Current Electricity

→ Rate of flow of charges through any cross sectional area is current

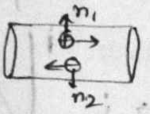
It is a scalar quantity. SI = Ampere (A).

→ $I_{avg} = \frac{\Delta Q}{\Delta t}$, $I_{instant} = \lim_{\Delta t \to 0} \frac{\Delta Q}{\Delta t} = \frac{dQ}{dt}$

→ Translation charge carriers $i = q/t = ne/t$

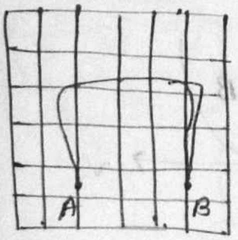
Rotational " " $i = \frac{q\omega}{2\pi} = \frac{vq}{2\pi r}$ $(v = r\omega)$

→ +ve charge direction is conventional current direction

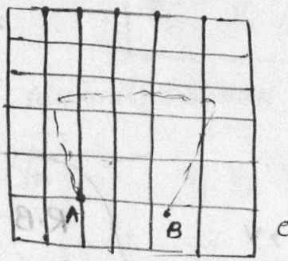


$I = (n_1 + n_2) e/t$

→ **Drift velocity**: avg velocity of a free e^- in conductor get drifted under the influence of external e^- field.



absence of e^- field



presence of e^- field

$$\frac{\vec{u_1} + \vec{u_2} + \cdots + \vec{u_n}}{n} = 0$$

$$a = \frac{-eE}{m}$$

e^- move in curved path from lower to higher potential

Relaxation time (τ): Avg. time b/w 2 successive collisions.

$$\vec{v} = \frac{u_1 + a\tau_1 + u_2 + a\tau_2 + \cdots + u_n + a\tau_n}{n} = \frac{u_1 + u_2 + \cdots + u_n}{n} + a\left(\underset{\overset{\uparrow}{\tau}}{\frac{\tau_1 + \tau_2 + \cdots + \tau_n}{n}}\right)$$

$$\vec{v} = a\tau = \frac{-eE}{m}\tau$$

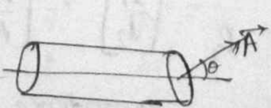
At S.T.P order of V_d is 10^{-4} m/sec.

Mobility (μ): V_d per unit e^- field.

$$\mu = \frac{e\tau}{m} = \frac{V_d}{E}$$

Current density ($\vec{J}$): Current passing per unit cross section of normal cross section.

It is a vector quantity, SI = A/m^2



$$i = \vec{J} \cdot \vec{A} = JA\cos\theta$$

direction of $\vec{J}$ is same as current flow.

momentum (P) of e^- = $\frac{m_e l i}{e}$

→ Relation b/w current & drift velocity

$i = neAV_d$, $J = neV_d$ e = charge of $e^- = 1.6 \times 10^{-19}$ C

→ Ohm's law

$V = iR$

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

vector form

$\vec{J} = \sigma \vec{E}$

$\sigma = \frac{ne^2 \tau}{m} = \frac{1}{\rho}$

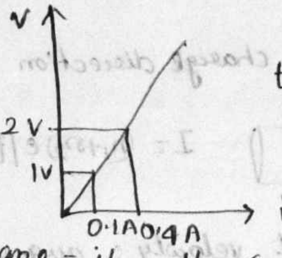
σ = conductivity – Siemen/m

ρ = resistivity

→ Resistance : Opposition of flow of current

SI = ohm (Ω)

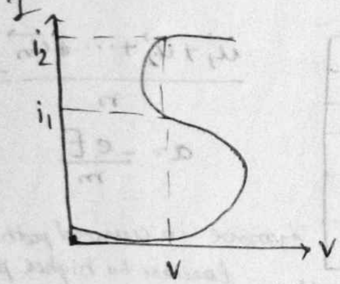
→ Ohmic conductors



$\tan\theta = \frac{V}{I} = R$

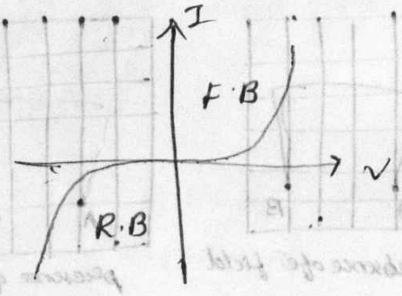
$\tan\theta = i/V = 1/R = G$ → conductance

→ Non-ohmic conductors :



Thermistor graph

Resistance varies with temp.



