

# BASIC OF ELECTRICAL ENGINEERING

## 1. Basic of electricity ÷

$$\Rightarrow \underline{\text{electron}} \div \begin{array}{l} \text{charge} = -1.6 \times 10^{-19} \text{ coulomb} \\ \text{mass} = 9.11 \times 10^{-31} \text{ Kg} \end{array}$$

Proton ÷

$$\begin{array}{l} \text{charge} = 1.6 \times 10^{-19} \text{ coulomb} \\ \text{mass} = 1.67 \times 10^{-21} \text{ Kg} \end{array}$$

$$\Rightarrow \frac{\text{mass of Proton}}{\text{mass of electron}} = 1840$$

$$\Rightarrow \text{current (i)} = \frac{dQ}{dt}$$

$I = \frac{dQ}{dt}$

 amper

$$\Rightarrow \text{Potential (V)} = \frac{W}{Q} \frac{(\text{work})}{(\text{charge})} \frac{\text{Jule}}{\text{coulomb}} \text{ or Volt}$$

$$\Rightarrow \text{Voltage drop (V)} = IR \quad \text{Volt or amp. ohm}$$

$$\Rightarrow \text{Resistance, } R = \rho \frac{l}{a} \text{ ohm}$$

$\rho$  = resistivity unit  $\Omega\text{-m}$  (ohm meter)

$$\Rightarrow 1 \text{ coulomb} = 6.25 \times 10^{18} \text{ electron}$$

①

## ⇒ Effect of temperature on resistance

- i) in pure metal having positive temperature coefficient of resistance.
- ii) In Alloy having positive temperature coefficient of resistance.
- iii) In insulating material having negative temperature coefficient of resistance.

## ⇒ TEMPERATURE COEFFICIENT OF RESISTANCE

$$\alpha = \frac{R_t - R_0}{R_0 t}$$

where  $R_t - R_0 \rightarrow$  change in resistance

$R_0 \rightarrow$  basic (initial) resistance

$t \rightarrow$  change in temperature

$$R_t = R_0(1 + \alpha t)$$

$$\alpha_t = \frac{d_0}{R_0(1 + d_0 t)}$$

⇒

Metal	temp coefficient
Manganin	0.00015 /°C
Constantan	0.00020 /°C
Copper	0.004 /°C

## ⇒ CONNECTION OF RESISTANCE

- i) Series :

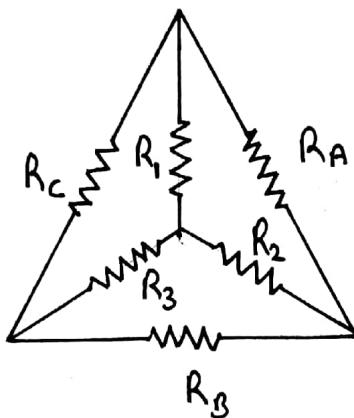
$$R_{eq} = R_1 + R_2 + R_3$$

(2)

ii) Parallel  $\div$

$$\frac{1}{R_{AB}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

STAR TO DELTA CONVERSION  $\div$

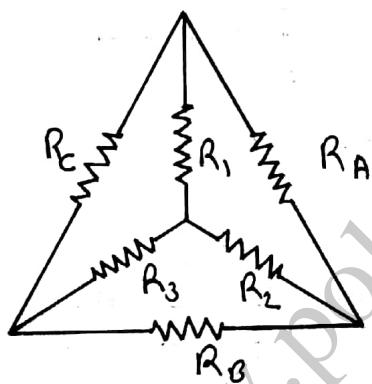


$$R_A = R_1 + R_2 + \frac{R_1 R_2}{R_3}$$

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

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

DELTA TO STAR CONVERSION  $\div$



$$R_1 = \frac{R_A R_C}{R_A + R_B + R_C}$$

$$R_2 = \frac{R_A R_B}{R_A + R_B + R_C}$$

$$R_3 = \frac{R_B R_C}{R_A + R_B + R_C}$$

OHM'S LAW  $\div$

$$I \propto V$$

$$I = \frac{V}{R} \quad \text{or} \quad \frac{V}{I} = \text{constant (R)}$$

$$V = I R \quad \text{volt}$$

Power calculation in DC  $\Rightarrow$

$$P = VI = \frac{V^2}{R} = I^2 R \quad \text{watt}$$

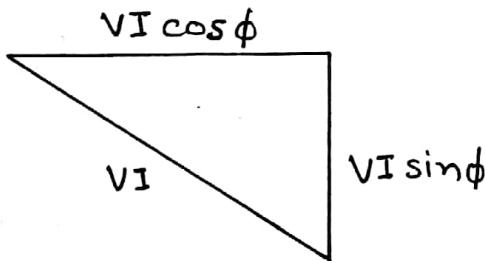
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⇒ Power calculation in AC →

$$\text{apparent power} = VI \quad (\text{volt-amp})$$

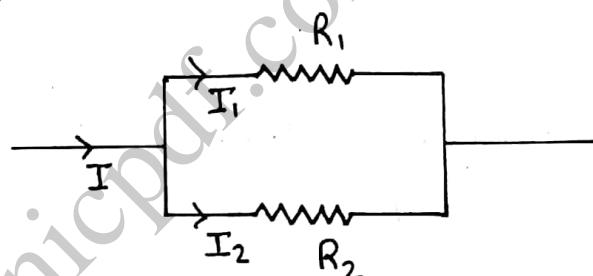
$$\text{active power} = VI \cos \phi \quad (\text{watt})$$

$$\text{reactive power} = VI \sin \phi \quad (\text{VAR})$$



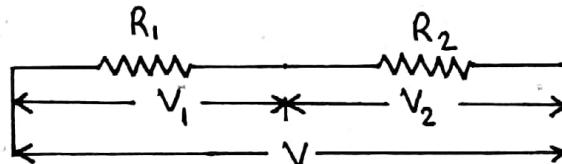
⇒ CURRENT DEVISION RULE ÷

$$I_1 = I \times \frac{R_2}{R_1 + R_2}$$



$$I_2 = I \times \frac{R_1}{R_1 + R_2}$$

⇒ VOLTAGE DEVISION RULE ÷

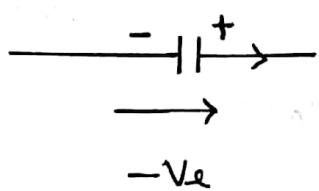


$$V_1 = V \times \frac{R_1}{R_1 + R_2}$$

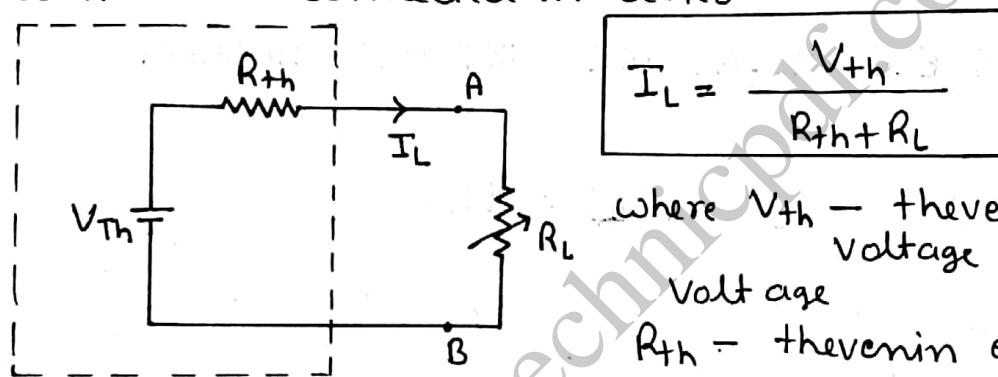
$$V_2 = V \times \frac{R_2}{R_1 + R_2}$$

QUANTITY	SI UNIT	QUANTITY	SI UNIT
Charge	coulomb (C)	Resistance	ohm ( $\Omega$ )
current	amper (A)	Resistivity	$\Omega \cdot m$
	or coulomb/sec	temp. coeff.	$^{\circ}C$
EMF	volt (V)	Power	watt
voltage drop	volt (V)	apparent power	VA
Potential diff.	volt (V)	active power	watt
	(4)	reactive power	VAR

→ Direction of emf source :-



→ THEVENIN'S THEOREM :- Any active network converted into single equivalent voltage source and single equivalent resistance and both are connected in series.

