BASIC OF ELECTRICAL ENGINEERING

1. Basic of electricity :

⇒ **electron** :

charge = -1.6×10^{-19} coulomb

mass = 9.11×10^{-31} Kg

⇒ **Proton** :

Charge = 1.6×10^{-19} coulomb

mass = 1.67×10^{-21} Kg

⇒ $\dfrac{\text{mass of Protone}}{\text{mass of electron}} = 1840$

⇒ current (i) $= \dfrac{dQ}{dt}$

$\boxed{I = \dfrac{Q}{t}}$ amper

⇒ Potential (V) $= \dfrac{W}{Q} \dfrac{(\text{work})}{(\text{charge})}$ $\dfrac{\text{Jule}}{\text{Colomb}}$ or Volt

⇒ Voltage drop (V) = IR Volt or amp· ohm

⇒ Resistance , $R = \rho \dfrac{l}{a}$ ohm

ρ = resistivity unit Ω-m (ohm meter)

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

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 COEFFICENT OF RESISTANCE ÷

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

where $R_t - R_0 \rightarrow$ change in resistance

$R_0 \rightarrow$ basic (initial) resistance

$t \rightarrow$ change in temperature

$$\boxed{R_t = R_0(1 + \alpha t)}$$

$$\boxed{\alpha_t = \frac{\alpha_0}{R_0(1 + \alpha_0 t)}}$$

Metal	temp coefficient
Maganin	0.00015 /°c
Constantan	0.00020 /°c
Copper	0.004 /°c

CONNECTION OF RESISTANCE ÷

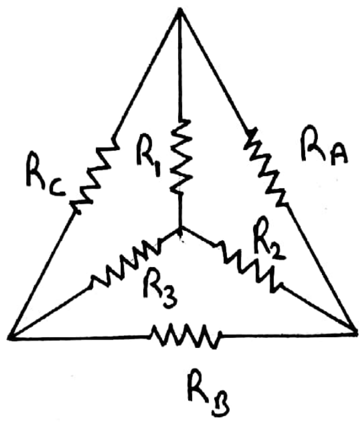
i) Series ÷

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

ii.) <u>Parallel</u> ÷

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

⇛ STAR TO DELTA CONVERSION ÷

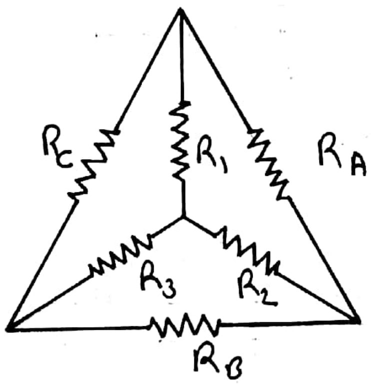


$$\boxed{R_A = R_1 + R_2 + \frac{R_1 R_2}{R_3}}$$

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

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

⇛ DELTA TO STAR CONVERSION ÷



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

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

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

⇛ OHM'S LAW ÷

$$I \propto V$$

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

$$\boxed{V = IR} \text{ volt}$$

⇛ Power calculation in DC ÷

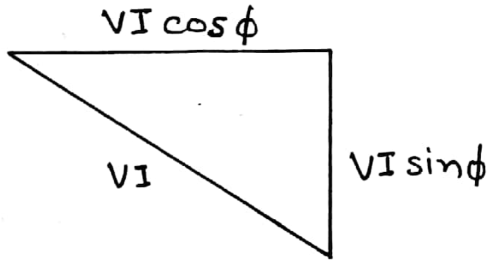
$$\boxed{P = VI = \frac{V^2}{R} = I^2 R} \text{ watt}$$

⇒ Power calculation in AC →

apperent power = VI (volt-amp)

active power = VI cos φ (watt)

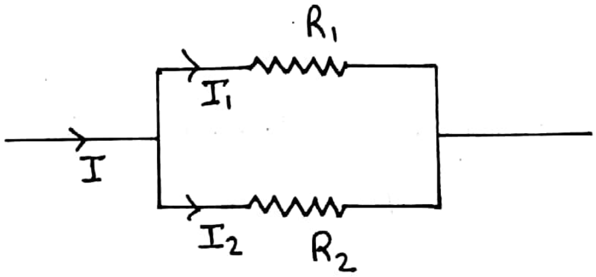
reactive power = VI sin φ (VAR)



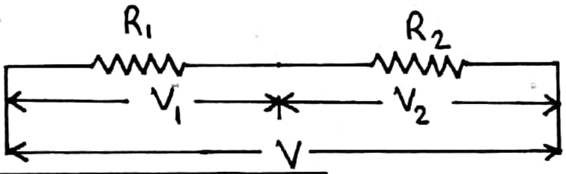
⇒ CURRENT DEVISION RULE ÷

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

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



⇒ VOLTAGE DEVISION RULE ÷



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

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

QUANTITY	SI UNIT
Charge	coulomb (C)
current	amper (A) or coulomb/sec
EMF	volt (V)
voltage drop	Volt (V)
Potential diff.	Volt (V)

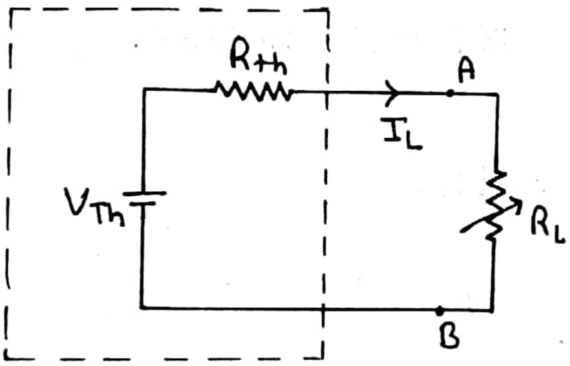
QUANTITY	SI UNIT
Resistance	ohm (Ω)
Resistivity	Ω-m
temp. coeffi.	/°c
Power	watt
apprent power	VA
active power	watt
reactive power	VAR

→ Direction of emf source :

−Ve +Ve

→ THEVENIN'S THEOREM :

Any active network converted in to single equivalent voltage source and single equivalent resistance and both are connected in series.