Semi conductor graph

→ Resistivity (or) specific resistance $R = \frac{\rho l}{A}$ SI – Ω.m (ohmmetre)

Conductivity (σ) = $\frac{1}{\rho}$ $R = \frac{\rho l^2}{V} = \frac{\rho l^2 d}{m}$ → density

if l ↑ ρ remain same.

→ Resistivity is a specific property, resistance is a bulk property.

→ It depends on temp, nature of material & impurities

→ Nichrome wire has high resistivity & m.p. (Heaters)

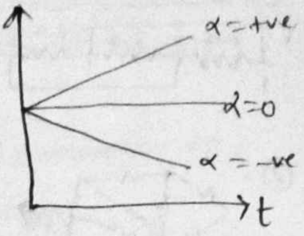
→ Tungsten filament has low resistivity & high m.p (Bulb)

$\frac{R_1}{R_2} = \left[\frac{l_1}{l_2}\right]^2 = \left[\frac{A_2}{A_1}\right]^2$

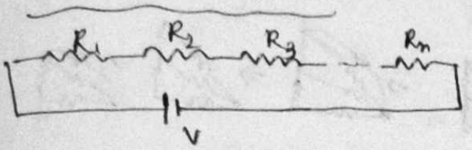
→ Temp. dependence of resistance

$\alpha = \frac{R_t - R_0}{R_0 \Delta t} = \frac{l_2 - l_1}{l_1 \Delta t}$ $R_t = R_0[1 + \alpha t]$

α = +ve for metals = −ve for non metal (semi conductors) = 0 for magnin wire



→ Resistors in series



(i = constant)

Potential of resistance = P.D ends of the resistor

If 'n' identical resistors are connected in series combination

$R_S = nR$

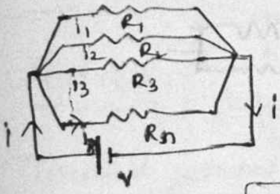
$$\boxed{R_S = R_1 + R_2 + R_3 \ldots}$$

$V_1 : V_2 : V_3 = R_1 : R_2 : R_3$

$V_1 = \left(\frac{R_1}{R_1+R_2+R_3}\right)V$ ||ly for V_2 & V_3

Resistors in parallel

→ eq, resistance of 'n' sided polygon at adj. corners $= \frac{(n-1)R}{n^2}$



[V = constant]

$$\boxed{\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

'n' identical resistors are connected ||el combination

$$\boxed{R_p = R/n}$$

$V_1 : V_2 : V_3 = 1 : 1 : 1$

$I_1 = \left(\frac{1/R_1}{1/R_p}\right) I$ ||ly for I_2, I_3

$i_1 : i_2 : i_3 = \frac{1}{R_1} : \frac{1}{R_2} : \frac{1}{R_3}$

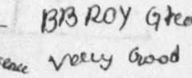
→ If the wire is cut into 'n' equal parts. If they are connected in ||el combination.

→ Possible arrangement of resistor of different $= 2^{n-1}$

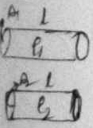
$R_{eff} = \frac{R}{n^2}$

→ for same kind $= 2^n$

$\sigma \propto 1/\rho$



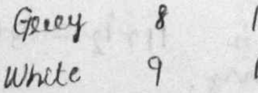
ρ_{eff} (series) $= \frac{\rho_1 + \rho_2}{2}$



ρ_{eff} (||el) $= \frac{2\rho_1\rho_2}{\rho_1+\rho_2}$

$\sigma_{eff} = \frac{\sigma_1 + \sigma_2}{2}$

Colour coding of resistors :

