Current Electricity :-

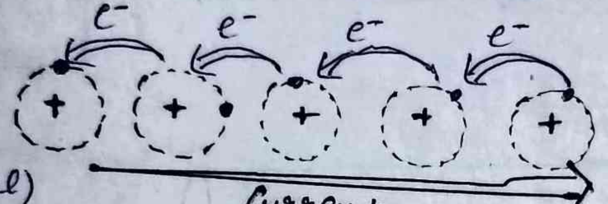
∵ (Rate of flow of electric charge across a cross-section of conductor)

∵ $\boxed{i = \frac{\Delta q}{\Delta t}}$ → Scaler Quantity → Ampere(A)

direction of Current

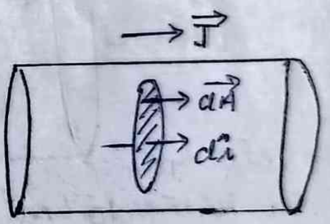
> direction of current is opposite to motion of e^- and moves in the direction of motion of positive charge

#



> Current density :- ($\vec{J}$)

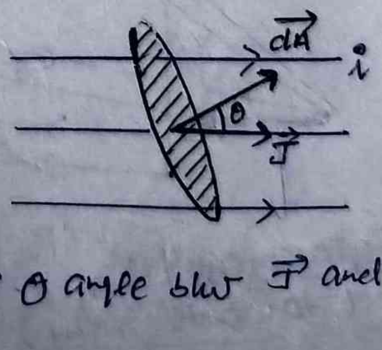
(Current per unit area)



∵ $\boxed{J = \frac{di}{dA}}$

∵ Its direction is along the current which passes through that point!

Current density is equal to current / area taken ⊥ to direction of current!



$$J = \frac{di}{(dA\cos\theta)}$$

$$di = J\,dA\cos\theta$$

$$di = \vec{J}\cdot\vec{dA}$$

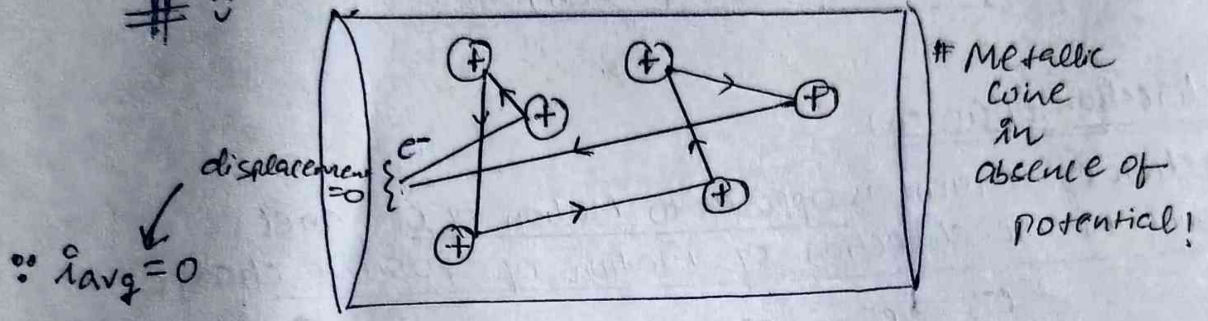
∵ θ angle b/w $\vec{J}$ and $\vec{dA}$

∵ $\boxed{i = \int \vec{J}\cdot\vec{dA}}$

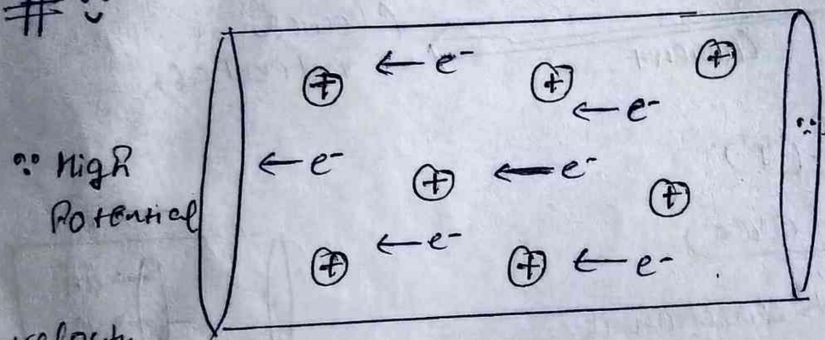
> Drift speed :-

∵ The free e^- collide with fixed +ve ion and follow zigzag path so no net flow charge in any direction!

∵

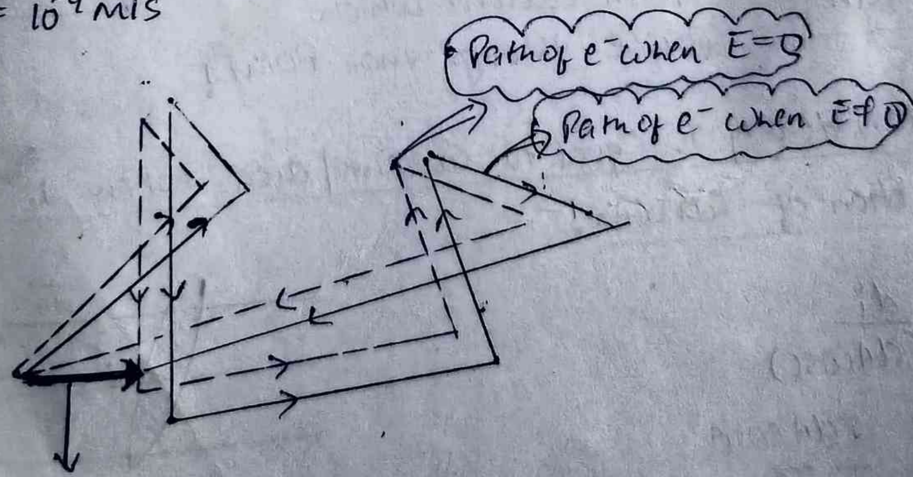


∵



drift velocity of the rate = 10^{-4} m/s

∵



∵ displacement ≠ 0
(drifted towards right)