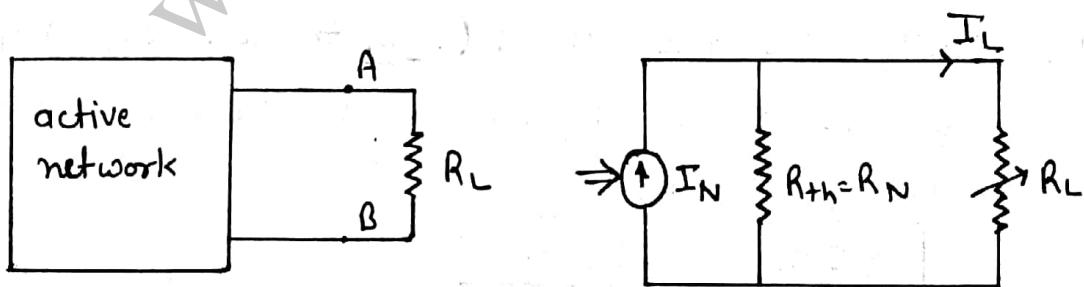


$$I_L = \frac{V_{th}}{R_{th} + R_L}$$

where  $V_{th}$  - thevenin equivalent voltage or open circuit voltage

$R_{th}$  - thevenin equivalent resistance

→ NORTON'S THEOREM :- Complete network current calculated as norton current  $I_N$  and total resistance is calculated as norton resistance



$$I_L = I_N \times \frac{R_N}{R_N + R_L}$$

$$R_{th} = \frac{\text{open circuit voltage}}{\text{short circuit current}}$$

(5)

- \* Internal resistance of ideal voltage source should be zero.
- \* Internal resistance of ideal current source should be infinity.

⇒

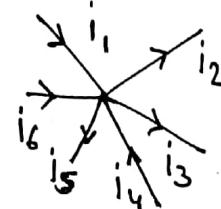
1 KWh = 860 KCal	***
1 KCal = 4184 Joule	
1 Kcal = 4.18 KJoule	
1 KWh = $3.6 \times 10^6$ Joule	

## 2) BASIC ELECTRICAL AND NETWORK THEOREM

⇒ i) KIRCHHOFF'S CURRENT LAW ÷ (KCL)

[incomming current = outgoing current]

$$i_1 + i_4 + i_6 = i_2 + i_3 + i_5$$



⇒ \* [no. of KCL equation = (no. of node - 1)] \*\*

⇒ ii) KIRCHHOFF'S VOLTAGE LAW ÷ (KVL) ⇒ In any loop algebraic sum of EMF and algebraic sum of voltage drop will be zero.

$$\sum \text{EMF} + \sum \text{IR} = 0$$

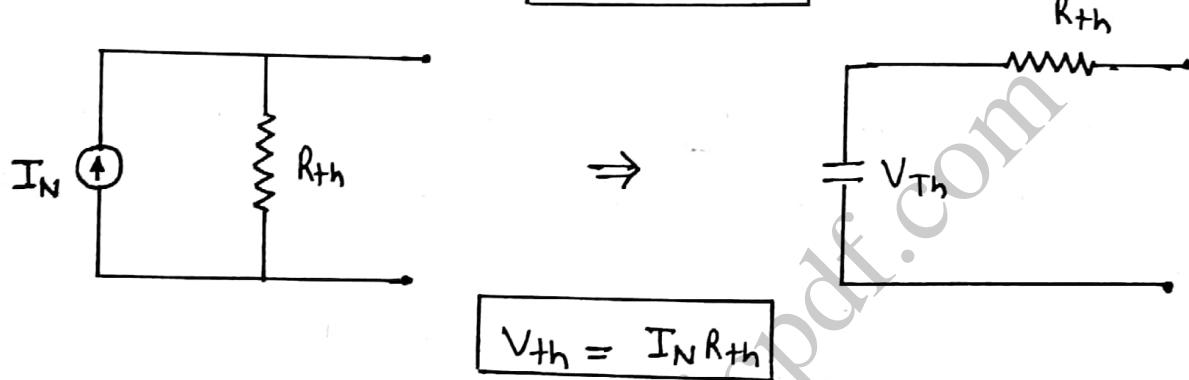
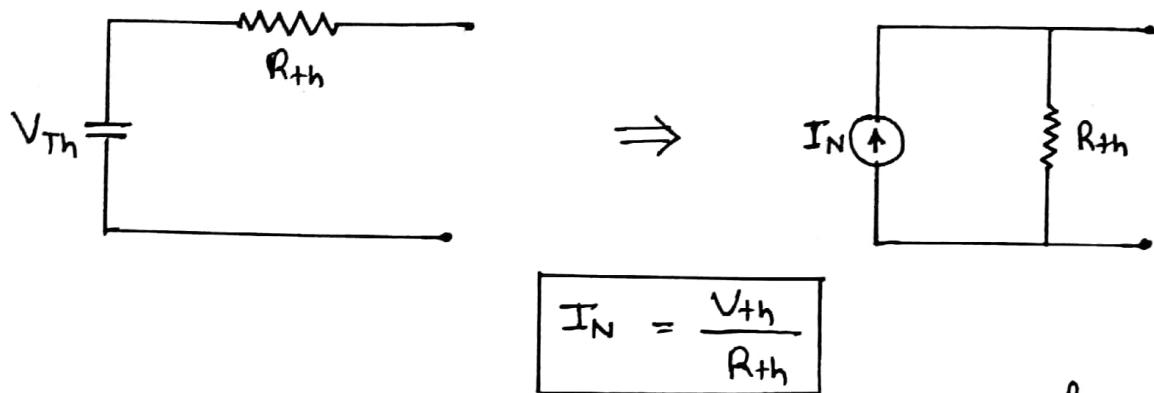
\* [no. of KVL equation = (b-n+1)]

where b = no of branch

n = no of node

(6)

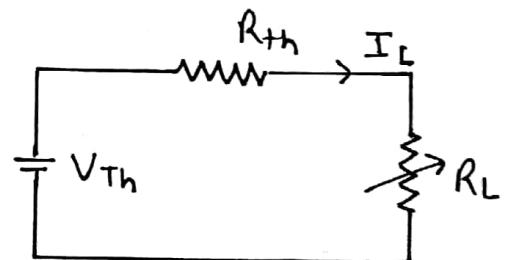
→ SOURCE CONVERSION :



→ MAXIMUM POWER TRANSFER :

$$P_L(\max) = \frac{V_{Th}^2}{4R_{Th}}$$

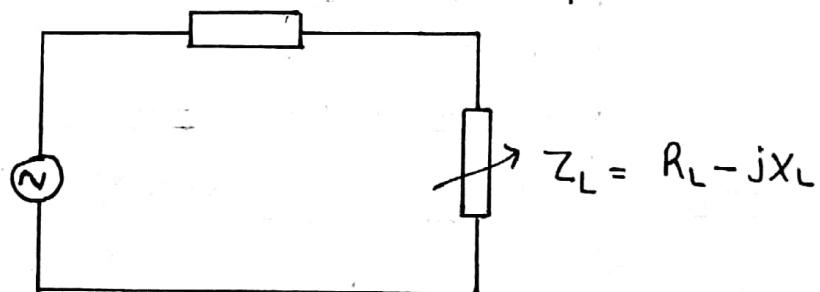
$$\therefore \eta = 50\%$$



\* Condition for maximum power + If  $\Rightarrow R_{Th} = R_L$

→ For AC

$$Z_{Th} = R_{Th} + jX_{Th}$$



for maximum power + If

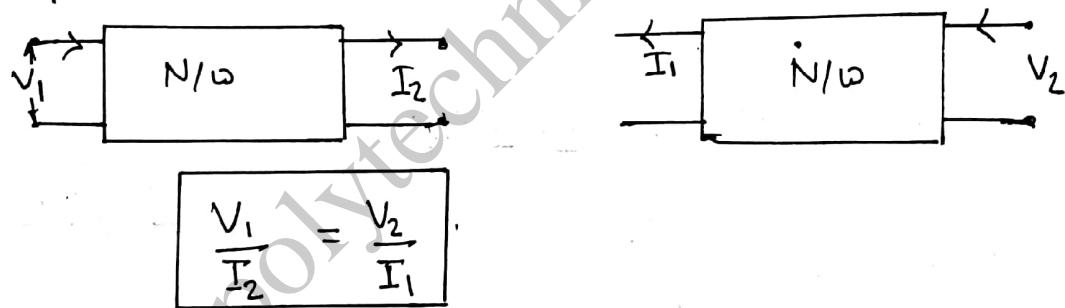
$$[Z_L = Z_{Th}^*] \quad (7)$$

→ SUPER POSITION THEOREM :

- \* it is apply linear network only.
- \* it apply when two or more then two active element present
- \* It is not use for power calculation
- \* It apply only linear, bilateral circuit.

⇒ RECIPROCITY THEOREM ⇒ Ratio of excitation to response is constant when the position of excitation and response are interchange.

- \* this theorem apply only when single active element is present.