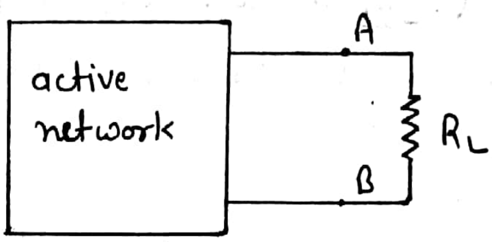
$$\boxed{I_L = \frac{V_{th}}{R_{th} + R_L}}$$

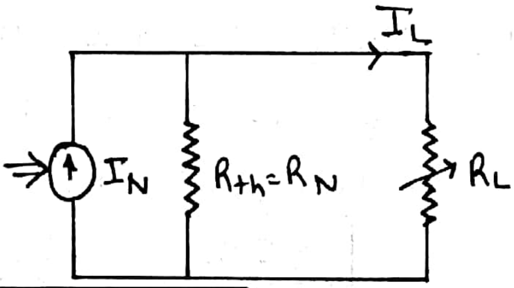
where V_{th} – thevenin equivelent voltage or open circuit Volt age

R_{th} – thevenin equivelent resistance

→ NORTON'S THEOREM :

Complete network current calculated as norton current I_n and total resistance is calculated as norton resistance





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

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

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

⇒ ***

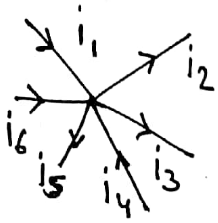
1 KWh	=	860 KCal
1 KCal	=	4184 Joule
1 Kcal	=	4.18 KJoule
1 KWh	=	3.6×10^6 Joule

2.) BASIC ELECTRICAL AND NETWORK THEOREM

⇒ i.) KIRCHOFF'S CURRENT LAW ÷ (KCL)

[incomming current = outgoing current]

$$\boxed{i_1 + i_4 + i_6 = i_2 + i_3 + i_5}$$



⇒ * [no. of KCL equtation = (no. of node − 1)] **

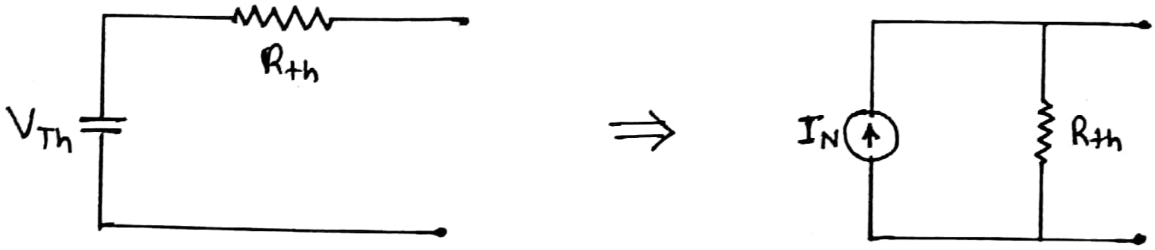
⇒ ii.) KIRCHOFF'S VOLTAGE LAW ÷ (KVL) ⇒ In any loop algebric sum of EMF and algebric sum of voltage drop will be zero.

$$\boxed{\Sigma EMF + \Sigma IR = 0}$$

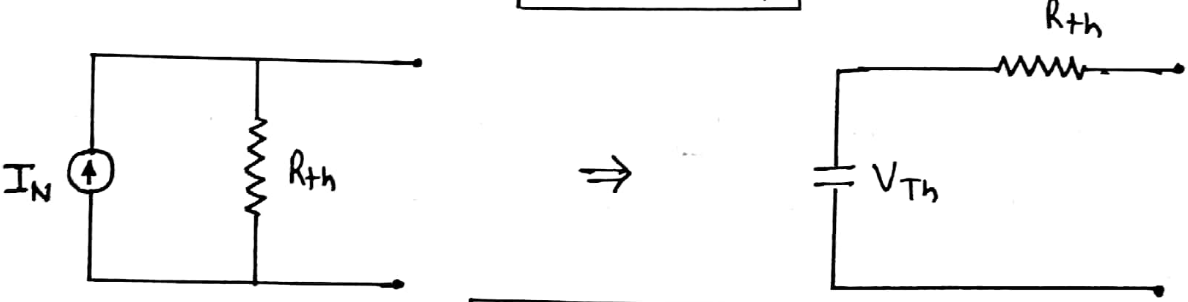
* [no. of KVL equtation = (b − n + 1)]

where b = no of branch.
n = no of node.

⇒ SOURCE CONVERSION ÷



$$\boxed{I_N = \frac{V_{th}}{R_{th}}}$$

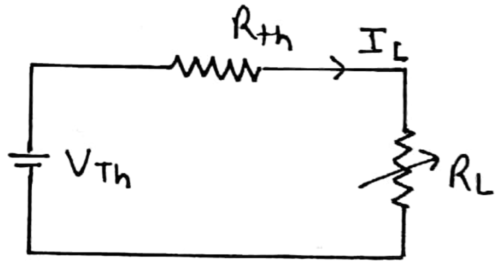


$$\boxed{V_{th} = I_N R_{th}}$$

⇒ MAXIMUM POWER TRANSFER ÷

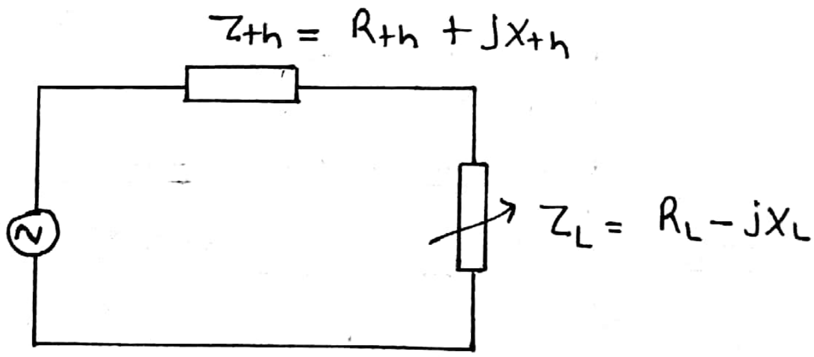
$$\left[P_{L(max)} = \frac{V_{Th}^2}{4R_{th}} \right]$$

$$[\% \ \eta = 50\%]$$



★ condition for maximum power t/f ÷ $R_{th} = R_L$

⇒ For AC



for maximum power t/f

$$[Z_L = Z_{th}^{*}]$$

⇒ SUPER POSITION THEOREM ÷

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

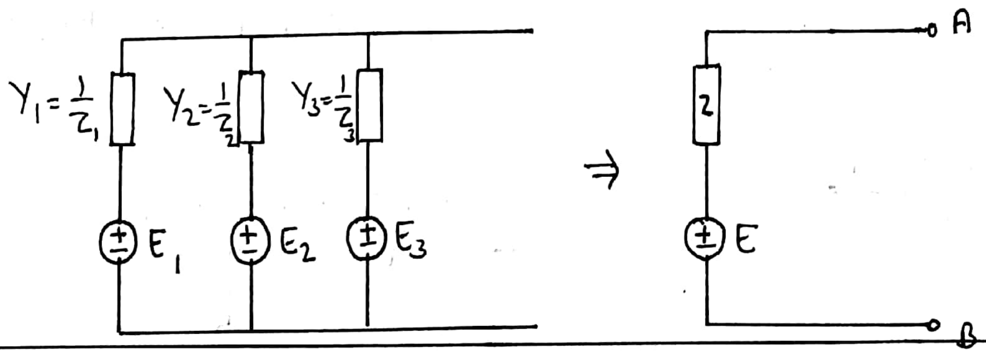
⇒ RECIPROCITY THEOREM ÷

Ratio of excitation to responce it constant when the position of excitation and responce are interchange.

