BEE - UNIT-01 and UNIT-02

Derivations & Theorem

~~CI Lecture-08~~

SRMPLWS - CDE
PEERRCDM - Mag

★ KVL

① In any closed loop, the algebraic sum of all branched voltages is zero.

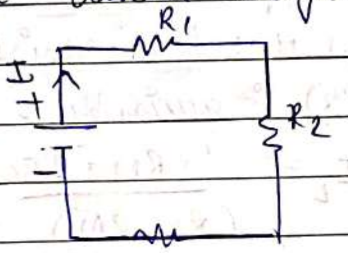
$\sum V + \sum IR = 0$

$V - IR_1 - IR_2 - IR_3 = 0$

② Sign convention

while tracing any path, the rise in potential is taken +ve and if there is a drop in potential then it is taken negative.

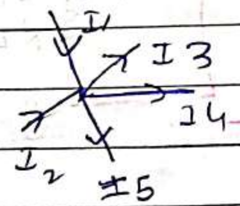
③



$V - IR_1 - IR_2 - IR_3 = 0.$

★ KCL

① The algebraic sum of all currents meeting at any junction is always zero.



$\sum I = 0$ any junction

$I_1 - I_3 + I_2 - I_5 - I_4 = 0$

② Sign convention -

incoming current flowing towards +ve,

outgoing -ve.

★ SUPERPOSITION THEOREM

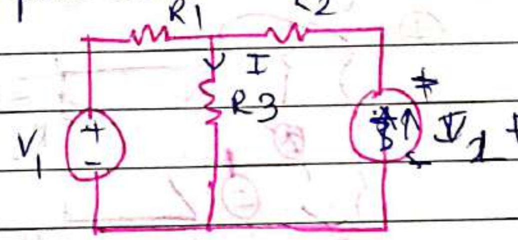
① In any linear bilateral active network containing,

→ two or more sources and many resistances, the current through any branch is ~~the algebraic sum of all such currents which would~~ given by algebraic sum of individual currents flowing through that branch, when only one source is active at a time, and other sources are replaced by their internal resistance.

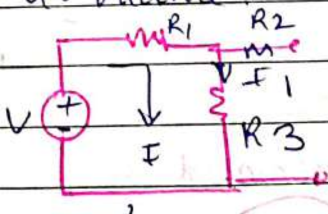
V → Rint = 0 short

I → Rin = ∞ open ckt

② explanation

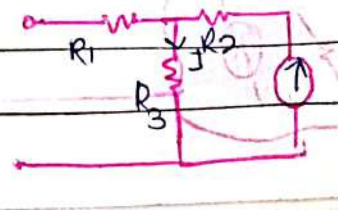


a. V active



$I' = \frac{V}{R_1 + R_3} \times I \downarrow$

b. I active



$I'' = \frac{V \times I}{R_1 + R_3} \downarrow$

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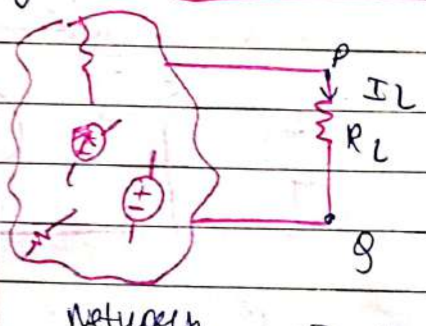
★ THEVNIN'S THEOREM

- In any linear, bilateral active network, the current flowing through the load resistance (RL) is given by

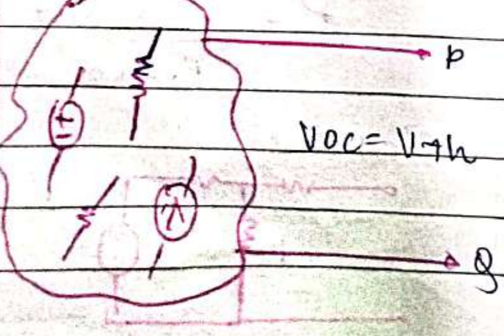
$$\rightarrow I_L = \frac{V_{Th}}{R_L + R_{Th}}$$

- where $\boxed{V_{Th}}$ is the open circuit voltage across the terminals PQ with RL remove.
- And $\boxed{R_{Th}}$ is the equivalent resistance of the network across load terminals PQ with R_L remove.
- And all sources are replaced by their internal resistance.

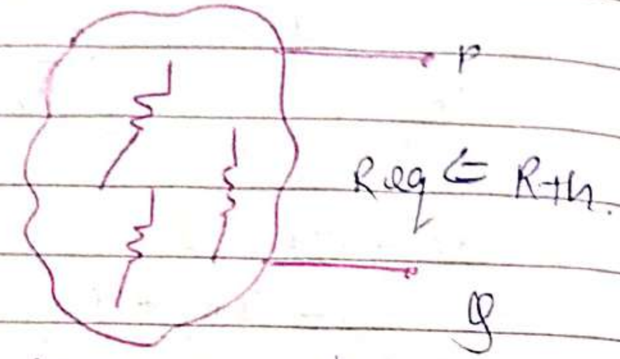
① 

Network $\quad I_L = \frac{V_{Th}}{R_L + R_{Th}}$

② R_L Removed.