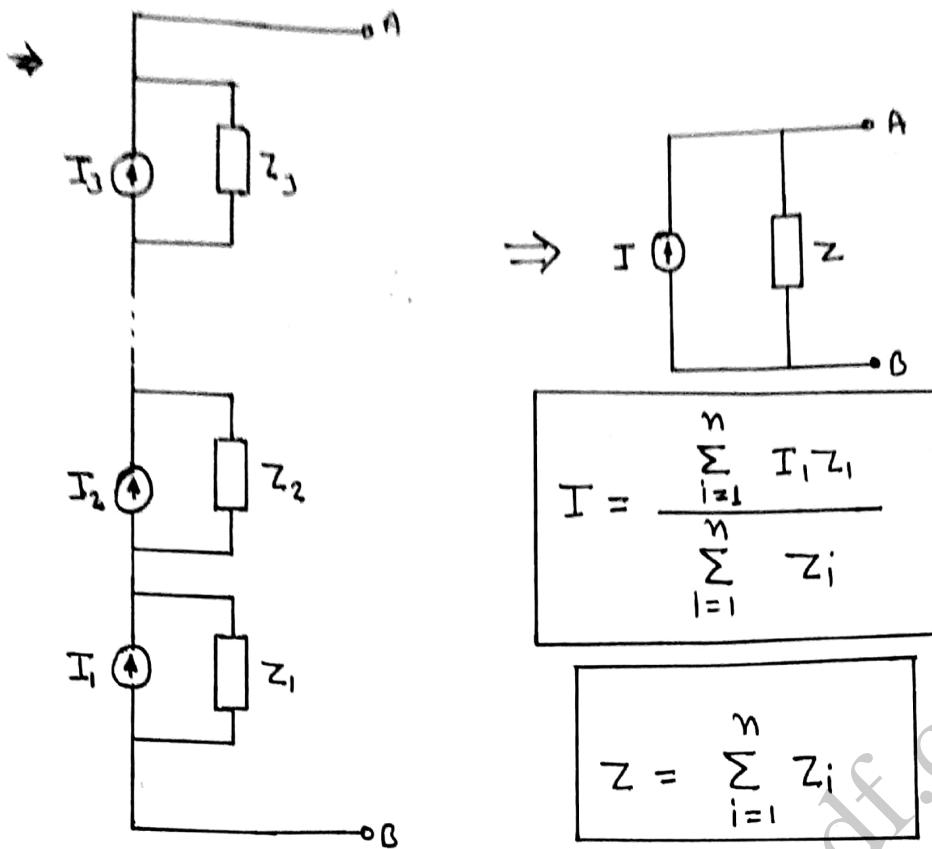


⇒ MILLMAN'S THEOREM :

$$E = \frac{\sum_{i=1}^n E_i Y_i}{\sum_{i=1}^n Y_i} = \frac{E_1 Y_1 + E_2 Y_2 + \dots + E_n Y_n}{Y_1 + Y_2 + \dots + Y_n}$$

$$Z = \frac{1}{\sum_{i=1}^n Y_i} = \frac{1}{Y_1 + Y_2 + \dots + Y_n}$$

(8)



Non linear  $\rightarrow$  active  $\rightarrow$  unidirectional

Linear  $\rightarrow$  passive  $\rightarrow$  bidirectional.

## 3

ELECTROSTATIC

⇒ COULOMB LAW ÷

$$F \propto \frac{Q_1 Q_2}{d^2}$$

$$F = K \frac{Q_1 Q_2}{d^2}$$



$$\boxed{F = \frac{1}{4\pi\epsilon_0\epsilon_r} \frac{Q_1 Q_2}{d^2}}$$

where  $\epsilon = \epsilon_0 \epsilon_r$  (permittivity) F/m

$$\epsilon_0 (\text{air}) = 8.854 \times 10^{-12} \text{ F/m}$$

$\epsilon_r$  (relative permittivity) air = 1 no unit

for air gap

$$\boxed{F = 9 \times 10^9 \frac{Q_1 Q_2}{d^2}}$$

⇒ ELECTRIC FIELD INTENSITY

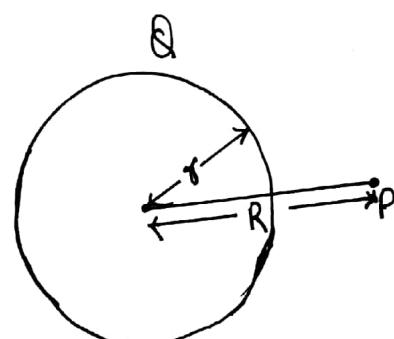
$$E = \frac{F}{Q} \text{ N/C}$$

$$\boxed{E = \frac{1}{4\pi\epsilon_0\epsilon_r} \frac{Q}{d^2} \text{ N/C}}$$

\* E at point P =  $\frac{1}{4\pi\epsilon_0\epsilon_r} \frac{Q}{R^2}$

\* E at surface =  $\frac{1}{4\pi\epsilon_0\epsilon_r} \frac{Q}{r}$

\*  $E_{\text{inside}} = \text{zero}$



(10)

⇒ ELECTRIC FIELD DENSITY [CHARGE DENSITY] ÷

$$D = \frac{Q}{A} \quad \frac{C}{m^2}$$

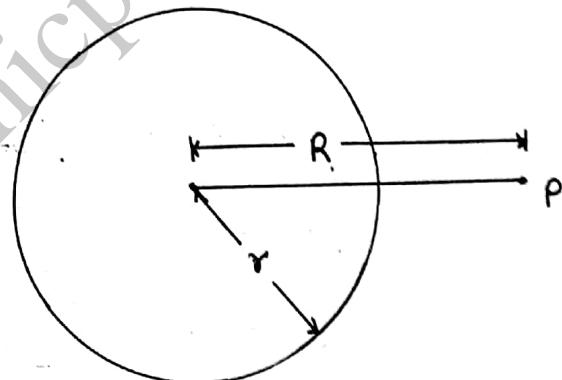
⇒ Relation between electrical field intensity and density ÷

$$D = \epsilon_0 \epsilon_r E$$

⇒ Potential ÷  $V = \frac{W}{Q} = \frac{Fd}{Q}$  (J/C or volt)

$$V = \frac{1}{4\pi \epsilon_0 \epsilon_r} \frac{Q}{d}$$

$$V \text{ at point } P = \frac{1}{4\pi \epsilon_0 \epsilon_r} \frac{Q}{R}$$



$$V \text{ at surface} = \frac{1}{4\pi \epsilon_0 \epsilon_r} \frac{Q}{r}$$

$$V_{\text{inside}} = V_{\text{at surface}} = \frac{1}{4\pi \epsilon_0 \epsilon_r} \frac{Q}{r}$$

⇒ Relation between electric field intensity and voltage ÷

$$E = \frac{V}{d} \quad \text{V/m}$$

⇒ CAPACITOR ÷  $[C = \frac{\epsilon A}{d}]$  Farad

$$\frac{Q \cdot d \cdot V}{Q = C \cdot V} \quad \text{coulomb}$$

$$C = \frac{Q}{V} \quad \text{farad}$$

(11)

- \* capacitor work as open circuit for DC.
- \* capacitor work as short circuit for AC.
- \* battery charging is not possible in case of AC.