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

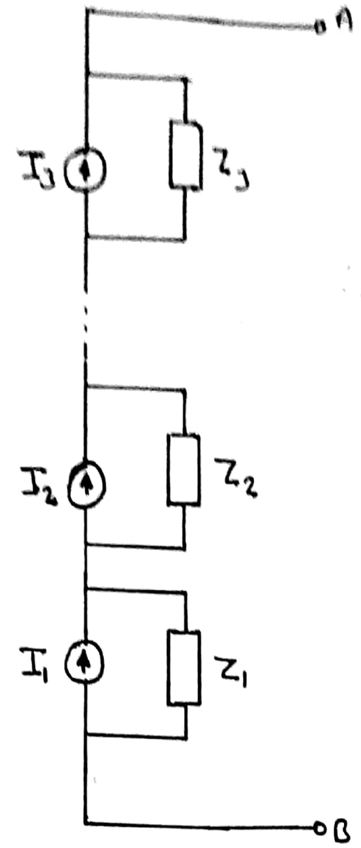
$$\boxed{\frac{V_1}{I_2} = \frac{V_2}{I_1}}$$

⇒ MILLMAN'S THEOREM ÷

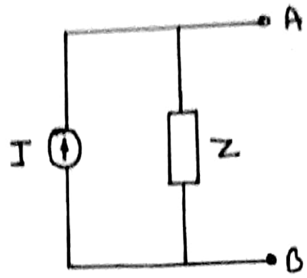


$$\boxed{E = \frac{\sum_{i=1}^{n} E_i Y_i}{\sum_{i=1}^{n} Y_i} = \frac{E_1 Y_1 + Y_2 E_2 + \dots + E_n Y_n}{Y_1 + Y_2 + \dots + Y_n}}$$

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



$\Rightarrow$



$$\boxed{I = \frac{\sum_{i=1}^{n} I_1 Z_1}{\sum_{i=1}^{n} Z_i}}$$

$$\boxed{Z = \sum_{i=1}^{n} Z_i}$$

Non liniar → active → unidirectional

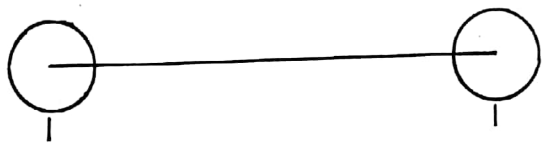
liniar → passive → bidirectionall.

3 ELECTROSTATIC

⇒ COULOMB LAW ÷

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

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



$$\boxed{F = \frac{1}{4\pi\varepsilon_0\varepsilon_r} \frac{Q_1 Q_2}{d^2}}$$

where $\varepsilon = \varepsilon_0 \varepsilon_r$ (permitivity) F/m

ε_0 (air) $= 8.854 \times 10^{-12}$ F/m

ε_r (relative pemativity) air = 1 no unit

for air gap

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

⇒ ELECTRIC FIELD INTENSITY

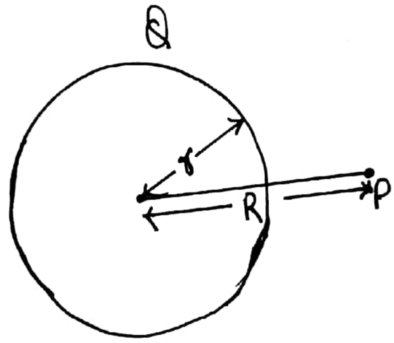
$$E = \frac{F}{Q} \quad N/C$$

$$\boxed{E = \frac{1}{4\pi\varepsilon_0\varepsilon_r} \frac{Q}{d^2}} \quad N/C$$

★ E at point P $= \frac{1}{4\pi\varepsilon_0\varepsilon_r} \frac{Q}{R^2}$

★ E at surface $= \frac{1}{4\pi\varepsilon_0\varepsilon_r} \frac{Q}{r}$

★ E inside = zero



⇒ ELECTRIC FIELD DENSITY (CHARGE DENSITY) ÷

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

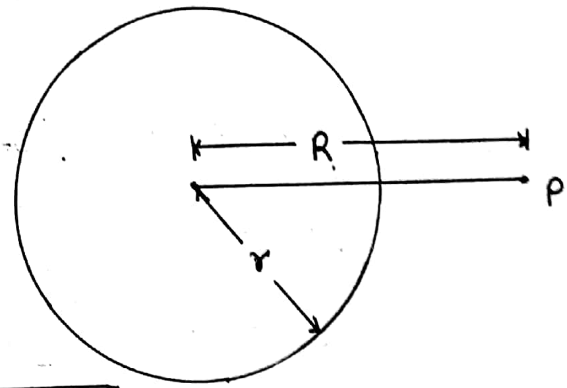
⇒ Relation between electrical field intensity and density ÷

$$\boxed{D = \varepsilon_0 \varepsilon_r E}$$

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

$$\boxed{V = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\frac{Q}{d}}$$

$$\boxed{V \text{ at point } P = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\frac{Q}{R}}$$



$$\boxed{V \text{ at surface} = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\frac{Q}{r}}$$

$$\boxed{V_{inside} = V_{at\ surface} = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\frac{Q}{r}}$$