③ Thevenin's Resistance.



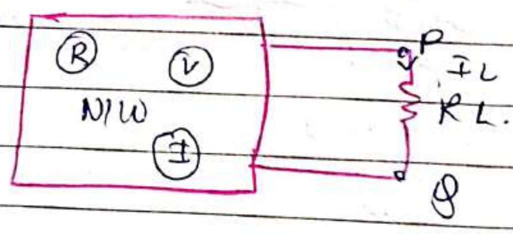
- sources are replaced by internal resistance.

★ NORTON'S THEOREM

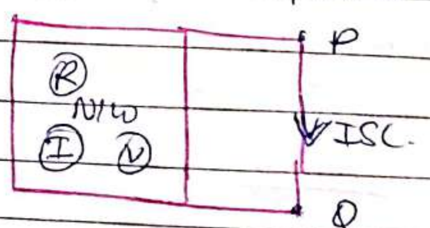
- In any linear, bilateral active network, the current flowing through the load resistance R_L (PQ) is given by :

$$I_L = \frac{R_N \cdot I_{SC}}{(R_L + R_N)}$$

- where $\boxed{I_{SC}}$ is short ckt current when R_L is removed.
- And $\boxed{R_N}$ is the equivalent resistance across PQ with R_L removed and all the sources are replaced by their internal resist.

① 

② R_L removed, short PQ terminal



Short - open.

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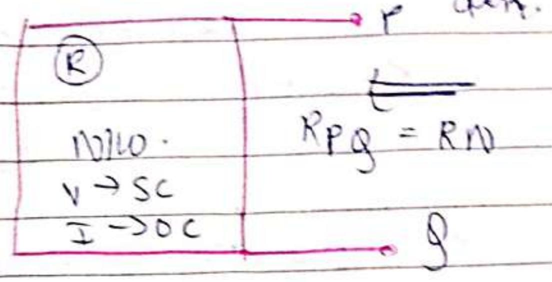
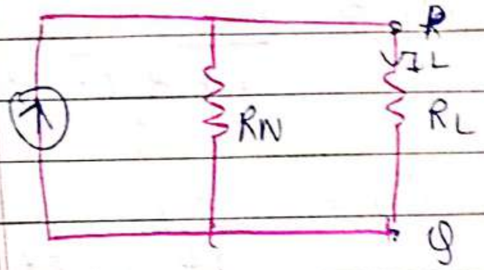
R. Pan Deepe

③ Norton's Resistance.



④ Norton's Network



- $I_L = \dfrac{I_{SC} \times R_N}{R_L + R_N}$

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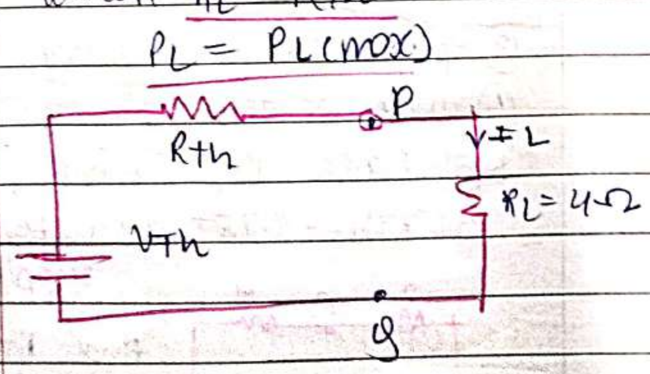
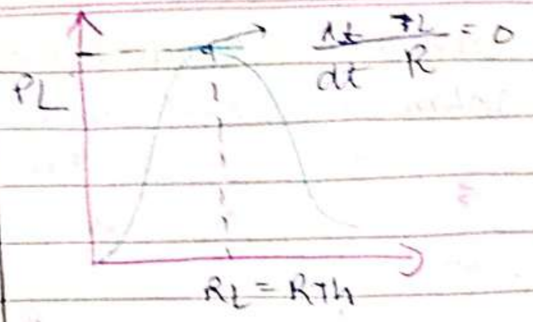
★ MAX POWER TRANSFER THEOREM

- In any linear, bilateral active network, the POWER Transferred to the load resistance R_L is maximum when Load resistance is equal to Thevenin's eq resistance.
- when $R_L = R_{Th}$
  $P_L = P_{L(max)}$

①





★ CONDITION FOR (P_L) max.