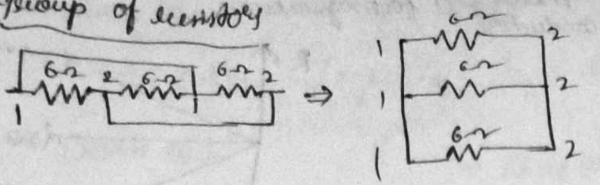


BB ROY Great Britain very Good wife

Colour	digit	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	
Grey	8	10^8	
White	9	10^9	
Gold		10^{-1}	5%
Silver		10^{-2}	10%
No colour			20%

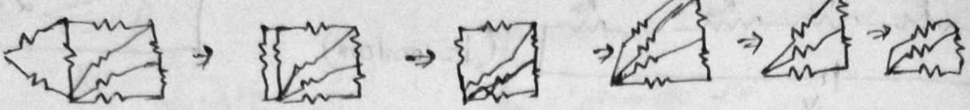
Group of resistors

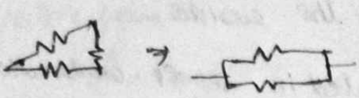
①



(EQUAL POTENTIAL POINT METHOD)

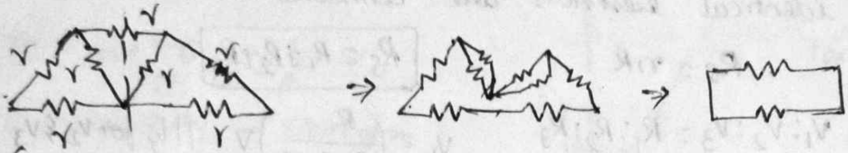
②





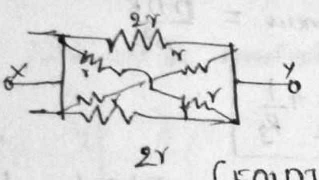
(CONNECTION REMOVAL METHOD)

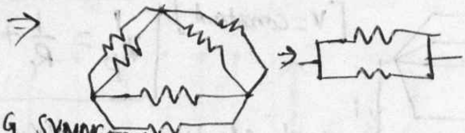
③



(MIRROR SYMMETRY)

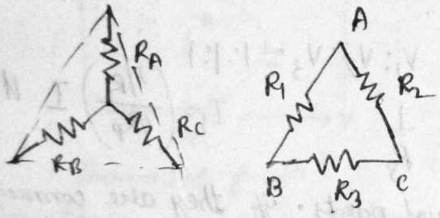
④





(FOLDING SYMMETRY)

⑤

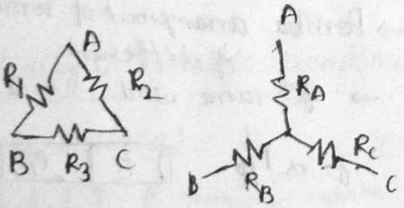


$$R_1 = \frac{R_AR_B + R_BR_C + R_CR_A}{R_C}$$

$$R_2 = \frac{R_AR_B + R_BR_C + R_CR_A}{R_B}$$

$$R_3 = \frac{R_AR_B + R_BR_C + R_CR_A}{R_A}$$

⑥

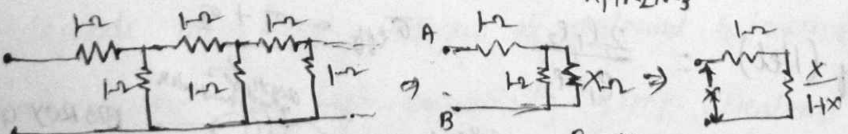


$$R_A = \frac{R_1R_2}{R_1+R_2+R_3}$$

$$R_B = \frac{R_1R_3}{R_1+R_2+R_3}$$

$$R_C = \frac{R_2R_3}{R_1+R_2+R_3}$$

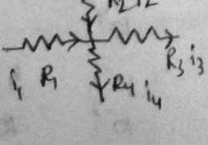
⑦



$R_S = X$

Kirchoff's laws:

1st law (or) KCL

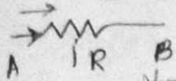


$i_1 + i_2 = i_3 + i_4$

law of conservation of charges

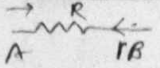
2nd law (or) KVL :

Potential fall



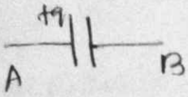
$V_A - iR = V_B$

Potential rise

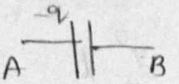


$V_A + iR = V_B$

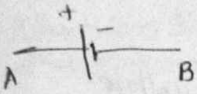
law of conservation of energy



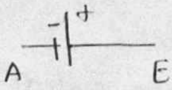
$V_A - q/_C = V_B$



$V_A + q/_C = V_B$



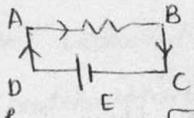
$V_A - E = V_B$



$V_{A+E} = V_B$

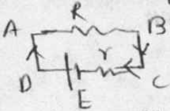
→ EMF of a cell : $E = V$ SI = volt (V)

Ideal cell :



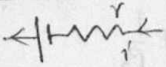
$$\boxed{i = E/R}$$

Real cell :



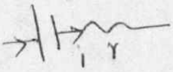
$$\boxed{i = \frac{E}{R+r}}$$

Terminal potential difference :



$V = E - ir$

Charging cell



$V = E + ir$

Relation b/w external & internal resistance ← $r = \left(\frac{E-V}{V}\right)R$

Grouping of cells

Series :

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

$V_A - V_C = E_{eq} - i \cdot r_{eq}$

$i = \frac{nE}{R+nr}$

$i_1 = \frac{E_1 - V}{r_1}$ in llel

Parallel :

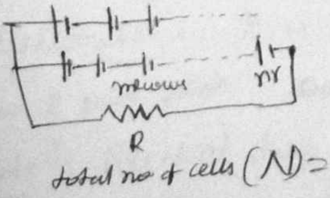
$E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$, $\frac{E_1/r_1 + E_2/r_2 + E_3/r_3}{1/r_1 + 1/r_2 + 1/r_3} = E_{eq}$

$i = \frac{E_1 r_2 + E_2 r_1}{R(r_1+r_2) + r_1 r_2}$

$i = \frac{nE}{nR + r}$

Mixed grouping of cells :

m-rows
n-columns



total no of cells (N) = mn

$i = \frac{mnE}{mR + nr}$

Max current : $i = \frac{nE}{2R}$ (or) $\frac{mE}{2r}$

Wrongly connected cells

$i = \frac{(n-2m)E}{R+nr}$ $(n-2m)E = E_{total}$

Joule's heating effect:

$Q = W = Vit = i^2Rt = \frac{V^2}{R}t$

Power $(P) = Vi = i^2R = V^2/R$

Bulb:

$R = \frac{V_r^2}{P_r}$ V_r & P_r are rated Va- applied voltage

V_c & P_c are consumed

$P_c = \left[\frac{V_a}{V}\right]^2 P_r$

$P_c \propto R \propto 1/P_r$

→ In series Less rated power has more brightness

$\frac{1}{P_{total}} = \frac{1}{P_1} + \frac{1}{P_2} + \frac{1}{P_3}$

→ ||el more rated power has more brightness

$P_c \propto 1/R \propto P_r$

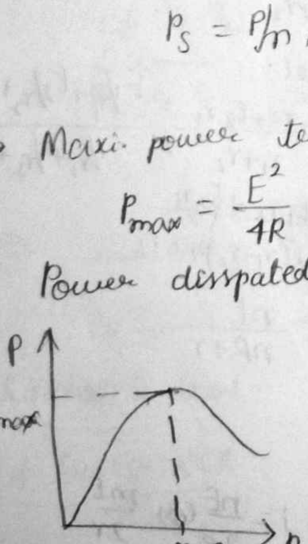
$P_c = P_1 + P_2 + P_3$

$P_s = P/n$, $P_p = nP$, $\frac{P_s}{P_p} = \frac{1}{n^2}$

→ Maxi. power transfer theorm

$P_{max} = \frac{E^2}{4R}$

Power dissipated in an external resistance is maxima. If $r = R$



$R = 0 \rightarrow P = 0$ (Short ckt)