⇒ Relation between electric field intensity and voltage ÷

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

⇒ **CAPACITOR** ÷ $\left[C = \frac{\varepsilon A}{d}\right]$ Farad

$Q \propto V$

$\boxed{Q = CV}$ coulomb

$\boxed{C = Q/V}$ farad

* 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

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

* PARALLEL COMBINATION :-

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

⇒ CHARGING OF A CAPACICTOR :-

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

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

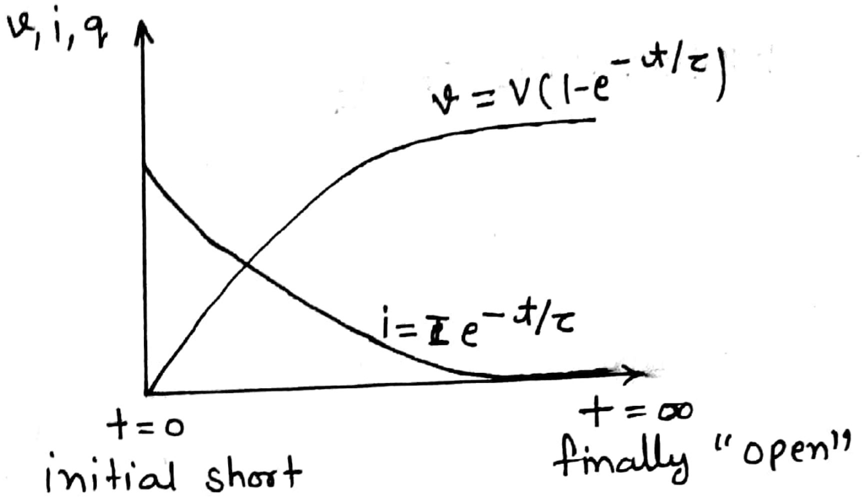
$$\boxed{q = Q(1-e^{-t/\tau})}$$

wher τ = time constant = RC

v = 63.2% of V

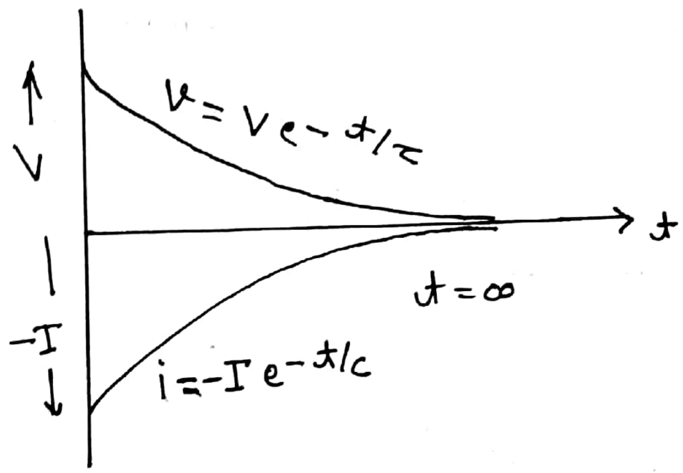
[∴ time constant = 63.2% of full voltage]

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



Charging of a capacitor

⇒ DISCHARGING OF A CAPACITOR :-



$$\boxed{\begin{aligned} v &= Ve^{-t/RC} \\ i &= -Ie^{-t/RC} \\ q &= Qe^{-t/RC} \end{aligned}}$$

⇒ ENERGY STORED IN A CAPACITOR :- $\boxed{E = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}}$

QUANTITY	SI UNIT	QUANTITY	SI UNIT
Force	Newton (N)	Permitivity	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 $= \frac{\text{area under one cycle}}{\text{time period}}$

→ avarage value of →

★ sinosuidal 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 peresent in the ac. It measured by PMMC.

→ RMS VALUE → It is that value of dc supply which do the same ammount 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 $= V_m, I_m$

★ trangular wave $= \frac{V_m}{\sqrt{3}}$ Volt

→ FORM FACTOR ÷ $\boxed{f.f. = \frac{\text{rms value}}{\text{average value}}}$

★ for sinewave = 1.11

★ half wave = 1.57

★ full wave rectifier = 1.11

★ for rectangular wave = 1

★ for trangular wave = 1.16

★ highest f.f	→ half wave
★ lowest f.f.	→ rectangular

⇒ **PEAK FACTOR** ÷ $P.F. = \dfrac{\text{Peak value (maximum value)}}{\text{rms value}}$

* ★ Peak factor for ÷ sin wave = 1.41
* ★ for half wave rectifier = 2
* ★ for full wave rectifier = 1.41
* ★ for rectangular - 1
* ★ for trangular - 1.73

⇒ **RIPPLE FACTOR** ÷ $R.F = \sqrt{(\text{formfactor})^2 - 1}$

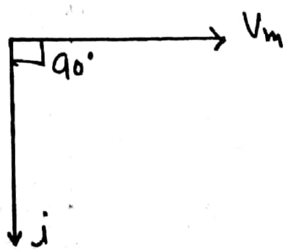
* ★ for sine wave = 0.482
* ★ for half wave rectifier = 1.21
* ★ for full wave rectifier = 0.482
* ★ for rectangular wave = 0
* ★ for trangular wave = 0.587 or 0.59

⇒ **RESISTANCE** → $i = \dfrac{V_m}{R}$

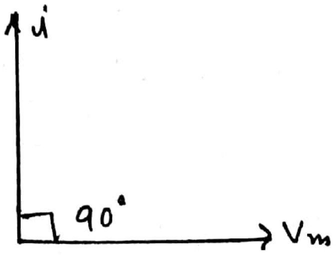
* ★ Power factor - unity
* ★ active power = $VI\cos\phi$ = VI watt
* ★ reactive power = zero
* ★ Active power = apperent power

⇒ **INDUCTOR** → ★ $i = \dfrac{V_m}{X_L}[\sin(\omega t + 90°)]$ ★ $\left[I_m = \dfrac{V_m}{X_L}\right]$

* ★ active power = $VI\cos 90°$ = zero (0)
* ★ apperent power = VI VA
* ★ reactive power = VI VAR (lagging reactive power)
* ★ Power consuption zero
* ★ Power fator - zero lagging



for inductor



for capacitor

⇒ **CAPACITOR** ÷ ★ Active Power zero

★ apprent power = VI

★ reactive power = $VI \sin 90° = VI$

★ [apperent power = leading reactive power]

★ Power factor = zero leading

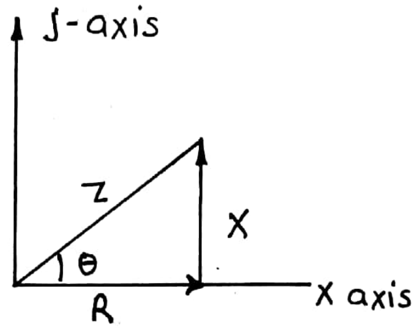
⇒ **IMPEDANCE** → Which offerd oppsition to flow of current in AC is called impedance.

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

+Ve sign → legging & −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 (℧), Semance

$$Y = G \pm jB$$

where +Ve sign − leading & −Ve sign − lagging

G = Conductance, B = Susceptance (℧)

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

⇒ **SERIES R-L CIRCUIT** ÷ $Z = R + jX_L$

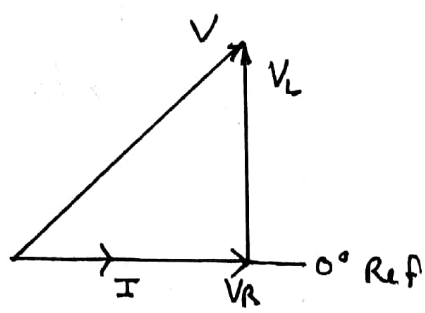
★ $|Z| = \sqrt{R^2 + X_L^2}$

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

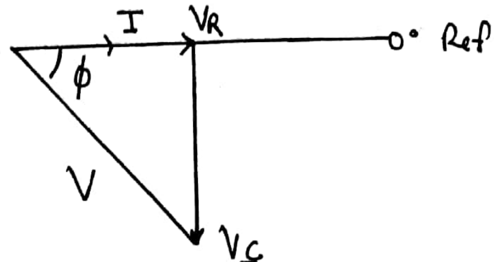
★ Power factor = $\cos\phi$

★ active power = $VI \cos\phi$

★ $\vec{V} = \vec{V_R} + \vec{V_L}$



⇒ SERIES RC CIRCUIT :- $Z = R - jX_C$



$[\vec{V} = \vec{V_C} + \vec{V_R}]$

* ★ $|Z| = \sqrt{R^2 + X_C^2}$
* ★ $\phi = \tan^{-1}\left(\frac{X_C}{R}\right)$
* ★ active power $= VI\cos\phi$