⇒ COMBINATION OF CAPACITOR

\* Series COMBINATION

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

\* PARALLEL COMBINATION :-

$$C_{eq} = C_1 + C_2 + C_3$$

⇒ CHARGING OF A CAPACITOR :-

$$V = V(1 - e^{-t/\tau})$$

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

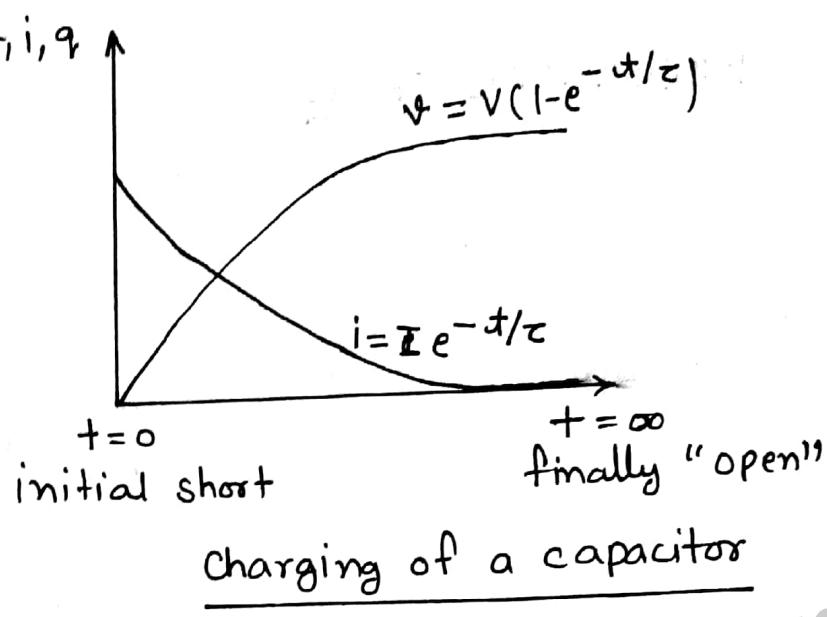
$$q_t = Q(1 - e^{-t/\tau})$$

where  $\tau$  = time constant =  $RC$

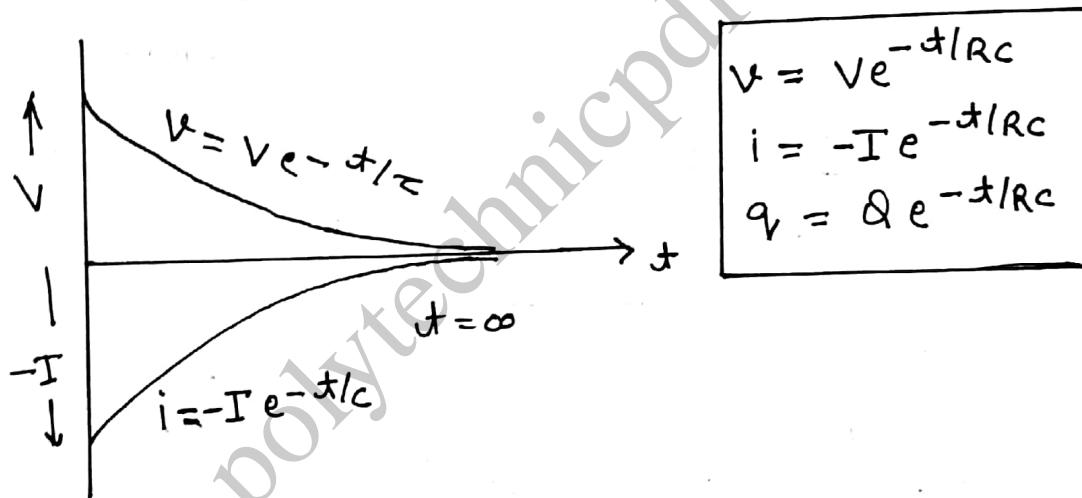
$$V = 63.2\% \text{ of } V$$

$\therefore$  time constant = 63.2% of full voltage ]

- \* time required for full charging a capacitor  
 $= 5\tau$



### ⇒ DISCHARGING OF A CAPACITOR ▷



### ⇒ ENERGY STORED IN A CAPACITOR ▷ $E = \frac{1}{2} C V^2 = \frac{1}{2} \frac{Q^2}{C}$

QUANTITY	SI UNIT	QUANTITY	SI UNIT
Force	Newton (N)	Permittivity	F/m
Electrical field intensity	N/C or V/m	Capacitor	Farad
electric field density	$\frac{C}{m^2}$		

#### 4- FUNDAMENTAL OF AC

⇒ Average value =  $\frac{\text{area under one cycle}}{\text{time period}}$

⇒ average value of →

\* sinusoidal supply =  $\frac{2V_m}{\pi}$  volt,  $\frac{2I_m}{\pi}$  amp

\* half wave rectifier output =  $\frac{V_m}{\pi}$  volt,  $\frac{I_m}{\pi}$  amp

\* full wave rectifier output =  $2V_m/\pi$  volt,  $\frac{2I_m}{\pi}$  amp

\* Rectangular wave =  $V_m$  volt,  $I_m$  amp

\* triangular wave =  $\frac{V_m}{2}$  volt,  $\frac{I_m}{2}$  amp

\* Average value represent the dc component present in the ac. It measured by PMMC.

⇒ RMS VALUE ⇒ It is that value of dc supply which do the same amount of the work in same time when AC apply.

Generally rms represent the working content of supply

RMS Value for :-

\* sinusoidal supply =  $\frac{V_m}{\sqrt{2}}$ ,  $\frac{I_m}{\sqrt{2}}$

\* half wave rectifier output =  $\frac{V_m}{2}$ ,  $\frac{I_m}{2}$

\* full wave rectifier output =  $\frac{V_m}{\sqrt{2}}$ ,  $\frac{I_m}{\sqrt{2}}$

\* Rectangular wave =  $V_m$ ,  $I_m$

\* triangular wave =  $\frac{V_m}{\sqrt{3}}$  volt

⇒ FORM FACTOR :-

$$\text{f.f.} = \frac{\text{rms value}}{\text{average value}}$$

\* for sinewave = 1.11

\* half wave = 1.57

\* full wave rectifier = 1.11

\* for rectangular wave = 1

\* for triangular wave = 1.16

\* highest f.f. → half wave

\* lowest f.f. → rectangular

$$\Rightarrow \text{PEAK FACTOR} \div \text{P.F.} = \frac{\text{Peak value (maximum value)}}{\text{rms value}}$$

- \* Peak factor for  $\div$  sin wave = 1.41
- \* for half wave rectifier = 2
- \* for full wave rectifier = 1.41
- \* for rectangular = 1
- \* for triangular = 1.73

$$\Rightarrow \text{RIPPLE FACTOR} \div \text{R.F.} = \sqrt{(\text{formfactor})^2 - 1}$$

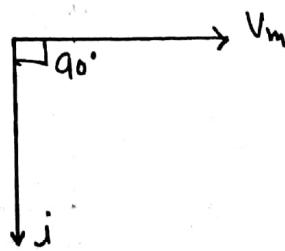
- \* for sine wave = 0.482
- \* for half wave rectifier = 1.21
- \* for full wave rectifier = 0.482
- \* for rectangular wave = 0
- \* for triangular wave = 0.587 or 0.59

$$\Rightarrow \text{RESISTANCE} \rightarrow i = \frac{V_m}{R}$$

- \* Power factor = unity
- \* active power =  $VI \cos\phi = VI$  watt
- \* reactive power = zero
- \* Active power = apparent power

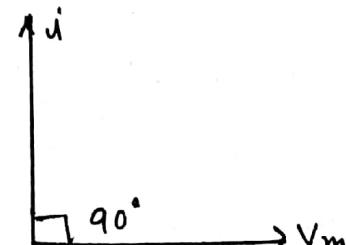
$$\Rightarrow \text{INDUCTOR} \rightarrow * i = \frac{V_m}{X_L} [\sin(\omega t + 90^\circ)] * \left[ I_m = \frac{V_m}{X_L} \right]$$

- \* active power =  $VI \cos 90^\circ = \text{zero (o)}$
- \* apparent power =  $VI$  VA
- \* reactive power =  $VI$  VAR (lagging reactive power)
- \* Power consumption Zero
- \* Power factor = zero lagging



for inductor

(15)



for capacitor

⇒ CAPACITOR → \* Active Power zero

\* apparent power =  $VI$

\* reactive power =  $VI \sin 90^\circ = VI$

\* [apparent power = leading reactive power]

\* Power factor = zero leading

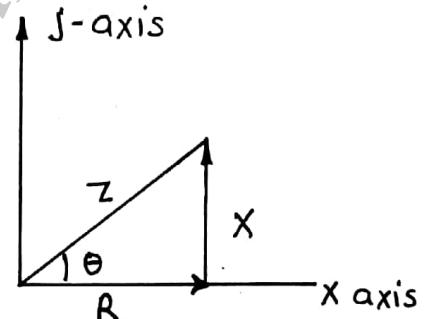
⇒ IMPEDANCE → Which offered opposition to flow of current in AC is called impedance.

$$[Z = R \pm jX] \text{ ohm}$$

+Ve sign → lagging & -Ve sign → leading

where →  $R$  is real part and  $X$  is imaginary part

$$|Z| = \sqrt{R^2 + X^2}$$



\*  $\tan \theta = \frac{X}{R} \Rightarrow \theta = \tan^{-1} \left( \frac{X}{R} \right)$

\* Power factor  $\cos \theta = \frac{R}{Z}$

⇒ ADMITTANCE → unit → mho ( $\Omega$ ) , Semance

$$Y = G \pm jB$$

where +Ve sign — leading & -Ve sign — lagging

$G$  = Conductance ,  $B$  = Susceptance ( $\Omega$ )

$$\left[ Y = \frac{1}{Z} \right]$$

⇒ SERIES R-L CIRCUIT →  $Z = R + jX_L$

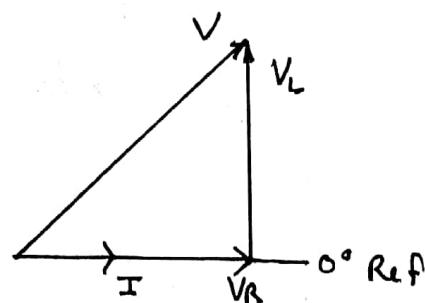
\*  $|Z| = \sqrt{R^2 + X_L^2}$

\*  $\phi = \tan^{-1} \left( \frac{X_L}{R} \right)$

\* Power factor =  $\cos \phi$

\* active power =  $VI \cos \phi$

\*  $\vec{V} = \vec{V}_R + \vec{V}_L$



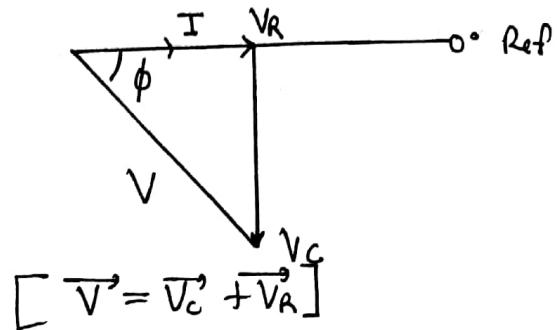
(16)

$\Rightarrow$  SERIES RC CIRCUIT  $\div$   $Z = R - jX_C$

\*  $|Z| = \sqrt{R^2 + X_C^2}$

\*  $\phi = \tan^{-1} \left( \frac{X_C}{R} \right)$

\* active power  $= VI \cos \phi$



$\Rightarrow$  SERIES RLC CIRCUIT  $\div$   $\vec{V} = \vec{V}_R + \vec{V}_L + \vec{V}_C$

\*  $\frac{V}{I} = R + j(X_L - X_C)$

\*  $Z = R + j(X_L - X_C) \Rightarrow |Z| = \sqrt{R^2 + (X_L - X_C)^2}$

\*  $\theta = \tan^{-1} \frac{(X_L - X_C)}{R}$

$\Rightarrow$  SERIES RESONANCE  $\div$  \*  $Z = R + j(X_L - X_C)$

at  $\omega \rightarrow \omega_0$  then j term will be zero.