- $I = \dfrac{V_{Th}}{R_L + R_{Th}}$

$P_L = P_{L\,max}$

$$\frac{dP_L}{dR_L} = 0$$

$$\frac{d}{dR_L}\left[\left(\frac{V_{Th}}{R_L + R_{Th}}\right)^2 \times R_L\right]$$

$$(V_{Th})^2 \frac{d}{dR_L}\left[\frac{R_L}{(R_{Th}+R_L)^2}\right]$$

$$\frac{R_L\, 2(R_{Th}+R_L) - (R_{Th}+R_L)^2 \times 1}{(R_{Th}+R_L)^2}$$

$$2R_L(R_{Th}+R_L) - (R_{Th}+R_L)^2 = 0$$

$$2R_L(R_{Th}+R_L) = (R_{Th}+R_L)^2$$

$$2R_L = R_{Th} + R_L$$

$$R_L = R_{Th}.$$

★ DEFINATION- RTC

- Is a measure of How much a material's resistance changes with temperature.
- change in R per degree of Temp expressed in ohm/per degree C°
- $+TCR \rightarrow R \propto T$
- $-TCR \rightarrow R \propto \frac{1}{T}$

Subtract
α_2
$\alpha_{1\,\Delta t}$
α_{12}

$\Delta t = t_2 - t_1$

$-\Delta t = t_1 - t_2$

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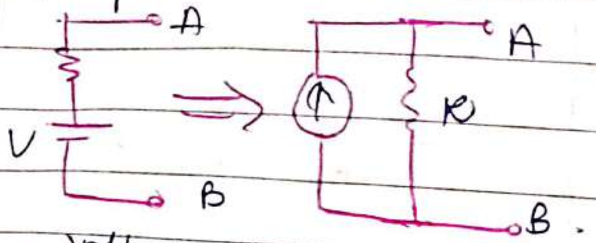
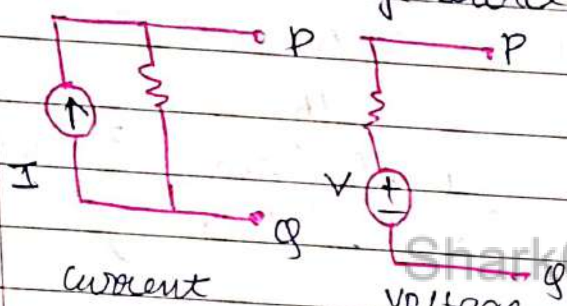
★ SOURCE TRANSFORMATION

① Voltage to current source.



voltage   current source (PARALLEL)

② current to voltage source



current   voltage (SERIES)

★ RTC DERIVATION

$\Delta R = (R_2 - R_1)\ \Omega$

$(R_2 - R_1) \propto (t_2 - t_1)$

$(R_2 - R_1) \propto (R_1 (t_2 - t_1))$

$R_2 - R_1 = \alpha_{R_1} (t_2 - t_1)$

$$\alpha_1 = \frac{R_2 - R_1}{R_1 (t_2 - t_1)}$$

$R_2 = R_1 [\alpha_1 \Delta t + 1]$

$R_1 = R_2 [\alpha_2 \Delta t + 1]$

$$\frac{R_2}{R_1} = 1 + \alpha_1 \Delta t$$

$\cancel{1+\alpha_1 \Delta t} = \dfrac{1}{\cancel{1+\alpha_1}}$

$$\alpha_1 \Delta t = \frac{1}{1+\alpha(\Delta t)} - 1$$

$$\alpha_1 \Delta t = \frac{1 - 1 + \alpha_2 \Delta t}{1 + \alpha_2(-\Delta t)}$$

$$\alpha_1 = \frac{\alpha_2 \Delta t}{(1 + \alpha_2 \Delta t)\Delta t}$$

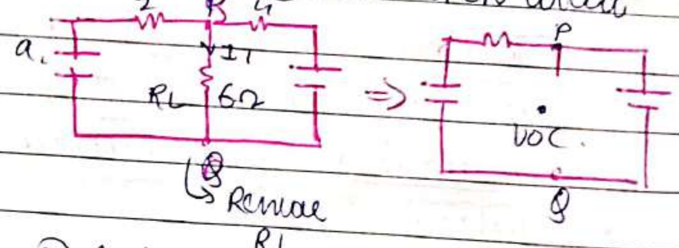
$$\alpha_{12} = \frac{\alpha_2}{1 + \alpha_2(\Delta t)}$$

$$\alpha_1 = \frac{\alpha_2}{1 + \alpha_2(t_1 - t_2)}$$

★ SOLVING THEVENIN Questions

① Identify Ⓟ and Ⓠ in R_L

② Remove R_L and OPEN circuit

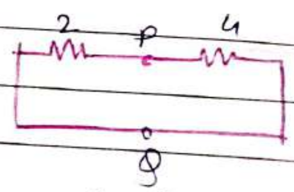


③ Apply KVL in whole loop.

④ Find I and Voc.