$F = qE$

$F = eE$ —(1)

and

$ma = eE$

$a = \frac{eE}{m}$ —(2)

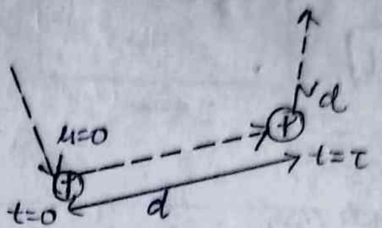
$\vec{a} = \frac{(-e)\vec{E}}{m}$

and

$v = u + at$

$v_d = (0) + at$

$\because$ $\boxed{v_d = \frac{eE(\tau)}{m}}$



$v_d = \frac{d}{\tau}$

$\because$ τ = relaxation time (Time take b/w two successive collision)

$\because$ d = Avg distance b/w two successive collision

"Material Specific"

If d↓↓ then $\tau \downarrow d$ and v_d decrease!

>Reln B/w I and v_d :-

length of conductor = l

free e-/unit volume = n

volume of conductor = Al

Now;

$n = \frac{N}{Al}$ (N = total free e-)

$N = nAl$

$\Delta q = N(e) = nAle$

$\Delta q = nAe(l)$ —(1)

and $v_d = \frac{l}{\Delta t}$ —(2)

from eq 1 and 2;

$\Delta q = nAe(v_d \Delta t)$

$\because$ $i_{avg} = \frac{\Delta q}{\Delta t} = nAev_d$

and

$$J = \frac{i}{A} = \frac{neAv_d}{A} = nev_d$$

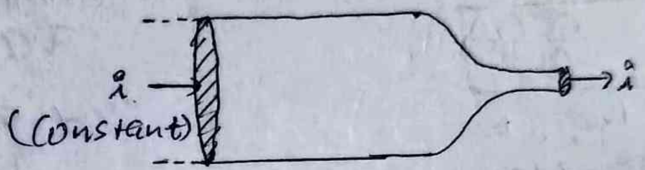
$$J = nev_d$$

$\therefore$ $\boxed{J = nev_d}$

for a Conductor;

Current does not change with change in Cross-Section Area!

$\therefore$ $\boxed{i_{in} = i_{out}}$



while, $\vec{E}$, J, v_d donot remain constant

> OHM'S LAW :-

Mobility :- drift speed per unit $\vec{E}$; $\boxed{\mu = \frac{v_d}{E}}$

> deriving OHM'S LAW :-

$J = nev_d$ and $v_d = \frac{eE\tau}{m}$

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

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

$\therefore$ $\boxed{J = \sigma E}$; σ = conductivity (depends on Material)

#

$\therefore$ $\sigma = \frac{1}{\rho} = \frac{ne^2\tau}{m}$; σ :- Conductivity, ρ :- Resistivity

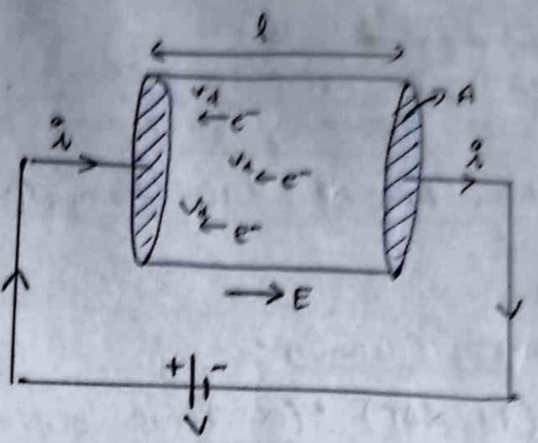
?? $\boxed{J=\sigma E} \rightarrow \boxed{V=iR}$

$J = \frac{i}{A} = \sigma E$

$\Rightarrow \frac{i}{A} = \sigma\left(\frac{V}{l}\right)$

$V = i\left(\frac{l}{\sigma A}\right)$

$V = i\left(\frac{\rho l}{A}\right) \quad \because \rho = \frac{1}{\sigma}$



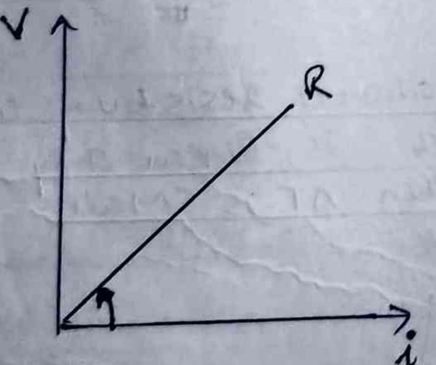
$\therefore \boxed{V = iR \text{ where } R = \frac{\rho l}{A}}$

> Conductance :- (G)

(Reciprocal of resistance)

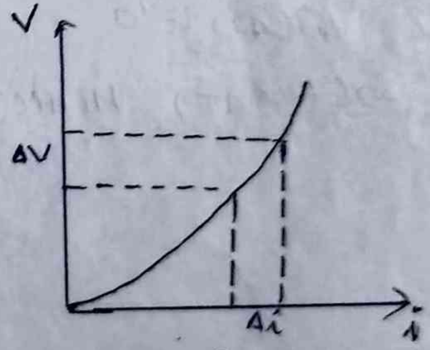
$G = \frac{1}{R} = \frac{A}{\rho l}$

$\therefore \boxed{G = \frac{A}{\rho L}}$



$\therefore$ Ohmic Conductor

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



$\therefore$ Non-ohmic Conductor

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

Effect of Temperature :-

(As temp ↑, it increase thermal agitation due to which rate of collision increase, the relaxation time ↓ ; resistivity ↑ & resistance ↑ also