$X_L - X_C = 0 \Rightarrow [X_L = X_C]$

$\Rightarrow \omega_0 L = \frac{1}{\omega_0 C} \Rightarrow \omega_0^2 = \frac{1}{L C} \Rightarrow \omega_0 = \frac{1}{\sqrt{LC}}$

so resonance frequency  $\omega_0 = \frac{1}{\sqrt{LC}}$  rad/sec

$$\left[ f_0 = \frac{1}{2\pi\sqrt{LC}} \text{ Hz} \right]$$

$$\left[ I = \frac{V}{|Z|} = \frac{V}{\sqrt{R^2 + (X_L - X_C)^2}} \right]$$

\* at series resonance impedance is minimum.

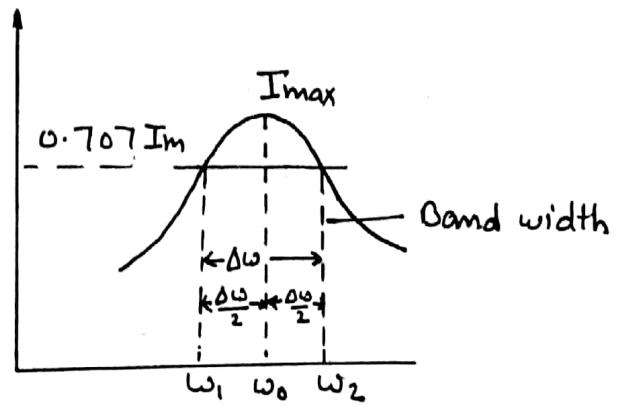
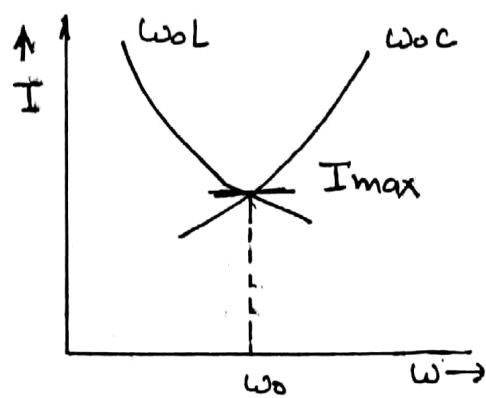
\* current flow maximum  $[I_m = V/R]$

\* at resonance unity power factor.

\* the magnitude of  $V_L$  and  $V_C$  is equal and  $180^\circ$  out of phase.

\* at  $\omega = \omega_0 \rightarrow$  unity power factor  
 $\omega L > \omega_0 \rightarrow$  leading power factor ⑯

at  $\omega > \omega_0$  — lagging power factor



$$\omega_1 = \omega_0 - \frac{\Delta\omega}{2}$$

$$\omega_2 = \omega_0 + \frac{\Delta\omega}{2}$$

$$\text{band width } \Delta\omega = \omega_2 - \omega_1$$

$\omega_1 \rightarrow$  lower cut off frequency  
 $\omega_2 \rightarrow$  higher cut off frequency

QUALITY FACTOR  $\div Q = \frac{|V_L|}{V} = \frac{|V_C|}{V}$

\* 
$$Q = \frac{X_L}{R} = \frac{X_C}{R} = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 R C}$$

\* 
$$Q = \frac{1}{\sqrt{LC}} \times \frac{L}{R} = \frac{1}{R} \sqrt{\frac{L}{C}}$$

$$Q = \frac{\text{resonance frequency}}{\text{Band width}}$$

$$\Delta\omega \text{ (band width)} = \frac{\omega_0}{Q} = \frac{R}{L}$$

- \* Series resonance circuit is called voltage magnifier circuit.

PARALLEL AC CIRCUIT  $\rightarrow$  Branch 1  $= Z_1 = \sqrt{R_1^2 + X_{C1}^2}$   $I_1 = \frac{V}{Z_1}$

$$\left[ \phi_1 = \tan^{-1} \frac{X_{C1}}{R_1} \right]$$

Branch 2  $= Z_2 = \sqrt{R_2^2 + X_{L2}^2}$   $I_2 = \frac{V}{Z_2}$   $\left[ \phi_2 = \tan^{-1} \frac{X_{L2}}{R_2} \right]$

PARALLEL AC CIRCUIT BY PHASOR ALGEBRA  $\div$

$$V = V + j0 = V$$

$$Z_1 = R_1 - jX_{C1} \quad Z_2 = R_2 + jX_{L2}$$

RECTANGULAR FORM  $\div I_1 = \frac{V}{Z_1} = \frac{V}{R_1 - jX_{C1}}$  (18)

$$I_2 = \frac{V}{Z_2} = \frac{V}{R_2 + jX_{L2}}$$

Line current  $I = I_1 + I_2 = \frac{V}{R - jX_{C1}} + \frac{V}{R_2 + jX_{L2}}$

POLAR FORM  $\div V = V \angle 0^\circ$

$$Z_1 = Z_1 \angle -\phi_1^\circ \text{ when } Z_1 = \sqrt{R_1^2 + X_{C1}^2}$$

$$\phi_1 = \tan^{-1} \frac{X_{C1}}{R_1}$$

$$Z_2 = Z_2 \angle \phi_2^\circ \text{ when } Z_2 = \sqrt{R_2^2 + X_{L2}^2} \quad \phi_2 = \tan^{-1} \frac{X_{L2}}{R_2}$$

$$I_1 = \frac{V}{Z_1} = \frac{V \angle 0^\circ}{Z_1 \angle -\phi_1^\circ} = \frac{V}{Z_1} \angle \phi_1^\circ$$

$$I_2 = \frac{V}{Z_2} = \frac{V \angle 0^\circ}{Z_2 \angle \phi_2^\circ} = \frac{V}{Z_2} \angle -\phi_2^\circ$$

$$\text{Line current } I = I_1 + I_2 = \frac{V}{Z_1} \angle \phi_1^\circ + \frac{V}{Z_2} \angle -\phi_2^\circ$$

ADMITTANCE (Y)  $\div Y = \frac{1}{Z} = \frac{1}{V}$

$$\frac{1}{Z_T} = \frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3} + \dots + \frac{1}{Z_n}$$

admittance is the reciprocal of impedance, we have  $Y_T = Y_1 + Y_2 + Y_3 + \dots + Y_n$

\*  $I_1 = \frac{V}{Z_1}, I_2 = \frac{V}{Z_2}, I_3 = \frac{V}{Z_3}, \dots$

$$[I = I_1 + I_2 + I_3 + \dots]$$

\* Components of admittance  $\div$

$$Y = A - jB_L = A + jB_c$$

$$|Y| = \sqrt{A^2 + B_c^2} \text{ and } \sqrt{A^2 + B_c^2}$$

\* Phase Angle  $\div \phi = \tan^{-1} -\frac{B_L}{A}$  and  $\tan^{-1} \frac{B_c}{A}$

the unit of A and B is semence

$$\Rightarrow \underline{\text{CONDUCTANCE}} \div \boxed{G = Y \cos \phi = \frac{1}{Z} \times \frac{R}{Z}}$$

$$G = \frac{R}{Z^2} = \frac{R}{R^2 + X_L^2}$$

$$\text{Susceptance } B_L = y \sin \phi = \frac{1}{Z} \times \frac{X_L}{Z}$$

$$B_L = \frac{X_L}{Z^2} = \frac{X_L}{R^2 + X_L^2}$$

$\Rightarrow$  Impedance at resonance  $\div$  Line current  $I_r = I_L \cos \phi$

$$\frac{V}{Z_r} = \frac{V}{Z_1} \times \frac{R}{Z_L}$$

$$\frac{1}{Z_r} = \frac{R}{Z^2 L} \Rightarrow \frac{1}{Z_r} = \frac{R}{L/C}$$

$$Z_r = \frac{L}{CR}$$

$\Rightarrow$  PARALLEL RESONANCE  $\div$  \* At parallel resonance impedance is maximum and current flow minimum.