⇒ SERIES RLC CIRCUIT :- $\vec{V} = \vec{V_R} + \vec{V_L} + \vec{V_C}$

* ★ $\frac{V}{I} = R + j(X_L - X_C)$
* ★ $Z = R + j(X_L - X_C) \Rightarrow |Z| = \sqrt{R^2 + (X_L - X_C)^2}$
* ★ $\theta = \tan^{-1}\frac{(X_L - X_C)}{R}$

⇒ SERIES RESONANCE :- ★ $Z = R + j(X_L - X_C)$

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

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

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

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

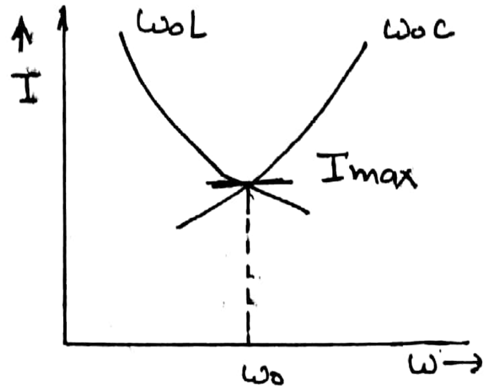
$$\left[f_0 = \frac{1}{2\pi\sqrt{LC}} \text{ Hz}\right]$$

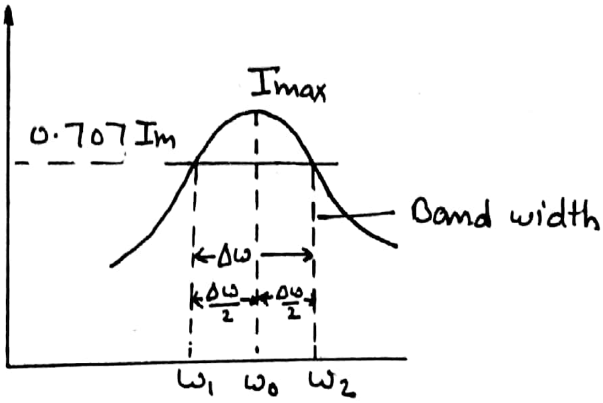
$$\left[I = \frac{V}{|Z|} = \frac{V}{\sqrt{R^2 + (X_L - X_C)}}\right]$$

* ★ 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° out of phase.

* ★ at $\omega = \omega_0 \rightarrow$ unity power factor
  $\omega < \omega_0 \rightarrow$ leading power factor

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





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

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

band width $\Delta\omega = \omega_2 - \omega_1$

$\omega_1 \rightarrow$ lower cut of frequency

$\omega_2 \rightarrow$ higher cut of frequency

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

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

★ $\boxed{Q = \frac{1}{\sqrt{LC}} \times \frac{L}{R} = \frac{1}{R}\sqrt{\frac{L}{C}}}$ $\boxed{Q = \frac{\text{resonance frequency}}{\text{Band width}}}$

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

★ Series resonance circuit is called voltage magnifier circuit.

PARALLEL AC CIRCUIT → Branch 1 - $Z_1 = \sqrt{R_1^2 + X_{C_1}^2}$ $I_1 = \frac{V}{Z_1}$

$\left[\phi_1 = \tan^{-1}\frac{X_{C_1}}{R_1}\right]$

Branch 2 = $Z_2 = \sqrt{R_2^2 + X_{L_2}^2}$ $I_2 = \frac{V}{Z_2}$ $\left[\phi_2 = \tan^{-1}\frac{X_{L_2}}{R_2}\right]$

PARALLEL AC CIRCUIT BY PHASOR ALGEBRA ÷

$V = V + j0 = V$

$Z_1 = R_1 - jX_{C_1}$ $Z_2 = R_2 + jX_{L_2}$

RACTANGULAR FORM ÷ $I_1 = \frac{V}{Z_1} = \frac{V}{R_1 - jX_{C_1}}$

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

line current $\left[I = I_1 + I_2 = \frac{V}{R - jX_{C1}} + \frac{V}{R_2 + jX_{L2}} \right]$

POLAR FORM ÷ $V = V\angle 0^\circ$

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

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

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

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

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

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) ÷ $Y = \frac{1}{Z} = \frac{I}{V}$

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

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

★ $I_1 = \frac{V}{Z_1}$, $I_2 = \frac{V}{Z_2}$, $I_3 = \frac{V}{Z_3}$ ...

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

★ **Components of admitance ÷**

$$\boxed{Y = G - jB_L = G + jB_C}$$

$|Y| = \sqrt{G^2 + B_L^2}$ and $\sqrt{G^2 + B_C^2}$

★ **Phase Angle ÷** $\boxed{\phi = \tan^{-1} -\frac{B_L}{G}}$ and $\boxed{\tan^{-1}\frac{B_C}{G}}$

the unit of G and B is semence

⇒ **CONDUCTANCE** ÷ $\boxed{G = Y\cos\phi = \frac{1}{Z} \times \frac{R}{Z}}$

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

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

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

⇒ Impedance at resonance ÷ line current $I_r = I_L\cos\phi$

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

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

⇒ **PARALLEL RESONANCE** ÷ ★ At parallel resonance impedance is maximum and current flow minimum.

★ at $\omega_0 = \omega$ → unity power factor
★ at $\omega_0 > \omega$ → lagging power factor
★ at $\omega_0 < \omega$ → leading power factor
★ Parallel resonance circuit is also called a current magnifire circuit

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

⇒ **QUALITY FACTOR** ÷ $Q = \frac{|I_L|}{I} = \frac{|I_c|}{I}$

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

$$\boxed{Q = \frac{\text{resonance frequency}}{\text{band width}}} \qquad \boxed{Q = \frac{\text{reactive Power}}{\text{active power}}}$$

5. MAGNETISATION

MAGNET

1.) NATURAL MAGNET

* Magnetite [Fe_3O_4]

2.) ARTIFICIAL MAGNET

(i) PARMANENT

* Alnico * harden steel

(ii) – TEMPERARY MAGNET

* electro magnet

MAGNETIC FLUX DENSITY ÷

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

where ϕ = flux (weber)

[1 tesla = 1 Wb/m²]

PERMABILITY ÷

$\mu = \mu_0 \mu_r$

μ_0 in air $= 4\pi \times 10^{-7}$ H/m

μ_r = relative permitivity μ_r (for air) = 1

MAGNETIC FLUX INTENSITY (H) ÷

* AMPER'S CIRCUIT LAW ÷ $\boxed{\oint H\,dL = \Sigma I}$

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

* Relation between B & H ÷ $\boxed{B = \mu_0 \mu_r H}$

* BIOT SEVERT LAW ÷ $\boxed{dH = \frac{1}{4\pi} \frac{I\,dl \sin\theta}{r^2}} \quad \frac{AT}{m}$