Variation of ρ with T :-

$\rho = \rho_0(1 + \alpha \Delta T)$; (α = Temp. Coefficient of resistivity)

Variation of R with T :-

∴ Considering dimension to be invariant

($\Delta T \rightarrow$ small)

$R = R_0(1 + \alpha \Delta T)$; (R = resistance of conductor)

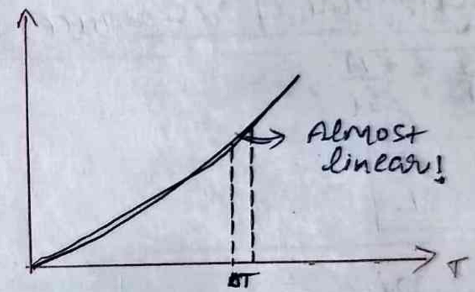
$\boxed{\rho = \rho_0(1 + \alpha \Delta T + \beta(\Delta T)^2)}$

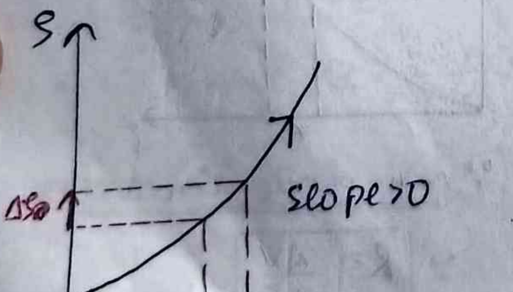
$\Rightarrow$ for $(\Delta T)^2 <<< \Delta T$

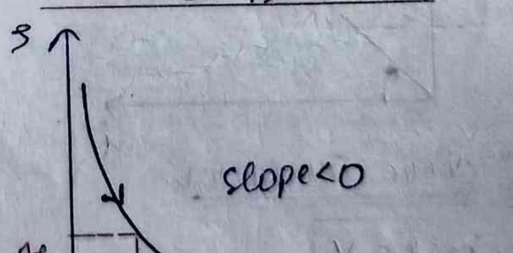
$\Rightarrow$ so; $\beta(\Delta T)^2 <<< \alpha \Delta T$

$\Rightarrow \beta(\Delta T)^2 \simeq 0$

$\Rightarrow \rho = \rho_0(1 + \alpha \Delta T)$ Hence; Variation of resistivity with temp is linear only when ΔT is small







Metals

$\rho = \rho_0(1 + \alpha \Delta T)$

$\alpha = \frac{\rho - \rho_0}{\rho_0 \Delta T} = \frac{1}{\rho_0}\left(\frac{\Delta \rho}{\Delta T}\right)$

$\alpha = \frac{1}{\rho_0}(\tan\theta) \Rightarrow \boxed{\alpha > 0}$

N-Metals

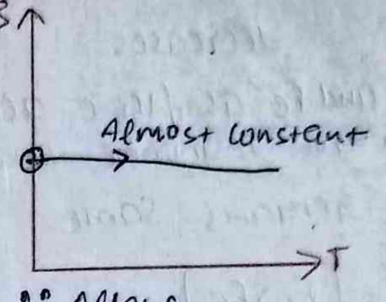
$\alpha = \frac{1}{\rho_0}(\tan\theta)$

$\boxed{\alpha < 0}$

for semi conductors;
Conductivity decreases with decrease in Temp
or Resistivity decrease with Temp.(↑)

∴ Temp.(↑) → holes (↑) → σ(↑) → ρ(↓) .∵

for Alloys; ρ always remains Constant with Temperature
(V-very low Temp. coefficient)

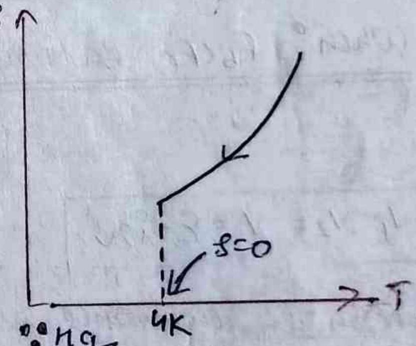


∴ Alloys

> Series Combination :-

∴ $\boxed{R_q = R_1 + R_2 + R_3 - - - -}$

Superconductor (offer zero resistance at Critical Temperature



∴ Hg

> Parallel Combination :-

∴ $\boxed{\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$

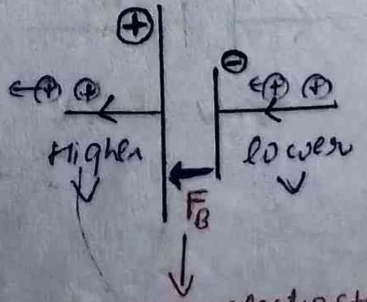
> Concept of Battery :-

(Internal force due to Battery mechanism makes charge inside the Battery move)

∴ in steady state;

$F_B = F_E = qE$

(e is in equilibrium)



∴ Non-electrostatic force due to chemical reaction

$W_{Battery} \Rightarrow F_B \times d \Rightarrow (qE)d \Rightarrow q(Ed)$

$\boxed{\therefore W_{Battery} = qV}$

EMF :- ($\mathcal{E}$) → potential diff b/w its terminal when not connected externally.