- \* at  $\omega_0 = \omega \rightarrow$  unity power factor
- \* at  $\omega_0 > \omega \rightarrow$  lagging power factor
- \* at  $\omega_0 < \omega \rightarrow$  leading power factor
- \* Parallel resonance circuit is also called a current magnifier circuit

\* Dynamic impedance of parallel resonance  $= \frac{L}{RC}$

$$\Rightarrow \underline{\text{QUALITY FACTOR}} \div Q = \frac{|I_L|}{I} = \frac{|I_C|}{I}$$

$$Q = \frac{R}{\omega_0 L} = \omega_0 C R = R \sqrt{\frac{C}{L}}$$

$$Q = \frac{\text{resonance frequency}}{\text{band width}}$$

$$Q = \frac{\text{reactive Power}}{\text{active power}}$$

## 5. MAGNETISATION

### ➤ MAGNET

1) NATURAL MAGNET

\* Magnetite  $[Fe_3O_4]$

2) ARTIFICIAL MAGNET

(i) PERMANENT

\* Alnico \* harden steel

(ii) - TEMPORARY MAGNET

\* electro magnet

### ➤ MAGNETIC FLUX DENSITY $\div$

$$B = \frac{\phi}{A} \quad Wb/m^2$$

where  $\phi$  = flux (weber)  
 $[1 \text{ tesla} = 1 \text{ Wb/m}^2]$

### ➤ PERMABILITY $\div$ $\mu = \mu_0 \mu_r$

$\mu_0$  in air  $= 4\pi \times 10^{-7} \text{ H/m}$

$\mu_r$  = relative permeability  $\mu_r$  (for air) = 1

### ➤ MAGNETIC FLUX INTENSITY (H) $\div$

#### \* AMPER'S CIRCUIT LAW $\div$

$$\oint H dL = \Sigma I$$

$$H = \frac{NI}{l} \quad AT/m$$

#### \* Relation between B & H $\div$

$$B = \mu_0 \mu_r H$$

#### ➤ BIOT SEVERT LAW $\div$

$$dH = \frac{1}{4\pi} \frac{I dt \sin \theta}{r^2} \quad \frac{AT}{m}$$

### ➤ FORCE BETWEEN TWO PARALLEL CURRENT CARRYING CONDUCTOR $\div$

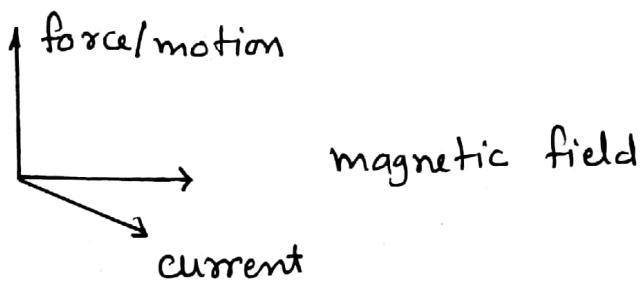
- \* When current flow same direction then attract each other
- \* When current flow in opposite direction the repel to each other.

$$F = 2 \times 10^{-7} \frac{I_1 I_2}{R}$$

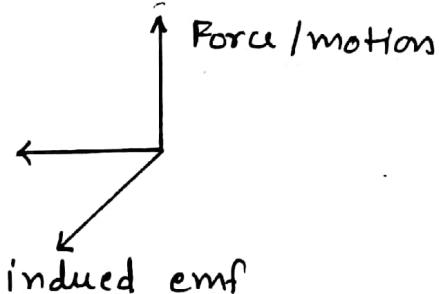
$$F = B I l \sin \theta$$

## ➤ FLAMING LEFT AND RIGHT HAND RULE

### i) LEFT HAND RULE



### ii) RIGHT HAND RULE



\* Used for motor

\* Used for generator  
[dynamic induced emf]

## 6.) MAGNETIC CIRCUIT

### ➤ MAGNETOMOTIVE FORCE (MMF)

\* MMF = N.I amp. turn

\* another unit Gilbert

### ➤ RELUCTANCE

$$S = \frac{1}{\mu} \frac{l}{a} \frac{AT}{Wb}$$

### ➤ OHM'S LAW

$$\text{Reluctance} = \frac{\text{MMF}}{\text{Flux}} \frac{AT}{Wb}$$

$$* S = \frac{NI}{\phi}$$

$$* S = S_1 + S_2 + S_3 + \dots$$

$$= \frac{1}{\mu_0 \mu_1} \frac{l_1}{a_1} + \frac{1}{\mu_0 \mu_2} \frac{l_2}{a_2} + \dots$$

$$* F = F_1 + F_2 + F_3 + \dots$$

$$F = N_1 I + N_2 I + N_3 I$$

$$F = H_1 l_1 + H_2 l_2 + H_3 l_3$$

$$F = \frac{B_1 l_1}{\mu_0 \mu_r} + \frac{B_2 l_2}{\mu_0 \mu_r} + \dots$$

$$AT (\text{in air gap}) \div AT_g = \frac{1}{\mu_0} B_g l_g \text{ AT}$$

(22)

$$AT_g = \frac{1}{4\pi \times 10^{-7}} B_g l_g$$

- Reluctivity =  $\frac{1}{\mu}$ ; [unit - m/H or mH<sup>-1</sup> or H<sup>-1</sup>]  
 → Permeance ÷ unit Wb/AT or Henery

## 7- ELECTRO MAGNETIC INDUCTION

- LEAKAGE FLUX ÷ ★ Leakage factor =  $\frac{\text{total flux}}{\text{useful flux}}$   $\frac{\phi_T}{\phi_u}$   
 ★  $\phi_T = \phi_u + \phi_L$  [Leakage flux > 1]
- FARADAY'S LAW ÷ i) FIRST LAW → When conductor cuts a flux or flux cuts a conductor or any relative change between flux and conductor then emf induced in a conductor.  
 ii) SECOND → The magnitude of this induced emf depends upon the rate of change of magnetic flux.
- $$e = N \frac{d\phi}{dt}$$
- LAWZ'S LAW ÷
- $$e = -N \frac{d\phi}{dt}$$
- \* It represent direction of static induced emf.
- STATIC INDUCED EMF ÷
- $$e = \frac{Nd\phi}{dt}$$
- DYNAMIC INDUCED EMF ÷
- $$e = Blv \sin\theta$$
- SELF INDUCED EMF ÷
- $$e = -L \frac{dI}{dt}$$
- $$L = \frac{N\phi}{I}$$

$$L = \frac{N^2 \mu A}{J}$$

→ MUTUAL INDUCED EMF ÷ \*

$$e = -M \frac{dI}{dt}$$

$$M = -N_2 \frac{K\phi_1}{I} H *$$

$$K = \frac{M}{\sqrt{L_1 L_2}}$$

\* When  $K=0 \rightarrow$  no coupling

\*  $K=1 \rightarrow$  normal coupling

\*  $K > 1 \rightarrow$  tight coupling

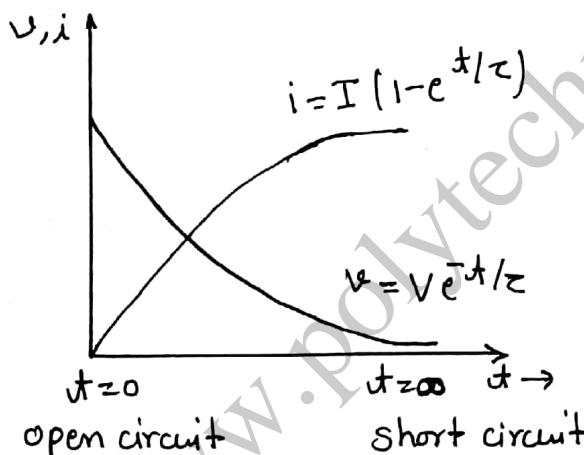
\*  $K < 1 \rightarrow$  loose coupling

→ CHARGING OF INDUCTOR ÷

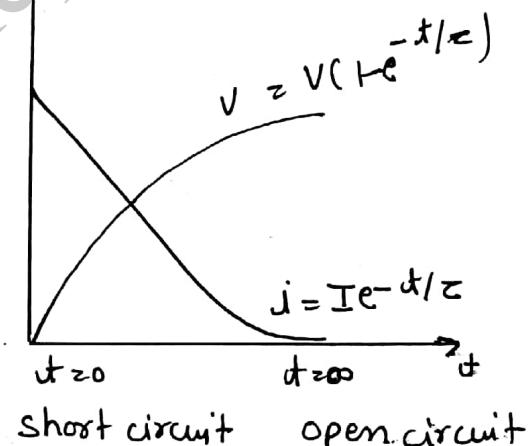
$$i = I(1 - e^{-t/\tau})$$

$$V = V e^{-t/\tau}$$

$$\tau = \frac{L}{R}$$



Charging



Discharging.

\* Inductor discharge the same direction as charging.