⑤ Make Rth Thevenin, find Rth

6. Rth. - SHORT all voltage supply.



Find Rth By P/S of Resistance

parallel

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★ Delta equations

- $R_{12} = (R_{12}) \times (R_{23} + R_{31})$
- $R_{12} = \dfrac{R_{12} \times (R_{23} + R_{31})}{R_{12} + R_{23} + R_{31}}$

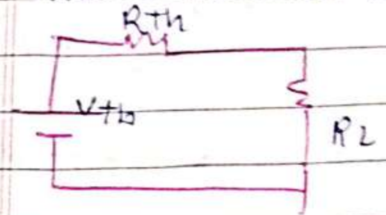
★ Star equations

- $R_{12} = R_1 + R_2$
- $R_{23} = R_2 + R_3$
- $R_{31} = R_3 + R_1$

★ Final star equations

- $R_1 = \dfrac{R_{12} * R_{31}}{R_{12} + R_{23} + R_{31}}$
- $R_2 = \dfrac{R_{23} * R_{12}}{R_1 + R_2 + R_3}$

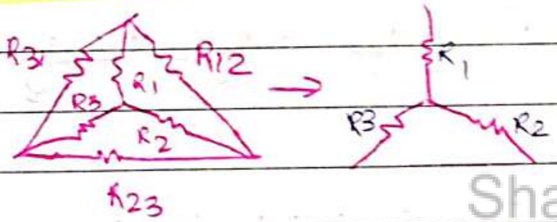
c. Rth + Thevenin circuit



Make a thevenin circuit with Rth, RL and Vth.

d. $I_L = \dfrac{V_{th}}{R_L + R_{Th}}$

★ DELTA TO STAR



- $R_{12} = R_1 + R_2 \rightarrow (1)$
- $R_{23} = R_2 + R_3 \rightarrow (2)$
- $R_{31} = R_3 + R_1 \rightarrow (3)$

- For Delta
- $R_{12} = \dfrac{(R_{12})(R_{23} + R_{31})}{R_{12} + R_{23} + R_{31}}$
- $R_{12} = \dfrac{(R_{12}) \times (R_{23} + R_{31})}{R_{12} + R_{23} + R_{31}} \rightarrow (4)$
- $R_{23} = (R_{23}) \parallel (R_{31} + R_{12}) / \text{sum}$
- $R_{23} = \dfrac{(R_{23}) \times (R_{31} + R_{12})}{R_{12} + R_{23} + R_{31}} \rightarrow (5)$
- $R_{31} = \dfrac{(R_{31}) \times (R_{12} + R_{23})}{R_{12} + R_{23} + R_{31}} \rightarrow (6)$

- $R_1 + R_2 = \dfrac{(R_{12}) \times (R_{23} + R_{31})}{R_{12} + R_{23} + R_{31}} \rightarrow (7)$
- $R_2 + R_3 = \dfrac{(R_{23}) \times (R_{31} + R_{12})}{R_{12} + R_{23} + R_{31}} \rightarrow (8)$
- $R_3 + R_1 = \dfrac{(R_{31}) \times (R_{12} + R_{23})}{R_{12} + R_{23} + R_{31}} \rightarrow (9)$

Add (7) + (8)

(~~I-lecture-09~~) • $R_1 + R_2 + R_2 + R_3 =$

$$\frac{(R_{12}) \times (R_{23} + R_{31}) + (R_{23}) \times (R_{31} + R_{12})}{R_{12} + R_{23} + R_{31}}$$

- $R_1 + 2R_2 + R_3$

$$= \frac{R_{12}R_{23} + R_{12}R_{31} + R_{23}R_{31} + R_{23}R_{12}}{R_{12} + R_{23} + R_{31}}$$

- $R_1 + 2R_2 + R_3$

$$= \frac{2R_{12}R_{23} + R_{12}R_{31} + R_{23}R_{31}}{R_{12} + R_{23} + R_{31}} \rightarrow (10)$$

- (10) − (9)

$\Rightarrow \cancel{R_1} + 2R_2 + \cancel{R_3} - \cancel{R_3} - \cancel{R_1}$

$= 2R_{12}R_{23} + R_{12}R_{31} + R_{23}R_{31} - R_{31} \times (R_{12} + R_{23})$

$$= \frac{2R_{12}R_{23} + \cancel{R_{12}R_{31}} + \cancel{R_{23}R_{31}} - \cancel{R_{31}R_{12}} - \cancel{R_{31}R_{23}}}{R_{12} + R_{23} + R_{31}}$$

$= 2R_2 = \dfrac{2R_{12}R_{23}}{R_{12} + R_{23} + R_{31}}$

- $R_2 = \dfrac{R_{12}R_{23}}{R_{12} + R_{23} + R_{31}}$
- $R_3 = \dfrac{R_{31} \cdot R_{23}}{R_{12} + R_{23} + R_{31}}$
- $R_1 = \dfrac{R_{12}R_{31}}{}$

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$R_1 = \frac{R_{12} R_{31}}{R_{12}+R_{23}+R_{31}}$ → Star.

STAR TO DELTA

- Add (4) + (5) + (6)
- Separate R_{12}
- Take $R_3 \to R_{12} + R_3$.