(work done by the Battery per unit charge

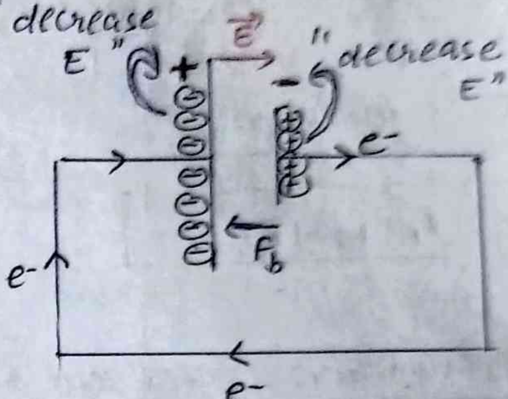
$$\mathcal{E} = \frac{W_{Battery}}{q} = \frac{qV}{q} = V$$

$\therefore \boxed{\mathcal{E} = V}$

E and F_e decreases as free e⁻ accumulate on +ve terminal however; F_b remains same.

so; $\boxed{F_b > F_e}$

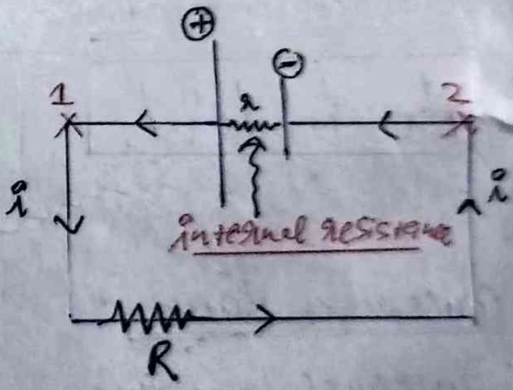
Battery drives -ve charge from +ve to -ve terminal



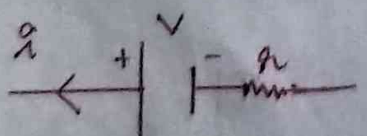
when; $F_b < F_e$ Battery stops working

$\therefore \boxed{V_1 - V_2 = V = \mathcal{E} - ir}$

internal resistance is resistance offered by conductor inside Battery!



(I)



$\therefore V = \mathcal{E} - ir$

(II)

$\therefore V = \mathcal{E} + iR$

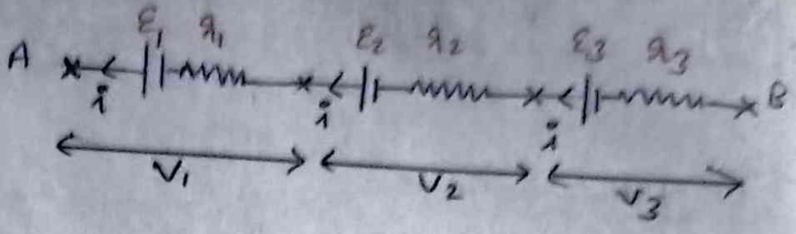
> Cells in series :-

$V_1 = \mathcal{E}_1 - i r_1$ — (1)

$V_2 = \mathcal{E}_2 - i r_2$ — (2)

$V_3 = \mathcal{E}_3 - i r_3$ — (3)

$V_{AB} = \mathcal{E}_{eq} - i r_{eq}$ — (4)



In series ;

$V_{AB} = V_1 + V_2 + V_3$

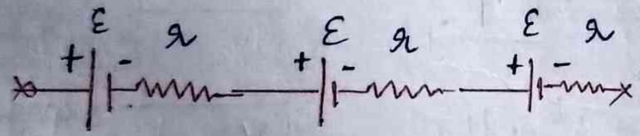
$\mathcal{E}_{eq} - i r_{eq} = (\mathcal{E}_1 - i r_1) + (\mathcal{E}_2 - i r_2) + (\mathcal{E}_3 - i r_3)$

$\mathcal{E}_{eq} - i r_{eq} = (\mathcal{E}_1 + \mathcal{E}_2 + \mathcal{E}_3) - i(r_1 + r_2 + r_3)$

By Comparing ;

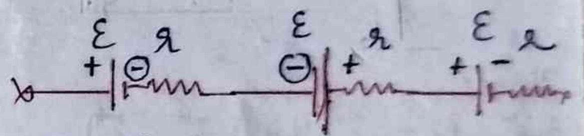
$\boxed{\mathcal{E}_{eq} = \mathcal{E}_1 + \mathcal{E}_2 + \mathcal{E}_3}$ $\boxed{r_{eq} = r_1 + r_2 + r_3}$

#



> $\mathcal{E}_{eq}$:- $(\mathcal{E} + \mathcal{E} + \mathcal{E}) = 3\mathcal{E}$

> r_{eq} :- $(r + r + r) = 3r$



> $\mathcal{E}_{eq} = (\mathcal{E} - \mathcal{E} + \mathcal{E}) = \mathcal{E}$

> r_{Eq} :- $(r + r + r) = 3r$.

> Cells in Parallel :-

$V = \mathcal{E}_1 - i_1 r_1 \Rightarrow i_1 = \left(\frac{\mathcal{E}_1}{r_1} - \frac{V}{r_1}\right)$ — (1)

$V = \mathcal{E}_2 - i_2 r_3 \Rightarrow i_2 = \left(\frac{\mathcal{E}_2}{r_2} - \frac{V}{r_2}\right)$ — (2)

$V = \mathcal{E}_3 - i_3 r_3 \Rightarrow i_3 = \left(\frac{\mathcal{E}_3}{r_3} - \frac{V}{r_3}\right)$ — (3)

$V = \mathcal{E}_{eq} - i r_{eq} \Rightarrow i = \left(\frac{\mathcal{E}_{eq}}{r_{eq}} - \frac{V}{r_{eq}}\right)$ — (4)