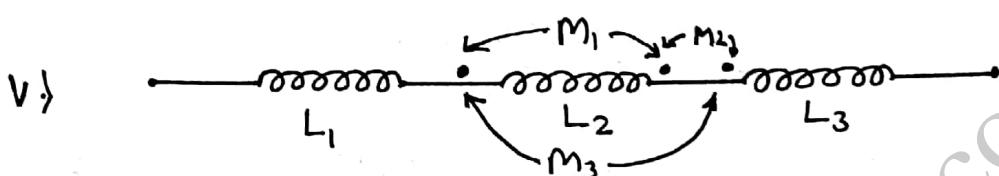
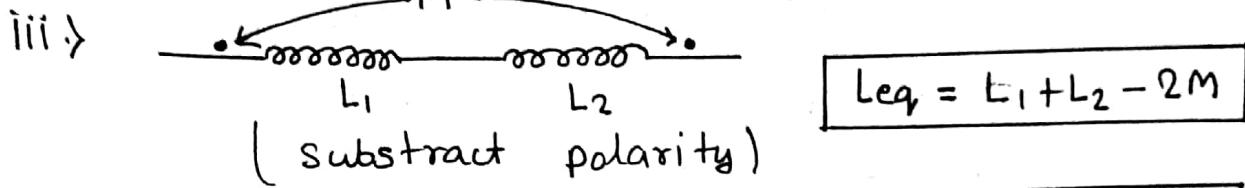
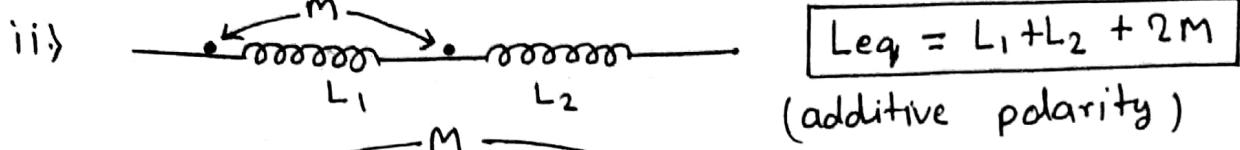
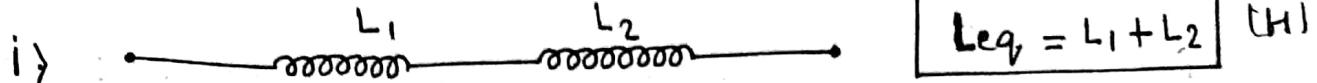
→ DISCHARGING OF INDUCTOR ÷

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

$$V = V(1 - e^{-t/\tau})$$

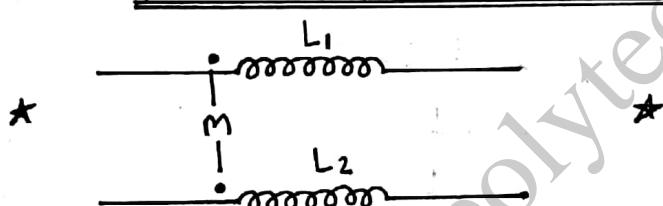
→ COMBINATION OF INDUCTOR ÷

SERIES COMBINATION ÷

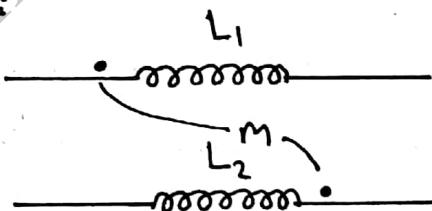


$$L_{eq} = L_1 + L_2 + L_3 + 2M_1 - 2M_2 - 2M_3$$

### ⇒ PARALLEL COMBINATION ∵



$$L_{eq} = \frac{L_1 L_2 - M^2}{L_1 + L_2 - 2M}$$



$$L_{eq} = \frac{L_1 L_2 - M^2}{L_1 + L_2 + 2M}$$

### ⇒ HYSTERESIS LOSS ∵ $P_h = K_h f V B_m^\chi$ watt

$$\chi = 1 \text{ to } 2$$

\*  $K_h$  for harder steel = 250

\*  $K_h$  for soft steel = 500

### ⇒ EDDY CURRENT LOSS →

$$P_e = K f^2 d^2 V B_{max}^2 \text{ watt}$$

RS

## \* RISE OF CURRENT IN AN INDUCTIVE CIRCUIT

RL series circuit  $\Rightarrow i = I(1 - e^{-t/\tau})$

$$I = \frac{V}{R} \quad \tau \text{ (time constant)} = \frac{L}{R}$$

de current in an inductor circuit

$$i = I(e^{-t/\tau}) \quad [\tau = \frac{L}{R}]$$

Energy stored in magnetic field

$$[E = \frac{1}{2} LI^2] \text{ Joule}$$

## \* MAGNETIC ENERGY STORED PER UNIT VOLUME

$$\begin{aligned} \text{energy stored / m}^3 &= \frac{B^2}{2\mu_0 M_s} \text{ Joule} \\ &= \frac{B^2}{2\mu_0} \text{ in air} \end{aligned}$$

- $\Rightarrow$  \* Ferro Magnetic Material  $M \approx 1000$
- \* Para Magnetic Material  $\mu > 1$
- \* Dia Magnetic material  $\mu < 1$

- \* Unit of magnetic flux = weber
- \* Magnetic flux density = Wb/m<sup>2</sup> or tesla
- \* Permeability - H/m
- \* Relative Permeability - no unit
- \* Magnetic flux intensity - AT/m
- \* MMF - AT
- \* Reluctance - AT/Wb

## 8. THREE PHASE SYSTEM

⇒ CONDITION FOR BALANCED :-

i) each phase displacement at  $120^\circ$

$$\theta = \frac{2\pi}{n} \quad (n > 2)$$

ii) current magnitude in each phase are equal

$$|I_R| = |I_Y| = |I_B|$$

iii) voltage magnitude in each phase is equal

$$|V_R| = |V_Y| = |V_B|$$

iv) Current in neutral is zero.

\* [in 2-φ system phase displacement is  $90^\circ$ ]

⇒ \* Indian standard voltage      3-φ - 415 Volt  
    1-φ - 230 Volt

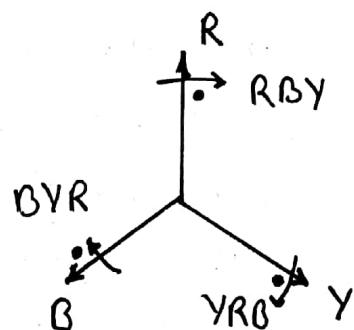
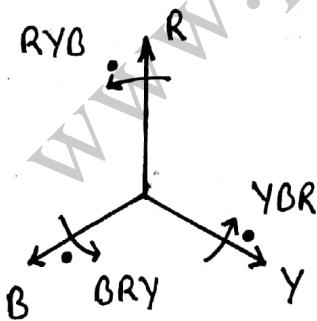
3-φ Balanced System :-

$$E_R = E_{max} \sin \theta$$

$$E_Y = E_{max} \sin (\theta - 120^\circ)$$

$$E_B = E_{max} \sin (\theta - 240^\circ)$$

⇒ PHASE SEQUENCE :-



\* Positive Phase Sequence

$$RYB = YBR = BRY$$

\* Negative Phase sequence

$$RBY = YRB = BYR$$

⇒ 3-φ star connection when load balanced :-

$$* I_L = I_{ph}$$

$$V_L = \sqrt{3} V_{ph} \quad \text{or} \quad V_{ph} = \frac{V_L}{\sqrt{3}} \quad \text{or} \quad V_{ph} = 0.577 V_L \quad V_L = 1.73 V_{ph}$$

$$P = \sqrt{3} V_L I_L \cos \phi$$

$$\text{or } P = 3 V_{ph} I_{ph} \cos \phi$$

$\Rightarrow$  3-φ Delta connection when load balanced  $\rightarrow$

$$I_L = \sqrt{3} I_{ph} \quad \text{or} \quad I_{ph} = 0.577 I_L$$

$$V_L = V_{ph} \quad P = \sqrt{3} V_L I_L \cos \phi \quad \text{or} \quad P = 3 V_{ph} I_{ph} \cos \phi$$

$\Rightarrow$  FOR UNBALANCE LOAD  $\div$

in Star connection  $P = V_{RN} I_R \cos \phi_R + V_{YN} I_Y \cos \phi_Y + V_{ON} I_B \cos \phi_B$

in delta connection  $P = V_{AY} I_1 \cos \phi_1 + V_{YB} I_2 \cos \phi_2 + V_{BA} I_3 \cos \phi_3$

$\Rightarrow$  TWO WATTMETER METHOD  $\div$

$$\text{total power} = w_1 + w_2 \quad [\text{Power factor} = \cos \phi]$$

$$\phi = \tan^{-1} \sqrt{3} \left( \frac{w_1 - w_2}{w_1 + w_2} \right)$$

\*  $w_1 = V_L I_L \cos (30^\circ + \phi)$  and \*  $w_2 = V_L I_L \cos (30^\circ - \phi)$

\*  $w_1 + w_2 = \sqrt{3} V_L I_L \cos \phi$  \*  $w_2 - w_1 = V_L I_L \sin \phi$