★ STAR TO DELTA

- we'll see equations
- $R_1 = \frac{R_{12} R_{31}}{R_{12}+R_{23}+R_{31}} \to (1)$
- $R_2 = \frac{R_{23} \cdot R_{12}}{R_{12}+R_{23}+R_{31}} \to (2)$
- $R_3 = \frac{R_{31} R_{23}}{R_{12}+R_{23}+R_{31}} \to (3)$
- multiply R_1R_2, R_2R_3, R_3R_1.

$\Rightarrow R_1R_2 = \frac{(R_{31})(R_{23})(R_{12})}{(R_{12}+R_{23}+R_{31})^2}$

- $R_1R_2 = \frac{(R_{12})^2 (R_{31})(R_{23})}{(R_{12}+R_{23}+R_{31})^2} \to (4)$
- $R_2R_3 = \frac{(R_{23})^2 \cdot (R_{31})(R_{12})}{(R_{12}+R_{23}+R_{31})^2} \to (5)$
- $R_3R_1 = \frac{(R_{31})^2 (R_{12})(R_{23})}{(R_{12}+R_{23}+R_{31})^2} \to (6)$

Add (4) + (5) + (6)

- $R_1R_2 + R_2R_3 + R_3R_1$

$\Rightarrow \frac{(R_{12})^2 (R_{31})(R_{23}) + (R_{23})^2 \cdot (R_{31})(R_{12}) + (R_{31})^2 (R_{12})(R_{23})}{(R_{12}+R_{23}+R_{31})^2}$

Separate multiplied & added one

$= \frac{\cancel{(R_{12}+R_{23}+R_{31})} (R_{12} R_{23} R_{31})}{(R_{12}+R_{23}+R_{31})^{\cancel{2}}}$

- $R_1R_2 + R_2R_3 + R_3R_1 = \frac{(R_{12}) R_{23} R_{31}}{R_{12}+R_{23}+R_{31}}$
- Separate R_{12}

$R_{12} \times \underbrace{\left[\frac{R_{23} \cdot R_{31}}{R_{12}+R_{23}+R_{31}}\right]}_{R_3} = R_1R_2 + R_2R_3 + R_3R_1$

$R_{12} \times R_3 = R_1R_2 + R_2R_3 + R_3R_1$

$R_{12} = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3}$

$R_{12} = \frac{R_1R_2}{R_3} + \frac{R_2R_3}{R_3} + \frac{R_3R_1}{R_3}$

- $R_{12} = R_1 + R_2 + \frac{R_1R_2}{R_3}$
- $R_{23} = R_2 + R_3 + \frac{R_2R_3}{R_1}$
- $R_{31} = R_3 + R_1 + \frac{R_1R_3}{R_2}$

★ SOLVING Superposition Questions.

1. Make 1st source active
   - write 2 KVL eqn's
   - Find I_1 and $I_2 = I'$
2. make 2nd source active
   - write 2 KVL eqn
   - Find I_1 and $I_2 = I''$
3. $I = I' + I''$.

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UNIT-03-MAGNETIC CIRCUITS.

Page No.
Date: / /20

★ **SOLVING NORTON'S Questions**

- $I = \frac{ISC \times RN}{RL + RN}$.

① Remove R_L and short PQ to find ISC - short current
- $ISC = I_1 - I_2$
KVL and find ISC.

② Norton Resistance.
- Short all voltage source. and Find R_N.

③ Norton's circuit.
R_N, I_L, R_L
Find $I_L = \frac{ISC \times RN}{R_L + RN}$

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★

④ Delta To star

a. Star R_{12}, R_{23}, R_{31}
b. Delta - $R_{12} = \frac{R_{12}(R_{23} + R_{31})}{sum}$
c. write same as addition $R_1 + R_2$
d. add ⑦ + ⑧
e. star equation →

$$R_2 = \frac{R_{12} R_{23}}{Sum} \quad \text{common.}$$

② star to Delta

a. write ③ final star equations.
b. multiply $R_1R_2 = \ldots R_2R_3$. → square$]^2 \times \frac{(x)}{(sum)^2}$

c. add ④ + ⑤ + ⑥
d. Separate and cut square in deno.

$\frac{(sum) \cdot (prod)}{(s)^2}$

↳ $\frac{Prod}{sum}$

e. separate R_{12} & $\underbrace{\frac{R_{23} \cdot R_{31}}{sum}}_{R_3}$

$R_{12} \cdot R_3 = \underline{LLH}$

$R_{12} = \frac{LHS}{R_3}$.

$R_{12} = \frac{''}{R_3} + \frac{''}{R_3} + \frac{''}{R_3}$

$R_{12} = \frac{prod}{R_3} \times$ sum of $R_1 + R_2$

$R_{12} = \frac{R_1R_2}{R_3} \times R_1 + R_2$.