$i = i_1 + i_2 + i_3$

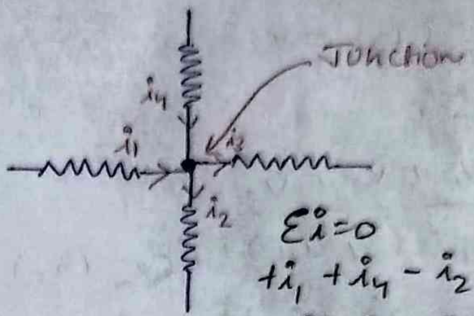
$$\frac{\mathcal{E}_{eq}}{r_{eq}} - \frac{V}{r_{eq}} = \left(\frac{\mathcal{E}_1}{r_1} + \frac{\mathcal{E}_2}{r_2} + \frac{\mathcal{E}_3}{r_3}\right) - V\left(\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}\right)$$

$$\boxed{\frac{\mathcal{E}_{eq}}{r_{eq}} = \frac{\mathcal{E}_1}{r_1} + \frac{\mathcal{E}_2}{r_2} + \frac{\mathcal{E}_3}{r_3}} \qquad \boxed{\frac{1}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}}$$

> **The Junction law:-**

"Sum of current entering at junction = Sum of current leaving it"

$\therefore$ $\boxed{i_1 + i_4 = i_2 + i_3}$



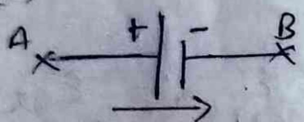
$\Sigma i = 0$

$+i_1 + i_4 - i_2 - i_3 = 0$

$\therefore$ $i_1 + i_4 = i_2 + i_3$

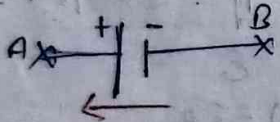
> **Sign Convention:-**

(I)



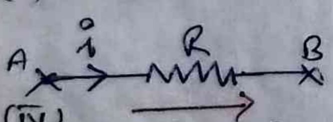
$\boxed{V = +\mathcal{E}}$

(II)



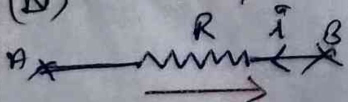
$\boxed{V = -\mathcal{E}}$

(III)



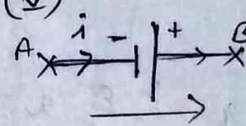
$\boxed{V = +iR}$

(IV)



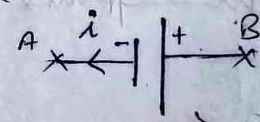
$\boxed{V = -iR}$

(V)



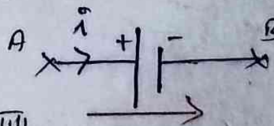
$\boxed{V = -\mathcal{E}}$ discharging phase!

(VI)



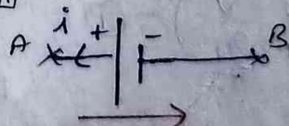
$\boxed{V = -\mathcal{E}}$ charging phase!

(VII)



$\boxed{V = +\mathcal{E}}$

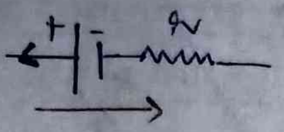
(VIII)



$\boxed{V = +\mathcal{E}}$

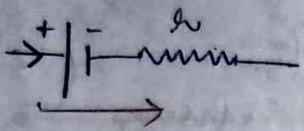
direction of current does not matter in finding potential drop

(IX)



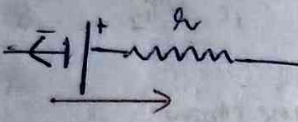
$\boxed{V = +\varepsilon - ir}$

(X)



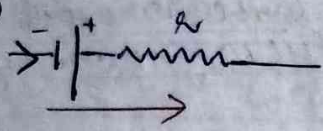
$\boxed{V = +\varepsilon + ir}$

(XI)



$\boxed{V = -\varepsilon - ir}$

(XII)

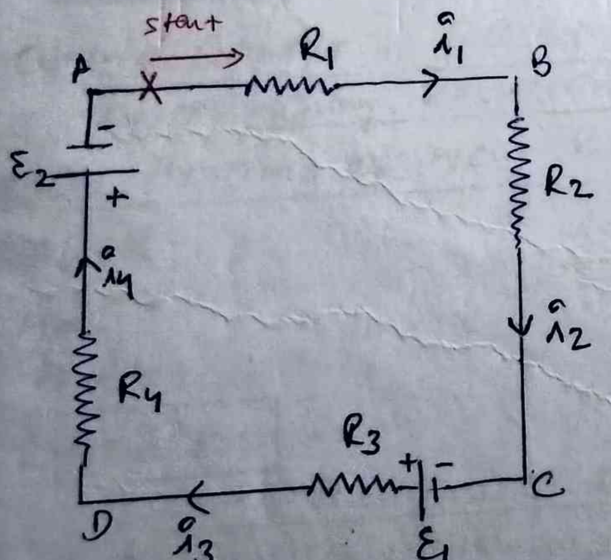


$\boxed{V = -\varepsilon + ir}$

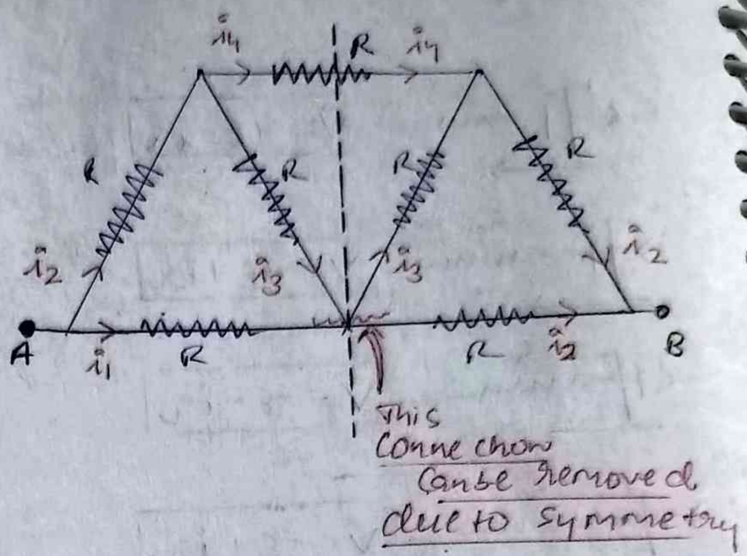
> The loop or voltage law :- (KVL)