- $\Rightarrow$  \* When both wattmeter reading is same then power factor is unity. ( $\phi = 90^\circ$ )
- \* When one wattmeter reading is zero - then power factor .. 0.5 ( $\phi = 60^\circ$ )
- \* When both wattmeter reading is same and opposite then power factor zero.
- \* When one wattmeter reading is positive and another wattmeter is -ve read then power factor less than 0.5

→ HOW TO APPLY FORMULA ÷ .  $\tan \phi = \sqrt{3} \frac{w_2 - w_1}{w_2 + w_1}$

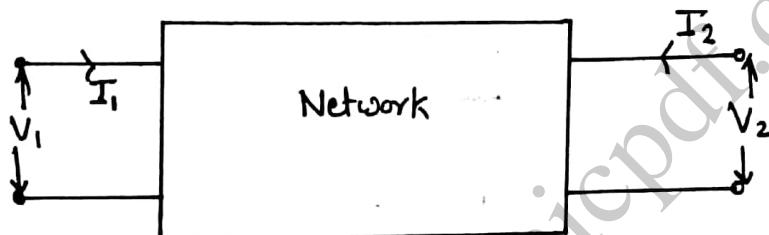
\* Lagging power factor

$$\tan \phi = \sqrt{3} \frac{w_1 - w_2}{w_1 + w_2}$$

\* Leading power factor

or  $\tan \phi = \sqrt{3} \left[ \frac{(\text{higher reading}) - (\text{lower reading})}{(\text{higher reading}) + (\text{lower reading})} \right]$

## 9. > TWO PORT NETWORK

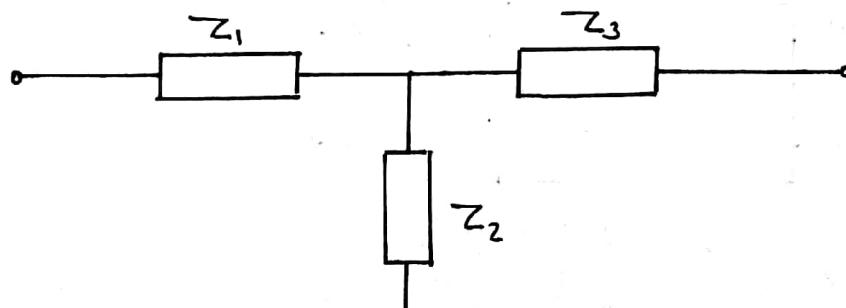


## OPEN CIRCUITT PARAMETER / Z- PARAMETER / IMPEDANCE

PARAMETER ÷ : 
$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

when  $I_2 = 0$  then  $Z_{11} = \frac{V_1}{I_1} \Omega$        $Z_{21} = \frac{V_2}{I_1} \Omega$

when  $I_1 = 0$  then  $Z_{12} = \frac{V_1}{I_2} \Omega$        $Z_{22} = \frac{V_2}{I_2} \Omega$



$$\begin{bmatrix} Z_{11} = Z_1 + Z_2 \\ Z_{21} = Z_2 \end{bmatrix}$$

$$\begin{bmatrix} Z_{12} = Z_2 \\ Z_{22} = Z_2 + Z_3 \end{bmatrix}$$

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# Y-PARAMETER / ADDMITTANCE PARAMETER / SHORT CIRCUIT

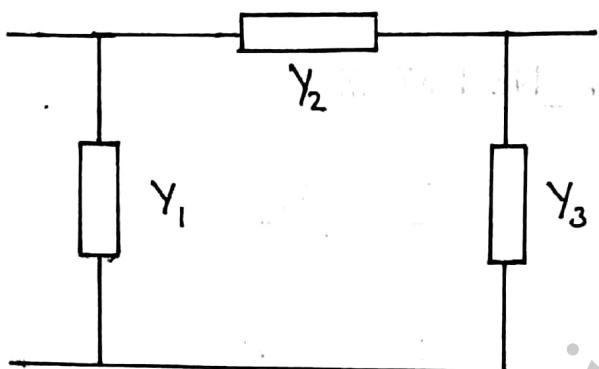
PARAMETER ÷

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

$$I_1 = Y_{11}V_1 + Y_{12}V_2 \quad I_2 = Y_{21}V_1 + Y_{22}V_2$$

$$\text{when } V_2=0 \quad Y_{11} = I_1/V_1 - \sigma \quad Y_{21} = \frac{I_2}{V_1} - \sigma$$

$$\text{when } V_1=0 \quad Y_{12} = \frac{I_1}{V_2} - \sigma \quad Y_{22} = \frac{I_2}{V_2} - \sigma$$

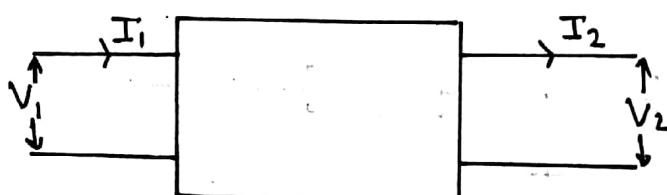


$$\begin{bmatrix} Y_{11} = Y_1 + Y_2 \\ Y_{21} = -Y_2 \end{bmatrix} \quad \begin{bmatrix} Y_{12} = -Y_2 \\ Y_{22} = Y_2 + Y_3 \end{bmatrix}$$

$$Y = \frac{1}{[Z]} = [Z]^{-1} \quad \text{or} \quad [Z] = \frac{1}{[Y]} = [Y]^{-1}$$

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \frac{1}{AB-BC} \begin{bmatrix} D & -B \\ -C & A \end{bmatrix}$$

# T PARAMETER (TRANSMISSION PARAMETER) ÷



$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ I_2 \end{bmatrix}$$

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$$V_1 = AV_2 + BV_2 \quad \text{and} \quad I_1 = CV_2 + DV_2$$

$$\text{when } V_2=0 \quad \text{then} \quad B = \frac{V_1}{I_1} \Omega \quad D = \frac{I_1}{V_2}$$

when  $I_2 = 0$

$$A = \frac{V_1}{V_2} \quad \text{and} \quad C = \frac{I_1}{V} - \sigma$$

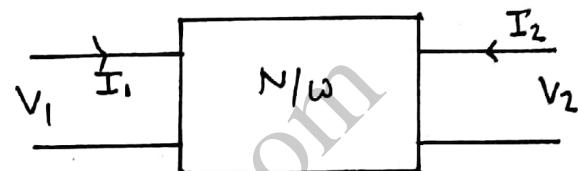
\*  $\begin{bmatrix} A & B \\ C & D \end{bmatrix}$  here  $A$  &  $D$  having no unit  
 $B$  unit  $\Omega$  and unit of  $C$   $\text{v}^{-1}$

\* Condition of symmetrical  $A=D$

\* Condition of unsymmetrical  $AD-BC=1$

⇒

### HYBRID PARAMETER



$$\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} V_2 \\ I_1 \end{bmatrix}$$

$$V_1 = h_{11}V_2 + h_{12}I_2 \quad I_2 = h_{21}V_2 + h_{22}I_1$$

when  $V_2 = 0$  then  $h_{11} = \frac{V_1}{I_1} \Omega$  (impedance)

$$h_{22} = \frac{I_2}{V_2}$$

when  $I_1 = 0$   $h_{11} = \frac{V_1}{V_2}$ ,  $h_{21} = \frac{I_2}{V_2} \text{ v}^{-1}$  (admittance)

\*

$$\begin{bmatrix} h_{11}(\Omega) & h_{12} \\ h_{21} & h_{22} (\text{v}^{-1}) \end{bmatrix}$$

### LAPLACE TRANSFORM

$$f(s) = \int_0^\infty f(t) e^{-st} dt$$

⇒ \*  $f(t) = u(t) \quad f(s) = \frac{1}{s}$

\*  $f(t) = \delta(t) \quad f(s) = 1$

\*  $f(t) = A R(t) \quad f(s) = \frac{A}{s^2} \quad (31)$

- \*  $f(t) = R(t)$        $f(s) = \frac{1}{s^2}$
- \*  $f(t) = t^2$        $f(s) = \frac{1}{s^3}$
- \*  $f(t) = e^{-at}$        $f(s) = \frac{1}{(s+a)}$
- \*  $f(t) = e^{at}$        $f(s) = \frac{1}{s-a}$
- \*  $f(t) = 10e^t$        $f(s) = \frac{10}{(s-a)}$
- \*  $f(t) = t^n u(t)$        $f(s) = \frac{n}{s^{n+1}}$
- \*  $f(t) = \sin \omega t$        $f(s) = \frac{\omega}{s^2 + \omega^2}$
- \*  $f(t) = \cos \omega t$        $f(s) = \frac{s}{\omega^2 + s^2}$

$\frac{d f(t)}{dt} \xrightarrow{t} s f(s) - f(0^+)$
$\int f(t) dt \xrightarrow{} \frac{f(s)}{s} - \frac{f(0^+)}{s}$

### Represent of element

ELEMENT	INITIAL CONDITION	FINAL CONDITION
$i_L(0^+)$	$i_L(0^+)$	$i_L(0^+)$
$V_C(0^+)$	$V_C(0^+)$	$V_C(0^+)$