★

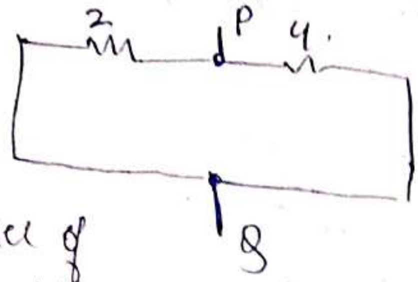
① Thevenins - open PQ

a. Send current I in whole ckt, make one full loop
b. Ignore voc and make equation of current, get I ✓
c. Make voc equation
d. Find Voc by putting value of I in equation.

Teacher's Signature ....

f. Highlight the Terminals PQ and Put only R in circuit

• Do S or P and find

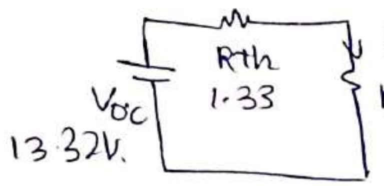


Parallel of 2 and 4

$$R_{Th} = \frac{2 \times 4}{2+4} = 1.33\,\Omega.$$

g. Thevenin's Network

• Add Rth and R_L and I_L Show in ckt.



h = $I_L = \dfrac{V_{th}}{(R_L + R_{th})}$ ✓

get I_L ✓.

(2) Norton's Problems

• a. Short PQ and flow ISC in ckt Terminal

• $I_{SC} = I_1 - I_2$

b. Make Two separate equations for loop 1 and loop 2

c. Ignore ISC and write KVL eqn

• $4I_2 + 2 = 0.$

$2I_1 - 10 = 0$

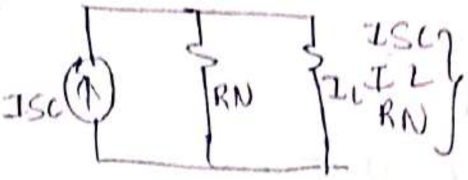
d. get I_1 and I_2 ✓

e. Find $I_{SC} = I_1 - I_2$ ✓

f. Find Rn

Make ckt with Resistor Rn ✓

g. Norton's Network.



$I_{SC} = I_1 - I_2 =$ ✓

h. Find I_L in Terminal

$$I_L = \frac{I_{SC} \times R_N}{(R_L + R_N)}$$ ✓

(3) Superposition theorem

• a. Make one source of voltage active at a time

b. Take one voltage source ✓

c. And SHORT the other

d. Make Two KVL equations And solve by (1) in calc. equation.

e. Same way, get I_1 ✓

f. Now do the same for another source, get I_2

g. $I_{Total} = I_1 + I_2$ ✓.

(4) Source Transformation

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UNIT-03-MAGNETIC CIRCUITS.

LAWS OF MAGNETISM

1) Like poles repell and unlike poles attract e/o.

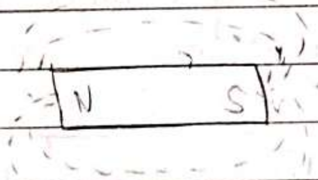
2) The force exerted by one pole on another pole is
$\propto$ product of pole strength
Inversely proportional to square of distance b/w them.

$F \propto \frac{m_1 m_2}{d^2}$ $\quad F = \frac{K m_1 m_2}{d^2}$

K = magnetic properties of medium.

★ MAGNETIC CIRCUIT

Region around the magnet upto where its poles have force of attraction
Represented by imaginary lines of force around the magnet.



1) Magnetic flux (ϕ)

- The total magnetic lines of force in a magnetic field
- unit - weber

2) Magnetic flux density (B)

- magnetic flux passing through unit area of cross section.
- $B = \frac{\phi}{a}$ $\quad$ Wb/m² or Tesla

3) Magnetising force / Field strength (H)

- force which decides the strength of the magnetic field
- gives the quantitative measure of the strongness / weakness of magnetic material.
- $H = \frac{NI}{l}$ $\quad$ AT/metre.

4) Permeability (μ)

- Ability of a material to conduct flux
- It is the ease with which the magnetic material allows flux to be set up through it
- $\mu = \frac{B}{H}$ $\quad$ Henry/metre.

5) Absolute Permeability (μ)

- The Ratio of B to H for a magnet placed in other than free space or air or vacuum.
- $\mu = \frac{B}{H}$

6) Permeability of free space

- Ratio of B to H for a magnetic placed in free space or air or vacuum.
- $\mu_0 \; 4\pi \times 10^{-7} = 12.56$

7) Relative permeability

- Permeability relative to the permeability of free space or air-
- $\mu_r = \frac{\mu}{\mu_0}$