$r > R \rightarrow P\uparrow$

$r = R \rightarrow P_{max}$

$r < R \rightarrow P\downarrow$

$R = \infty \rightarrow P = 0$

(Openckt)

→ **Heater** : $MS\Delta T = \frac{V_a^2}{R}t = i^2Rt$

$R \propto t$ $\quad t$ = time

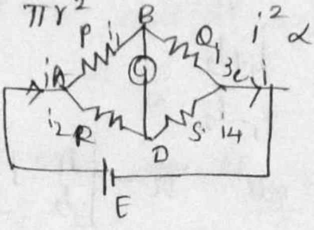
Series : $R_s = R_1 + R_2 \Rightarrow t_s = t_1 + t_2$

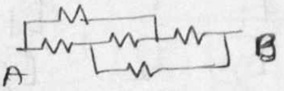
||el : $R_p = \frac{R_1R_2}{R_1+R_2} \Rightarrow t_p = \frac{t_1t_2}{t_1+t_2}$

→ **Fuse wire** : $H = \frac{i^2\rho l}{\pi r^2} \Rightarrow i^2\rho = 2\pi^2 r^3 H_0$

$i^2 \propto r^3$

→ **Wheatstone Bridge** :

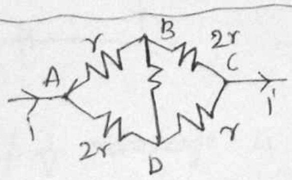




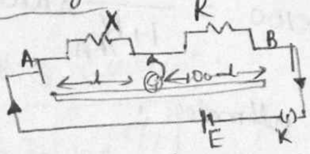
$\frac{P}{Q} = \frac{R}{S}$

* Current flows due to potential difference. In B & D p.diff = 0 so we can removed B & D.

Unbalanced Wheatstone Bridge :



Meter bridge :



$\frac{X}{R} = l/_{100-l}$ left gap ← X, R ↙ Rigth gap

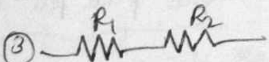
Magnin wire of area of crossection is constant.

End correction :

$\frac{X}{R} = \frac{l+\alpha}{100-l+\beta}$

① for metal wire $T\uparrow R\uparrow \rho\uparrow l\uparrow$

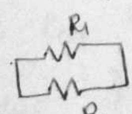
② for semiconductor $T\uparrow R\downarrow \rho\downarrow l\downarrow$

③ 

left gap

$\frac{R_1+R_2}{R} = \frac{l}{100-l}$

Use
→ To find unknown resistance of wire.

④ 

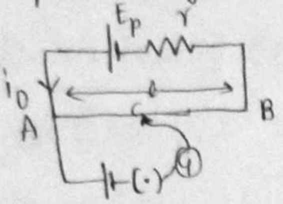
$\frac{R_1R_2}{(R_1+R_2)R} = \frac{l}{100-l}$

→ **Potentiometer** : It is a device measure potential difference b/w 2 given points without drawing a current.

Principle : Potential drop across any crossection of the wire is directly proportional to balancing length.

$\frac{V_{AC}}{l} = K$ potential gradient

→ potential gradient is potential drop per unit length.



$$E_S = \left[\frac{E_P}{R_0+r}\right]\left[\frac{R_0}{L}\right] l$$

R_0 = resistance of wire

r = internal resistance of cells

L = length of wire

l = balancing length.

$$\frac{E_1}{E_2} = \frac{l_1}{l_2}, \quad \frac{E_1}{E_2} = \frac{l_1+l_2}{l_1-l_2}$$

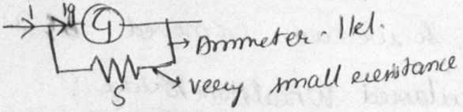
if null deflection in galvanometer at $l = l_1$

$E_{unknown} = Kl_1$

→ Internal resistance of cell $r = \left[\frac{l_1}{l_2} - 1\right] R$

→ Conversion of Galvanometer into Ammeter :

error $\Delta i = i - i'$



→ Ammeter - llel.