FORCE BETWEEN TWO PARALLEL CURRENT CARING CONDUCTOR ÷

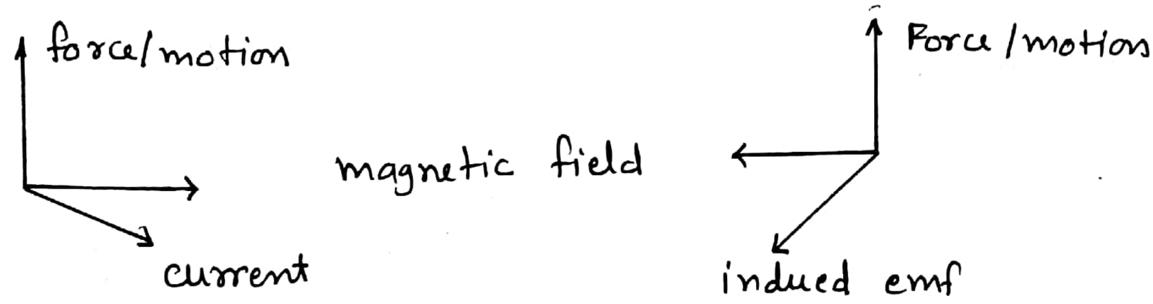
* when current flow same direction then attrect each other
* When current flow in opposite direction the reple to each other.

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

$$\boxed{F = BIl \sin\theta}$$

➤ 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** ÷ $\boxed{S = \frac{1}{\mu}\frac{l}{a}}$ $\frac{AT}{Wb}$

➤ **OHM'S LAW** ÷ ★ $\boxed{\text{Reluctance} = \frac{MMF}{Flux}}$ $\frac{At}{Wb}$

★ $\boxed{S = \frac{NI}{\phi}}$ ★ $S = S_1 + S_2 + S_3 + \dots$

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

★ $F = F_1 + F_2 + F_3 + \dots$ $\left[\because H = \frac{NI}{l}\right]$

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

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

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

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

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

⇒ Reluctivity $= \frac{1}{\mu}$; [unit - m/H or mH^{-1} or H^{-1}]

⇒ Parmanance ÷ unit Wb/AT or Hanery

7- ELECTRO MAGNETIC INDUCTION

⇒ LEAKAGE FLUX ÷ ★ $\boxed{\text{leakage factor} = \frac{\text{total flux}}{\text{Useful flux}} \quad \frac{\phi_T}{\phi_u}}$

★ $\boxed{\phi_T = \phi_u + \phi_L}$ [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.

$$\boxed{e = N\frac{d\phi}{dt}}$$

⇒ LANZ'S LAW ÷ $\boxed{e = -N\frac{d\phi}{dt}}$

★ It represent direction of static induced emf.

⇒ STATIC INDUCED EMF ÷ $\boxed{e = \frac{N d\phi}{dt}}$

⇒ DYNAMIC INDUCED EMF ÷ $\boxed{e = Blv \sin\theta}$

⇒ SELF INDUCED EMF ÷ $\boxed{e = -L\frac{dI}{dt}}$ $\boxed{L = \frac{N\phi}{I}}$

★ $\boxed{L = \frac{N^2 \mu A}{l}}$

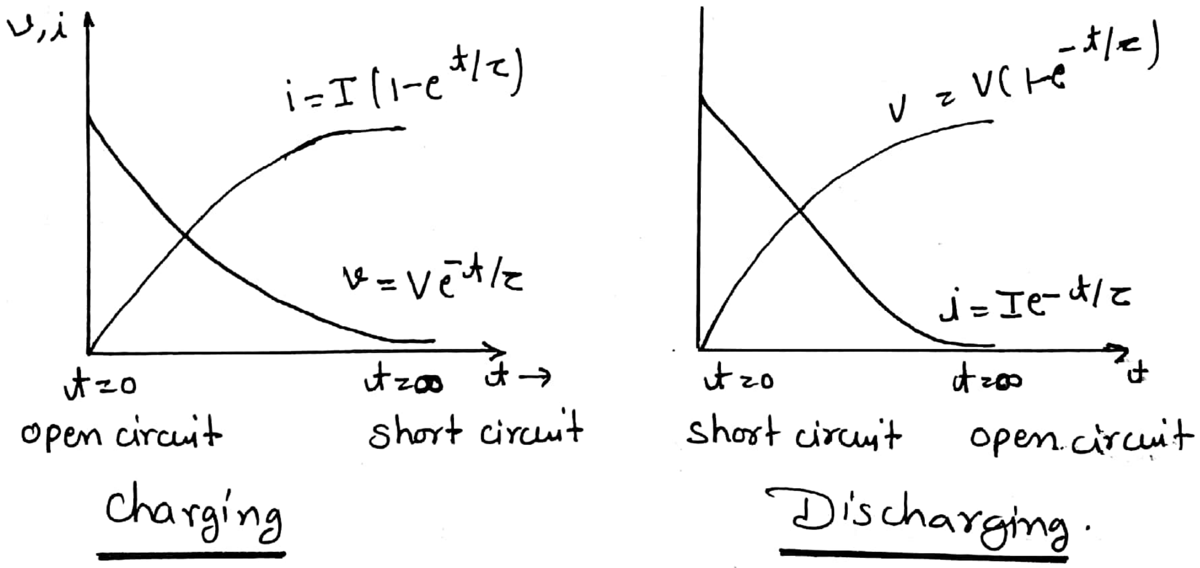
⇒ MUTUAL INDUCED EMF :- ★ $\boxed{e = -M \frac{dI}{dt}}$

$\boxed{M = -N_2 \frac{K\phi_1}{I}}$ H ★ $\boxed{K = \frac{M}{\sqrt{L_1 L_2}}}$

★ When $K = 0 \rightarrow$ no coupling
- ★ $K = 1 \rightarrow$ normal coupling
- ★ $K > 1 \rightarrow$ tight coupling
- ★ $K < 1 \rightarrow$ loose coupling

⇒ CHARGING OF INDUCTOR :- $\boxed{i = I(1 - e^{-t/\tau})}$

$\boxed{v = Ve^{-t/\tau}}$ $\boxed{\tau = \frac{L}{R}}$



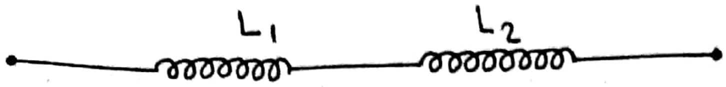
★ Inductor discharge the same direction as charging.