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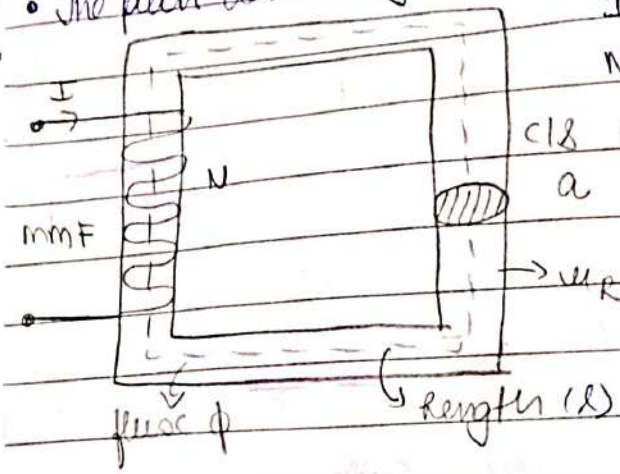
★ MAGNETIC CIRCUIT

- The path taken by the magnetic flux



I = current
N = no of turn
ϕ = flux
B = flux density

μ = Absolute permeability
μ_r = Relative permeability
l = mean length of flux path mets.

- Total flux in core $\phi = B \cdot a$

$$= \mu H a.$$

$$= \mu \cdot \frac{NI}{l} a.$$

$$\frac{mmF}{Reluctance} = \frac{NI}{\left(\frac{l}{\mu a}\right)}$$

- mmf = magnetomotive force (NI)
- Reluctance = opposition to the magnetic flux

(2)

a → $S = \frac{l}{\mu a}$ $\left(\text{analogous to } R = \rho \frac{l}{a}\right)$

- mmf - emf
- reluctance - resistance
- current and flux

} Analogous terms.

★ ELECTROMAGNETIC INDUCTION.

- When conductor is moved in magnetic field, an emf is induced in the conductor.

- The phenomenon of cutting the flux lines by the conductor to get the induced emf in it — EMF

- Requirements
  - → conductor / coil
  - → Magnetic field
  - → Relative motion b/w coil and magnet.

★ FARADAY'S LAW

(1) 1st Law

- Whenever magnetic lines of force linking with the coil, changes, and emf is induced

(2) 2nd Law

- Magnitude of induced emf is proportional to the rate of change of flux linkage ($N\phi$)

- $e = \frac{N\phi_2 - N\phi_1}{t} = \frac{N d\phi}{dt}$

★ LENZ LAW

- But Lenz said that the direction of this emf is such that it will oppose the cause which produces it

→ $e = -N\frac{d\phi}{dt}$ -ve sign Lenz law

TYPES OF EMF

① Dynamically induced emf
- Induced by physically moving either coil or magnetic field
- Let B = flux density
  l = length
  v = velocity.

- Let conductor be moved through distance dx in time dt then.
- Area swept by conductor $a = l\,dx$.

Flux cut by conductor $= Bl\,dx$.

$$e = \frac{d\phi}{dt} \cdot \frac{Bl \cdot dx}{dt} = Blv \text{ volt}$$

$$\boxed{e = blv\sin\theta}$$

② Self induced emf
- Induced in one coil because of rate of change of its own flux linked with it.
- $e = -\frac{N d\phi}{dt}$ multiply and divide by I

$$e = -N\frac{d\phi}{dt} \times \frac{I}{I}$$

- If permeability of material remains constant the ϕ / I ratio is constant.

SELF INDUCTANCE

- $e = \frac{N\phi}{I} \cdot \frac{dI}{dt}$ | $L = \frac{N^2}{S}$

where $\frac{N\phi}{I} \rightarrow$ coefficient of self induction or self inductance $\left[e = -L\frac{di}{dt}\right]$

- Unit of self inductance - Henry

- Flux linkages per ampere or property of coil to oppose change in current.
- $L = \frac{N\phi}{I} = \frac{N^2}{S}$ $\because \phi = \frac{NI}{S}$

FACTORS AFFECTING Self Inductance

① directly proportional to square of number of turns.
② Magnetic properties of material
③ $\propto \frac{1}{l}$
④ $e \propto N^2$, $e \propto \frac{1}{l_{core}}$
⑤ $e \propto$ Area, $e \propto \beta$
⑥ Also varies with current

MUTUAL INDUCTANCE

- emf induced in a coil due to change in flux of other coil linked with it
- $e_2 = N_2 \frac{d\phi_1}{dt}$

$$= N_2 \frac{d}{dt}\left(\phi_1 \times \frac{I_1}{I_1}\right)$$

$$= \frac{N_2\phi_1}{I_1} \times \frac{dI_1}{dt} = M\frac{dI_1}{dt}$$

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where M is called the coefficient of mutual inductance

- Defined as the ability of one coil to induce an emf in the nearby coil by induction when the current in first coil changes

★ ~~MUTUAL INDUCTANCE~~ coupling constant

- Two coils having N_1 and N_2 turns carrying I_1 and I_2 Amp produces

- $L_1 = \frac{N_1 \phi_1}{I_1}$ and $L_2 = \frac{N_2 \phi_2}{I_2}$

- Let K_1 fraction of flux ϕ_1 links coil 2.

$$M = \frac{N_2 K_1 \phi_1}{I_1} \quad K_1 \leq 1 \rightarrow (1)$$

- Let K_2 fraction of flux ϕ_2 links coil 1.

