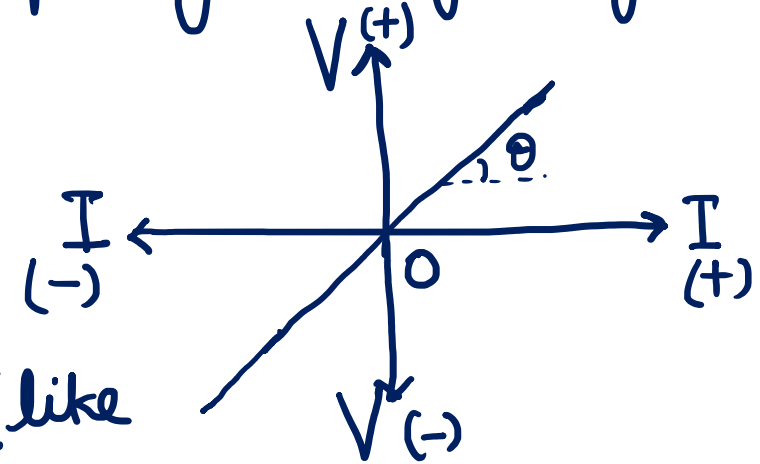
b) The conductor which obey Ohm's law are called Ohmic conductors and the conductor which do not obey Ohm's law are called non-ohmic conductors.

Adda247

Ohmic Conductors–

→ Obeys Ohm's law, $\Delta V \propto i$

→ The graph for ΔV v/s i is a straight line passing through origin as shown.



→ Resistance (R) is independent of current (i)

$$R = \frac{\Delta V}{I} = \tan\theta = \text{Slope} = \text{constant}$$

→ Practical example are – Metallic conductor (like copper, silver) for small current, Copper sulphate solution with copper electrodes.

Non-Ohmic Conductors – Do not obey Ohm's law.

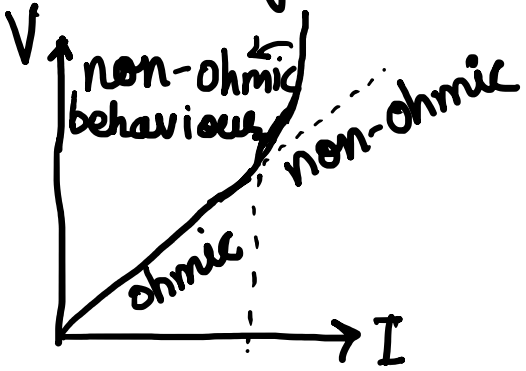
→ ΔV v/s i graph is not a straight line.

→ Resistance R is not constant and depends on current i.

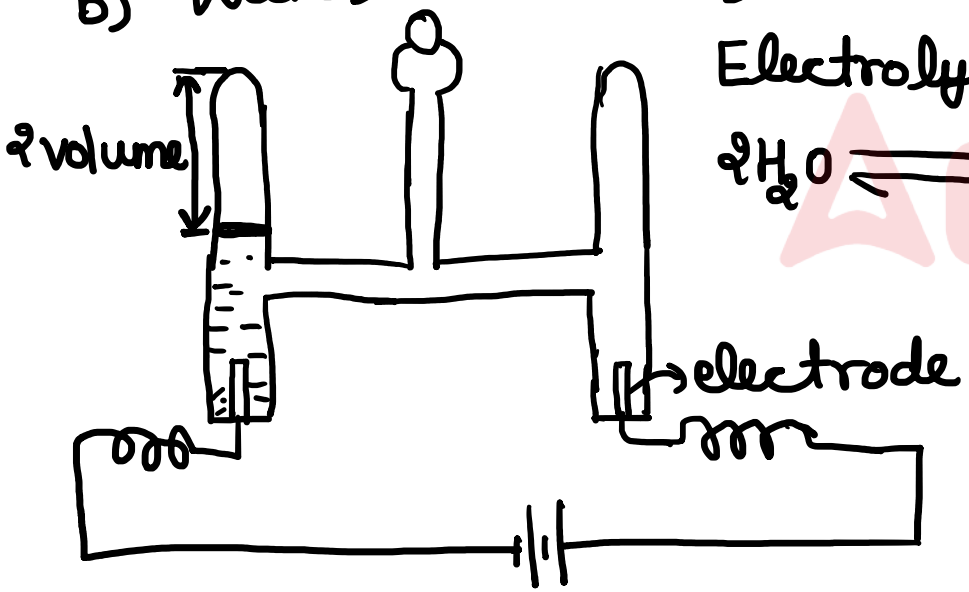
→ Example – a) Metallic conductor at high currents
b) Water Voltameter
c) p-n junction diode
d) Thyristor