The algebric sum of all potential diff along closed loop in a circuit is zero

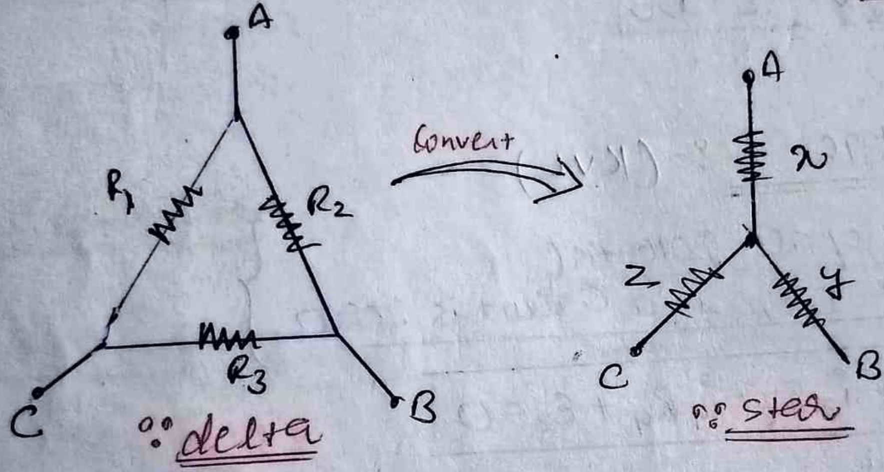
$$\boxed{+i_1R_1 + i_2R_2 - \varepsilon_1 + i_3R_3 - i_4R_4 + \varepsilon_2 = 0}$$



> Methods of Symmetry :-



> Delta to star :-



∴ $\boxed{x = \dfrac{R_1 R_2}{(R_1+R_2+R_3)}}$

∴ $\boxed{y = \dfrac{R_2 R_3}{(R_1+R_2+R_3)}}$

∴ $\boxed{z = \dfrac{R_1 R_3}{(R_1+R_2+R_3)}}$

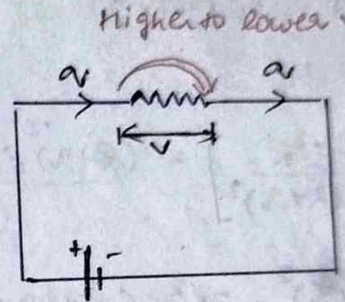
∴ Heating effect of current :- (Electrical E → Heat E)

> The energy liberated / second :- Power
(work done in a Battery / unit time)

$$P = \frac{dW}{dt} = \frac{dq(\Delta V)}{dt} = \left(\frac{dq}{dt}\right)\Delta V = iV$$

∴ $\boxed{P = Vi}$

#



Electrical Pot. E lost in a device;

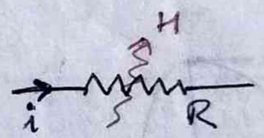
$dU = (dq)V = (i\,dt)(iR) = i^2R\,dt$

$dU = i^2R\,dt$

$\int dU = i^2R\int dt$

∴ $\boxed{U = i^2Rt}$

> Joule's law of electrical heating :-



When a current is passed through a device having Resistance R, then Amount of heat produced;

$H \propto R$

$H \propto i^2$

$H \propto t$

∴ $\boxed{H = i^2Rt}$

#

1 KWh = 3.6×10^6 J = 1 unit

1 BTU = 1055 J

(British Thermal Unit)

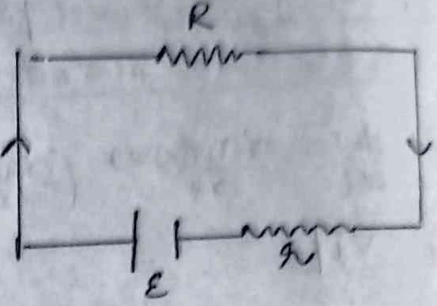
#

Power → Series $\boxed{\frac{P_1P_2}{(P_1+P_2)}}$

Power → Parallel $\boxed{(P_1+P_2)}$

> Max. Power Transfer theorem :-

Current delivered By Battery : $i = \frac{\varepsilon}{r+R}$



Power dissipated across R : $i^2R = \frac{\varepsilon^2 R}{(r+R)^2}$

for P to be max :

$\frac{dP}{dR} = 0$

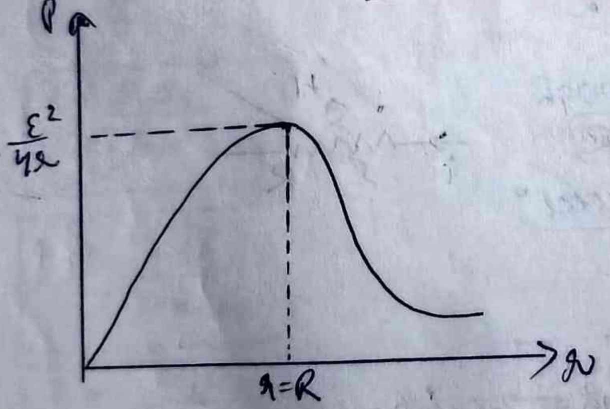
$$\frac{d}{dR}\left[\frac{\varepsilon^2 R}{(R+r)^2}\right] = \frac{(R+r)^2\varepsilon^2 - \varepsilon^2 R[2(R+r)]}{(R+r)^4} = 0$$