⇒ DISCHARGING OF INDUCTOR :- $\boxed{i = I e^{-t/\tau}}$

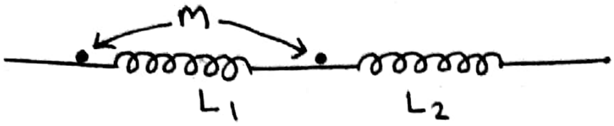
$\boxed{v = V(1 - e^{-t/\tau})}$

⇒ COMBINATION OF INDUCTOR :-

SERIES COMBINATION :-

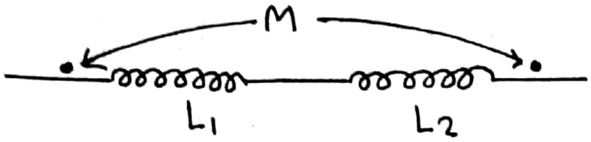
i) 

$$\boxed{L_{eq} = L_1 + L_2} \text{ (H)}$$

ii) 

$$\boxed{L_{eq} = L_1 + L_2 + 2M}$$

(additive polarity)

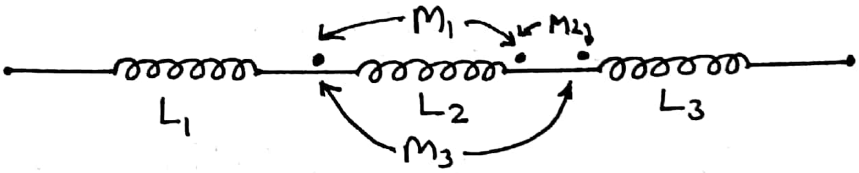
iii) 

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

(substract polarity)

iv) 

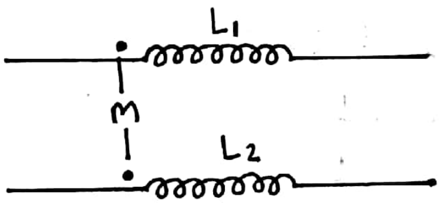
$$\boxed{L_{eq} = L_1 + L_2 + 2M}$$

v) 

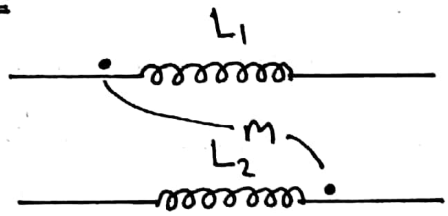
$$L_{eq} = L_1 + L_2 + L_3 + M_1 - M_3 + M_1 - M_2 - M_3 - M_2$$

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

⇒ PARALLEL COMBINATION :-

★ 

$$\boxed{L_{eq} = \frac{L_1L_2 - M^2}{L_1 + L_2 - 2M}}$$

★ 

$$\boxed{L_{eq} = \frac{L_1L_2 - M^2}{L_1 + L_2 + 2M}}$$

⇒ HYSTERESIS LOSS :-

$$\boxed{P_h = K_h f V B_m^x} \text{ watt}$$

$x = 1$ to 2

- ★ K_h for harder steel $= 250$
- ★ K_h for shoft steel $= 500$

⇒ EDDY CURRENT LOSS →

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

★ RISE OF CURRENT IN AN INDUCTIVE CIRCUIT ÷

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

$I = \frac{V}{R}$ τ (time constant) $= \frac{L}{R}$

de current in an inductor circuit

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

Energy stored in magnetic field

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

★ MAGNETIC ENERGY STORED PER UNIT VOLUME ÷

energy stored / m^3 $= \frac{B^2}{2\mu_0 \mu_r}$ Joule

$= \frac{B^2}{2\mu_0}$ in air

- ★ Ferro Magnetic Material $\mu \cong 1000$
- ★ Para Magnetic Material $\mu > 1$
- ★ Dia Magnetic material $\mu < 1$

- ★ Unit of magnetic flux = weber
- ★ Magnetic flux density = Wb/m^2 or tesla
- ★ Permability - H/m
- ★ Relative Permability — 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°

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

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.

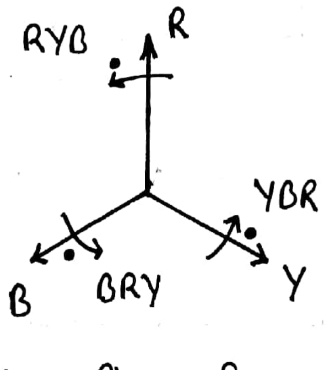
★ [in 2-ϕ system phase displacement is 90°]

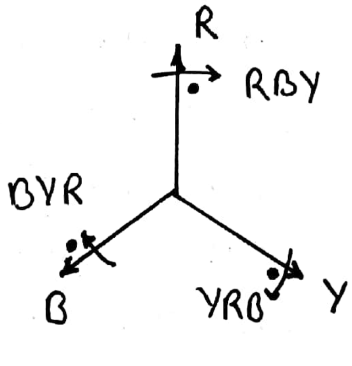
⇒★ Indian standard voltage 3-ϕ – 415 Volt
1-ϕ – 230 Volt

3-ϕ Balanced System ÷

$$E_R = E_{max} \sin\theta$$
$$E_y = E_{max} \sin(\theta - 120°)$$
$$E_B = E_{max} \sin(\theta - 240°)$$

⇒ **PHASE SEQUENCE ÷**





★ Positive Phase Sequence

$$\boxed{RYB = YBR = BRY}$$

★ Negative Phase sequence

$$\boxed{RBY = YRB = BYR}$$

⇒ **3-ϕ star connection when load balanced ÷**

★ $I_L = I_{ph}$

$V_L = \sqrt{3}\, V_{ph}$ or $\boxed{V_{ph} = \frac{V_L}{\sqrt{3}}}$ or $\boxed{V_{ph} = 0.577 V_L}$ $\boxed{V_L = 1.73 V_{ph}}$

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

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

⇒ 3-ϕ Delta connection when load balanced →

$\boxed{I_L = \sqrt{3}\, I_{ph}}$ or $\boxed{I_{ph} = 0.577\, I_L}$

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

⇒ FOR UNBALANCE LOAD ÷

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

in delta connection $\boxed{P = V_{RY} I_1 \cos\phi_1 + V_{YB} I_2 \cos\phi_2 + V_{BR} I_3 \cos\phi_3}$

⇒ TWO WATTMEATER METHOD ÷

total power $= W_1 + W_2$ [Power factor = $\cos\phi$]

$\phi = \tan^{-1}\sqrt{3}\left(\frac{W_1 - W_2}{W_1 + W_2}\right)$

★ $\boxed{W_1 = V_L I_L \cos(30° + \phi)}$ and ★ $\boxed{W_2 = V_L I_L \cos(30° - \phi)}$

★ $\boxed{W_1 + W_2 = \sqrt{3}\, V_L I_L \cos\phi}$ ★ $\boxed{W_2 - W_1 = V_L I_L \sin\phi}$

⇒ ★ when both wattmeter reading is same then power factor is unity. ($\phi = 90°$)

- ★ When one wattmer reading is zero - then power factor 0.5 ($\phi = 60°$)

★ When both watt meter reading is same and opposite then power factor zero.