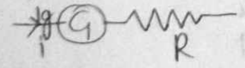
→ very small resistance

$$S = \frac{G}{n-1} = \frac{i_g G}{i - i_g}$$

$$R_{eff} = \frac{GS}{G+S}$$

% error in ammeter ⇒ $\frac{\Delta i}{i} \times 100 = \frac{1}{1+R/R_A} \times 100$ [∠ R_A = resistance of ammeter]

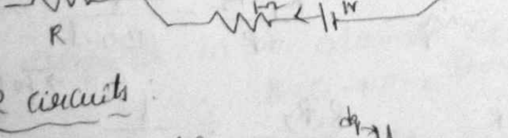
→ Conversion of Galvanometer into voltmeter :



$V_{new} = i_g [G+R]$ $\quad R = (n-1) G$

$\frac{V_g}{V} : \frac{V_R}{V} = G:R$, $R_{eff} = R+G$

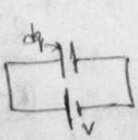
→ Point potential theory :



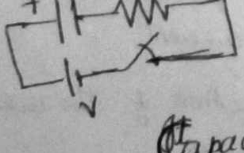
$$\frac{V-3}{1} + \frac{V-2}{1} + \frac{V-1}{1} = 0$$

C-R circuits

Charging of capacitor



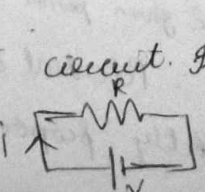
$V = Q/C$



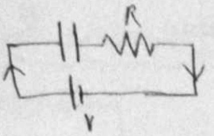
t = 0 sec, q = 0

$V_C = Q/C = 0$

Capacitor is acts as short circuit. It acts as a conducting wire.



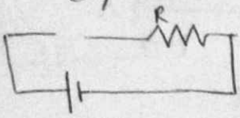
$i = \frac{V}{R}$ (max)

ii) 

$t = \infty$ sec, $q = q_0, i = 0$

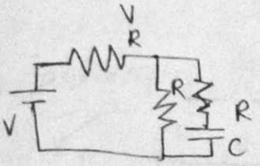
fully charged capacitor is called steady state

Capacitor is open circuit.



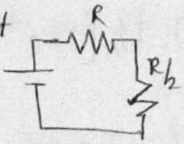
$V = V_C + V_R \Rightarrow V_R = 0$

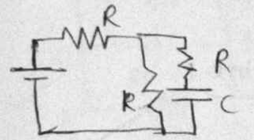
$\boxed{V = V_C}$



$t = 0$ sec, short ckt

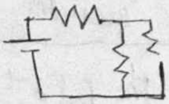
$i = \frac{2V}{3R}$





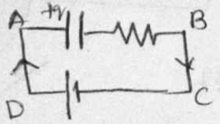
$t = \infty$ sec, open ckt

$i = \frac{V}{2R}$



	i	i_1	i_2
$t=0$ short ckt	$\frac{2V}{3R}$	$\frac{V}{3R}$	$\frac{V}{3R}$
$t=\infty$ sec open ckt	$\frac{V}{2R}$	$\frac{V}{2R}$	0

Growth of charge:



$q_0 = CV \rightarrow$ final charge

$q = q_0[1-e^{-t/CR}]$ τ → time const

$q = 63\% \, q_0$

63% of maxcharge is stored in the capacitor at one time const

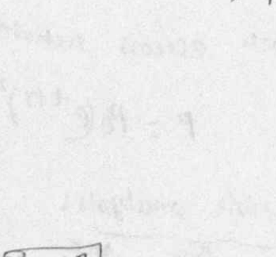
τ↓ capacitor has fast charging.