By – Sonu Kumar

a) Metallic conductor at high currents

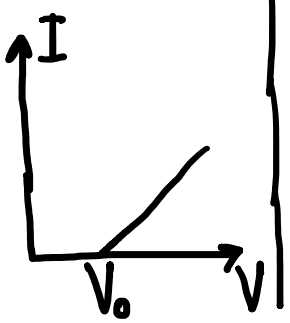


b) Water Voltameter –

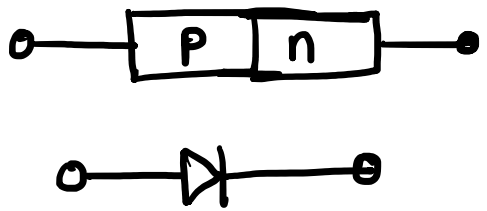


Electrolysis of Water

$$2H_2O \rightleftharpoons 2H_2 + O_2$$

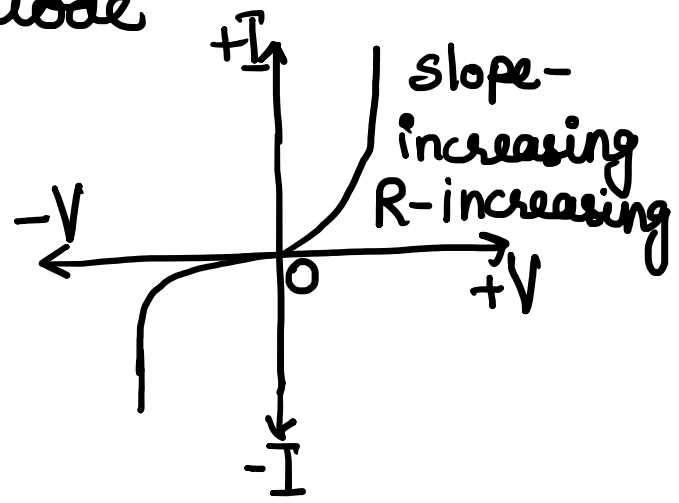


c) p-n junction diode –

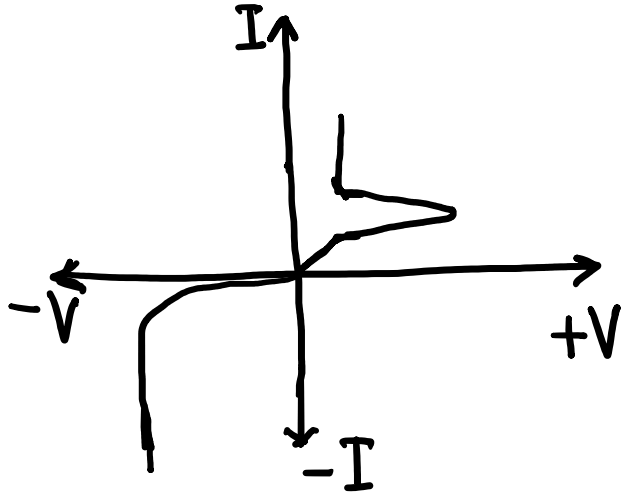


semiconductor

$$R = \frac{\Delta V}{\Delta I} = \frac{dV}{di}$$



d) Thyristor



By – Sonu Kumar

KVS PGT PHYSICS

Current Electricity

By – Sonu Kumar