★ when one watt meter reading is positive and another wattmeter is −ve read then power factor less then 0.5

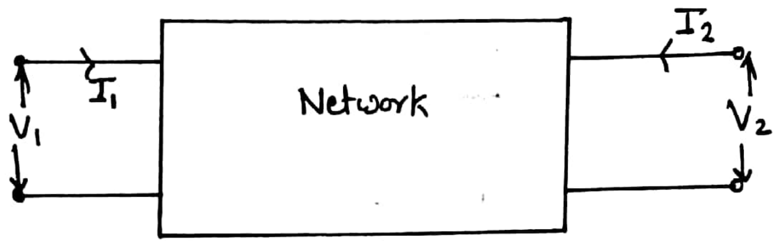
⇒ HOW TO APPLY FORMULA ÷. $\boxed{\tan\phi = \sqrt{3}\,\frac{W_2-W_1}{W_2+W_1}}$

★ lagging power factor

$\boxed{\tan\phi = \sqrt{3}\,\frac{W_1-W_2}{W_1+W_2}}$ ★ 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

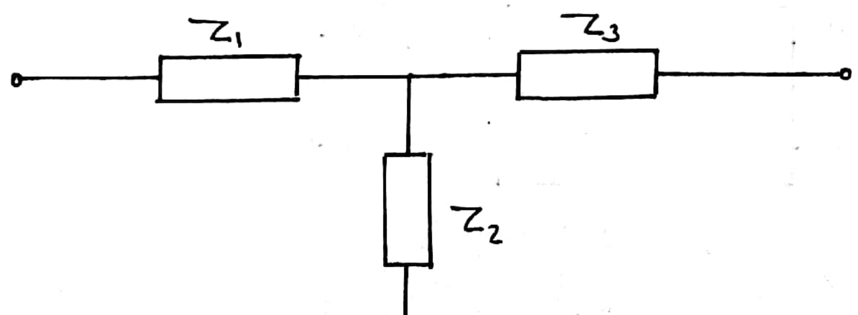


⇒ OPEN CIRCUTT PARAMETER / Z-PARAMETER / IMPEDANCE PARAMETER ÷ :

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

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

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



$$\begin{bmatrix} Z_{11} = Z_1 + Z_2 & Z_{12} = Z_2 \\ Z_{21} = Z_2 & Z_{22} = Z_2 + Z_3 \end{bmatrix}$$

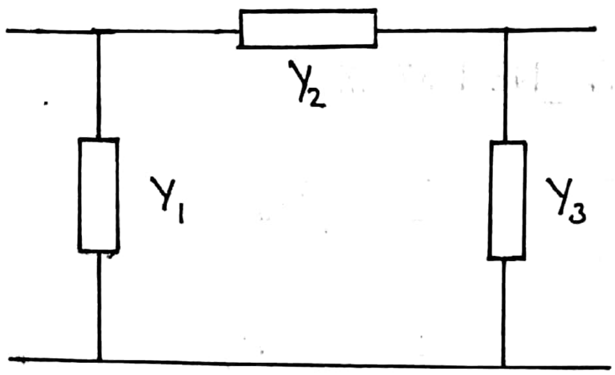
Y-PARAMETER / ADDMITTANCE PARAMETER / SHORT CIRCUTT PARAMETER ÷

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

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

when $V_2 = 0$ $\quad Y_{11} = I_1/V_1 \ ℧ \qquad Y_{21}\ \dfrac{I_2}{V_1}\ ℧$

when $V_1 = 0$ $\quad Y_{12} = \dfrac{I_1}{V_2}\ ℧ \qquad Y_{22} = \dfrac{I_2}{V_2}\ ℧$

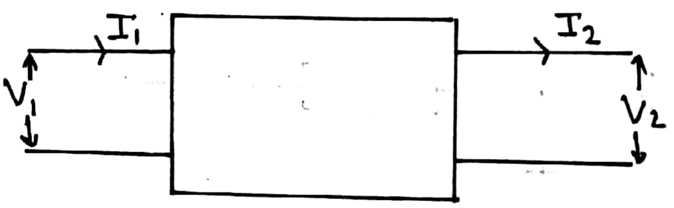


$$\begin{bmatrix} Y_{11} = Y_1 + Y_2 & Y_{12} = -Y_2 \\ Y_{21} = -Y_2 & Y_{22} = Y_2 + Y_3 \end{bmatrix}$$

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

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

T PARAMETER (TRANSMISSION PARAMETER) ÷



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

(30)

$V_1 = AV_2 + BI_2$ and $I_1 = CV_2 + DI_2$

when $V_2 = 0$ then $B = \dfrac{V_1}{I_1}\ \Omega \qquad D = \dfrac{I_1}{I_2}$

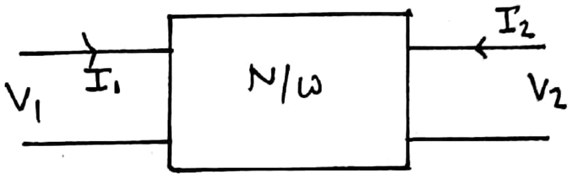
when $I_2 = 0$

$A = \frac{V_1}{V_2}$ and $C = \frac{I_1}{V}$ ℧

* $\begin{bmatrix} A & B \\ C & D \end{bmatrix}$ here A & D having no unit
B unit Ω and unit of C ℧

* Condition of symetrical $A = D$
* Condition of unsymetrical $AD - BC = 1$

⇒ HYBRID PARAMETER



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

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

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

$h_{22} = \frac{I_2}{I_1}$

when $I_1 = 0$ $h_{11} = \frac{V_1}{V_2}$, $h_{21} = \frac{I_2}{V_2}$ ℧ (admitance)

* $\begin{bmatrix} h_{11}(\Omega) & h_{12} \\ h_{21} & h_{22}\ (℧) \end{bmatrix}$

LAPLACE TRANSFORM

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

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

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

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

★ $f(t) = R(t)$ $\quad f(s) = \frac{1}{s^2}$

★ $f(t) = t^2$ $\quad f(s) = \frac{1}{s^3}$

★ $f(t) = e^{-at}$ $\quad f(s) = \frac{1}{(s+a)}$

★ $f(t) = e^{at}$ $\quad f(s) = \frac{1}{s-a}$

★ $f(t) = 10^{et}$ $\quad f(s) = \frac{10}{(s-a)}$

★ $f(t) = t^n u(t)$ $\quad f(s) = \frac{\angle n}{s^{n+1}}$

★ $f(t) = \sin \omega t$ $\quad f(s) = \frac{\omega}{s^2+\omega^2}$

★ $f(t) = \cos \omega t$ $\quad f(s) = \frac{s}{\omega^2+s^2}$

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

★ $\boxed{\int f(t)\, dt \longrightarrow \frac{f(s)}{s} - \frac{f(0^+)}{s}}$

Represent of element

ELEMENT	INITIAL CONDITION	FINAL CONDITION