Growth of current:

$q = q_0[1-e^{-t/\tau}]$ $i = \frac{dq}{dt}$

$i = \frac{d}{dt}[q_0 - q_0 e^{-t/\tau}]$

$i = i_0 e^{-t/\tau}$



Find the time const (τ):

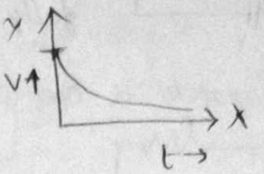
1. Short circuit the battery
2. Find Reff b/w capacitor plates
3. Product of capacitor & resistance $\boxed{\tau = CR}$

Potential across capacitor varying with time:

$V_C = V_0[1-e^{-t/\tau}]$

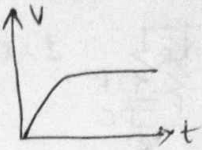
Potential across a resistor varying with time:

$$V_R = V_0 e^{-t/T}$$



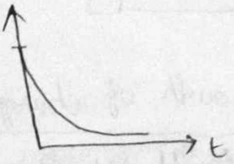
Energy stored in capacitor varying with time:

$$U = U_0\left[1 - e^{-t/T}\right]^2$$



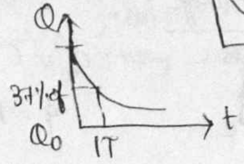
Power across a resistor varying with time:

$$P = P_0\left[e^{-t/\tau}\right]^2$$



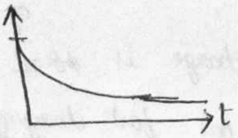
Decay of charge: $Q = \dfrac{Q_0}{e}$

$Q = Q_0 e^{-t/T}$



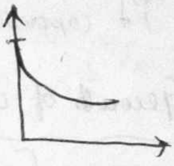
Decay of current:

$i = i_0 e^{-t/\tau}$



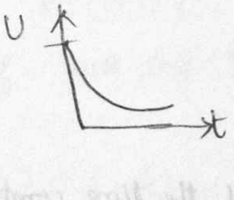
Voltage across capacitor varying with time (t):

$V_C = V_0 e^{-t/\tau}$



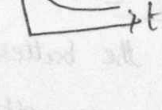
Voltage across resistor varying with time (t):

$V_R = V_0 e^{-t/T}$

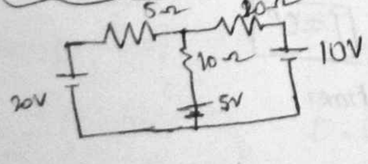


Power across resistor

$P = P_0 (e^{-t/T})^2$



Thevenin's analysis:

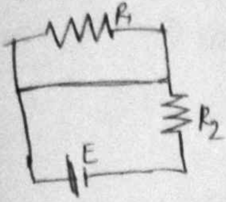


Rule ①: Open circuit at a resistor ~~to~~ throu
do you want to find current.
Measure current in next loop.

Rule ②: Find potential b/w ends of 10.

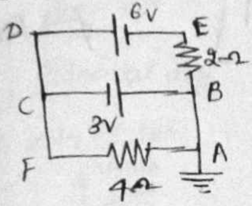
Rule ③: Find equivalent resistance by removing
all resistors

→ **Short circuiting**: 2 point in electric ckt connected by conducting wire are called short circuited (both potential same) - no current flow.



→ Here R_1 is short ckt. i.e, P_{diff} across $R_1 = 0$. No current flow through R_1 & current through R_2 is E/R_2

→ **Earthing**: If a point is earthed then its potential is zero.



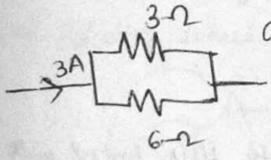
$V_A = V_B = 0$, $V_F = V_C = V_D = -3V$

$V_E = -9V$, $V_B - V_E = 9V$

i) Current through 2Ω is

$\frac{V_B - V_E}{2}$ (or) $\frac{9}{2}$ A (from B to E)

ii) Current through 4Ω is $\frac{V_A - V_F}{4}$ (or) $\frac{3}{4}$ A (from A to F)



current through 3Ω

A) $i_3 = \left(\frac{6}{3+6}\right) \times 3 = 2A$