$$\varepsilon^2(R+r)^2 - 2\varepsilon^2 R(R+r) = 0$$

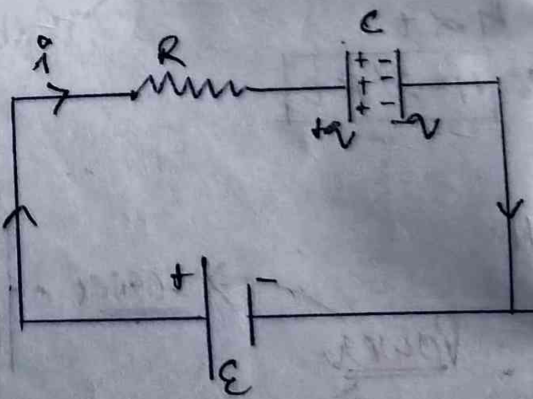
$$\varepsilon^2(R+r)[R+r-2R] = 0$$

$$R - r = 0 \Rightarrow \therefore \boxed{R = r}$$

(ext resistor = int resistor of Battery)



> RC- charging Circuit :-



equation of loop :

$$+iR + \frac{q}{C} - \varepsilon = 0$$

$$iR = \frac{C\varepsilon - q}{C}$$

$$\frac{dq}{dt} = \frac{C\varepsilon - q}{RC}$$

$$\frac{dq}{\mathcal{E}C-q} = \frac{dt}{RC}$$

$$\int \frac{1}{(\mathcal{E}C-q)}\,dq = \int \frac{1}{RC}\,dt$$

$$\left[-\ln(\mathcal{E}C-q)\right]_0^q = \left[\frac{t}{RC}\right]_0^t$$

$$\ln(\mathcal{E}C-q) - \ln(\mathcal{E}C) = \frac{-t}{RC}$$

$$\ln\left(\frac{\mathcal{E}C-q}{\mathcal{E}C}\right) = \frac{-t}{RC}$$

$$\frac{\mathcal{E}C-q}{\mathcal{E}C} = e^{-t/RC}$$

$$1-\frac{q}{\mathcal{E}C} = e^{\frac{-t}{RC}}$$

$$\therefore \boxed{q = \mathcal{E}C\left(1-e^{\frac{-t}{RC}}\right)}$$

$$i = \frac{dq}{dt} = \frac{d}{dt}\left[\mathcal{E}C\left(1-e^{\frac{-t}{RC}}\right)\right]$$

$$i = +\frac{\mathcal{E}C}{RC}\, e^{\frac{-t}{RC}}$$

$$\therefore \boxed{i = \frac{\mathcal{E}}{R}\, e^{\frac{-t}{\boxed{RC}}}}$$

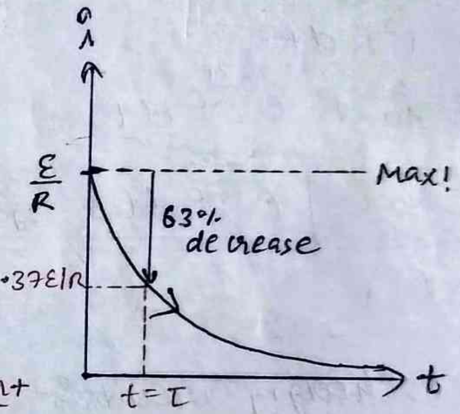
Time constant

$\tau = RC$

at i, $t=\tau$

$$i = \frac{\mathcal{E}}{R}\left(\frac{1}{e}\right) = .37\frac{\mathcal{E}}{R}$$

$$\boxed{i = .37\mathcal{E}/R}$$



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$V_{resistan.} = iR$

$$\Rightarrow \frac{\mathcal{E}}{R}e^{\frac{-t}{RC}} \times R = \mathcal{E}e^{\frac{-t}{RC}}$$

$$\boxed{V_R = \mathcal{E}e^{-t/RC}}$$

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$$V_{capacitance} = \frac{q}{C} = \frac{\mathcal{E}C\left(1-e^{\frac{-t}{RC}}\right)}{C}$$

$$\Rightarrow \mathcal{E}\left(1-e^{-t/RC}\right)$$

$$\boxed{V_C = \mathcal{E}\left(1-e^{\frac{-t}{RC}}\right)}$$

$$\therefore \underline{V_C + V_R = \mathcal{E}}$$

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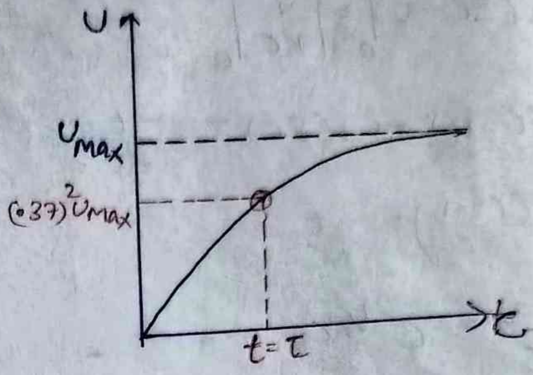
Energy stored in Capacitor :-

$$U = \frac{q^2}{2C} = \frac{\varepsilon^2 C^2 (1-e^{-t/RC})^2}{2C} = \frac{1}{2}\varepsilon^2 C (1-e^{-\frac{t}{RC}})^2$$

$$\therefore \boxed{U_C = \frac{1}{2}C\varepsilon^2(1-e^{-t/RC})^2}$$



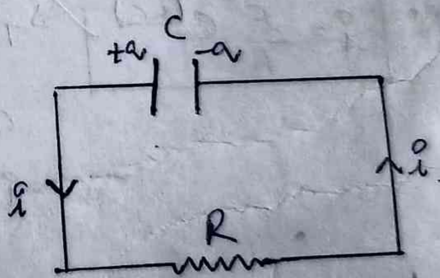
> Energy lost as heat :-

$dH = i^2 R\, dt$

$dH = i_0^2 R\, e^{-\frac{2t}{RC}} dt$

$$H = i_0^2 R \int e^{-\frac{2t}{RC}} dt = \left(\frac{\varepsilon}{R}\right)^2 R \left[\frac{e^{-\frac{2t}{RC}}}{\frac{-2}{RC}}\right]_0^\infty = \boxed{\frac{1}{2}C\varepsilon^2}$$

> R-C discharging Circuits :-



$+iR - \frac{q}{C} = 0$

$\Rightarrow iR = \frac{q}{C}$

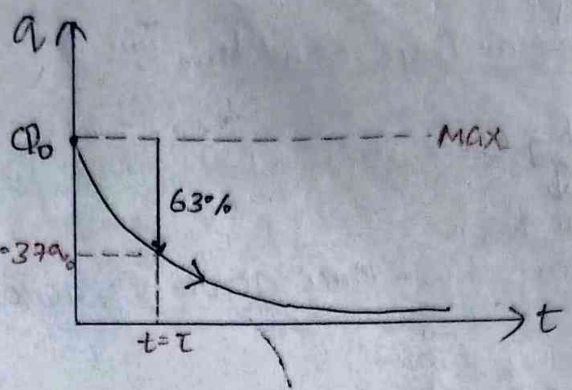
$\Rightarrow \left(-\frac{dq}{dt}\right) = \frac{q}{RC}$

Since the Cap. is discharging so; q (↓) with time then; $\frac{dq}{dt} < 0$

$\Rightarrow \frac{dq}{q} = \frac{-dt}{RC}$

$$\int_{q_0}^{q} \frac{dq}{q} = -\int_0^t \frac{dt}{RC}$$

$$\ln\left(\frac{q}{q_0}\right) = \frac{-t}{RC}$$



$\therefore \boxed{q = q_0 e^{-t/RC}}$

at $t = \tau$

$q = \cdot 37 q_0$ — (1)

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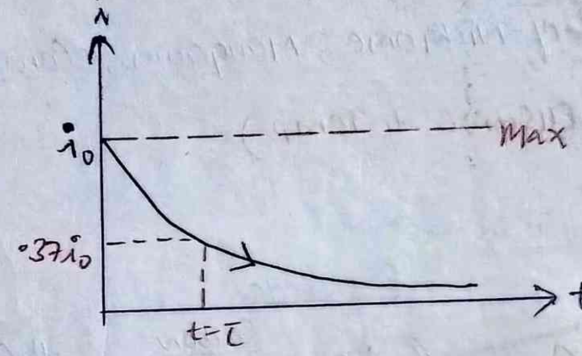
$q = q_0 e^{-t/RC}$

$i = -\frac{dq}{dt}$

$\Rightarrow -\frac{d}{dt}\left(q_0 e^{-t/RC}\right)$



$\boxed{i \Rightarrow \frac{q_0}{RC} e^{-t/RC}}$

$\boxed{V_C = \frac{q}{C} = \frac{q_0}{C} e^{-t/RC}}$ $\boxed{V_R = iR = (i_0 R) e^{-t/RC} = \frac{q_0}{C} e^{-t/RC}}$

$\therefore \boxed{V_C = V_R}$

energy stored in Cap (U) $= \frac{q^2}{2C} = \frac{q_0^2 e^{-2t/RC}}{2C}$; at $t=0$ $\boxed{U = \frac{q_0^2}{2C}}$

The stored energy is lost as heat completely.

Energy lost as heat (dH):-

$dH = i^2 R\, dt$

$= i_0^2 R e^{-2t/RC} dt$

$$H = i_0^2 R \int_0^\infty e^{-2t/RC} dt = \frac{i_0^2 R}{2/RC}\left(e^{-\infty} - (-e^0)\right) = \boxed{\frac{q_0^2}{2C}}$$

Equivalent Time Constant :-

$\tau = \underbrace{R_{eq}}_{\downarrow} C$

where R_{eq} is equivalent Resistance across Capacitor!

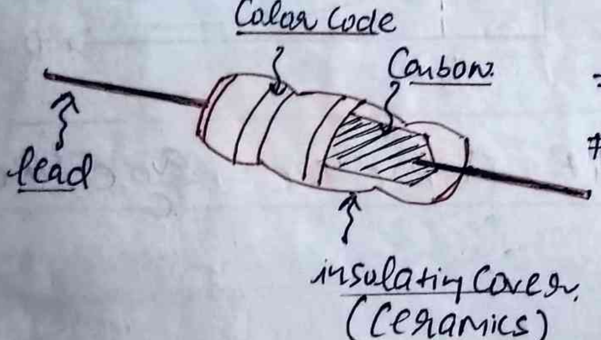
TYPE OF RESISTORS :-

(i) Wired resistors :-

(Made of Nichrome, Manganin, Constantan)

(less sensitive to Temp.)

(ii) Carbon resistors :-



Compact (Tiny)

inexpensive

Color Codes :-

	Number	Multiplier
Black	0	10^0
Brown	1	10^1
Red	2	10^2
orange	3.	10^3
Yellow	4	10^4
Green	5	10^5
Blue	6	10^6
violet	7	10^7
Gray	8	10^8
white	9	10^9

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B B ROY OF GREAT BRITAIN HAD A VERY GOOD WIFE WHO WORE GOLD AND SILVER NECKLACE

> Tolerance:-

	No.	Multiplier	Tolerance
Gold	–	10^{-1}	5%
Silver	–	10^{-2}	10%
No colour	–	–	20%