$$M = \frac{N_1 K_2 \phi_2}{I_2} \quad K_2 \leq 1 \rightarrow (2)$$

multiply (1) & (2)

$$M^2 = \frac{K_2 N_1 \phi_2}{I_2} \times \frac{K_1 N_2 \phi_1}{I_1}$$

$$= K_1 K_2 \frac{N_2 \phi_2}{I_2} \cdot \frac{N_1 \phi_1}{I_1} = K_1 K_2 L_1 L_2$$

$$\therefore M = \sqrt{K_1 K_2}\sqrt{L_1 L_2} = K\sqrt{L_1 L_2}$$

- where K is called as the coefficient of coupling $= \frac{M}{\sqrt{L_1 L_2}}$

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

- Defined as the ratio of actual mutual inductance present between two coils to its maximum possible value.
- if $K = 1$ - tightly coupled
- if $K < 1 \rightarrow$ loosely coupled.

★ ENERGY STORED IN Magnetic field

- If I increases by di ampere in time dt sec then induced in the coil is

$\rightarrow e = -L \frac{di}{dt}$ volt.

- The emf opposes the current & energy drawn from source to overcome this opposition is stored in MF.
- voltage to neutralise $= -e$.

- Energy absorbed in time dt
$=$ Power $\times$ time
$(-e) i \, dt$
$L \frac{di}{dt} \cdot i \, dt$
$= Li \, di$ joule.

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Electric	DIFFERENCE Magnetic
(1) Heat is current flows	(1) Flux sets up
(2) insulation to restrict	(2) No insulation
(3) continuous energy required to maintain	(3) energy req only establish

P F. E R R | conductivity ~~current density~~ conductance
D
M

Total energy absorbed when current reaches final value of I

$= \int_0^I L i\,di = L\int_0^I i\,di = \frac{L}{2}(i^2)_0^I$

$= \frac{1}{2} LI^2$ Joule.

energy stored per unit volume

$E = \frac{1}{2}\frac{N\phi}{I} \times I^2 \quad \because L = \frac{N\phi}{I}$

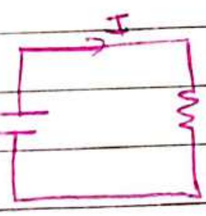
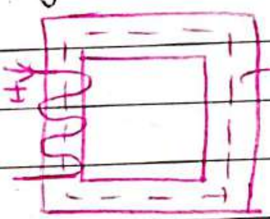
$= \frac{1}{2} N \cdot B \cdot a I = \frac{1}{2} B \cdot a \cdot H \cdot l$
$(\phi = Ba) \quad (NI = mmf)$

$= \frac{1}{2} BH \; J/m^3 \quad \because a \times l = \text{Volume}$

$\frac{1}{2}\mu H^2 \; J/m^3 \quad B = \mu H$

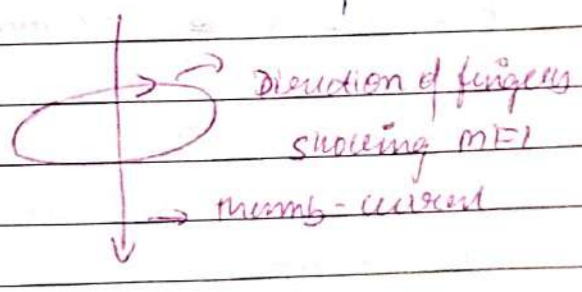
$\frac{1}{2}\frac{B^2}{\mu} \; J/m^3 \quad \because H = \frac{B}{\mu}$

Electric	Magnetic
(5) $I = \frac{emf}{R}$	(5) $\phi = \frac{mmf}{\text{Reluctance}}$
(6) $R = \rho\frac{l}{a}\,\Omega$	(6) $S = \frac{1}{\mu_0\mu_r}\cdot\frac{l}{a}$ At/wb
(7) voltage $= IR$	(7) mmf $= \phi \cdot S$
(8) Intensity $E = \frac{V}{d}$	(8) Magnetic Intensity $H = \frac{NI}{l}$
(9) conductance $\frac{1}{R}$	(9) Permeance $\frac{1}{S}$
(10) conductivity	(10) Permeability
(11) current density $\frac{I}{a}$	(11) Flux density $B = \frac{\phi}{a}$

ELECTRICAL circuit	Magnetic circuit
	
closed path for electrical current is called electrical circuit (1)	(1) closed path for flux is called magnetic circuit
current flows through ckt (2)	(2) Flux is set up in ckt
current flows due to emf	(3) Flux is created due to mmf
Resistance opposes flow of current. (3)	(4) Reluctance opposes the flux.

★ RIGHT HAND THUMB RULE

- ==Direction of induced emf== is given by Fleming's right hand rule
- Hold the thumb and first two fingers of right hand mutually perpendicular to each other.
- If ==thumb shows== direction of ==motion,== and first finger shows the direction of magnetic field then middle finger points in the direction of induced emf



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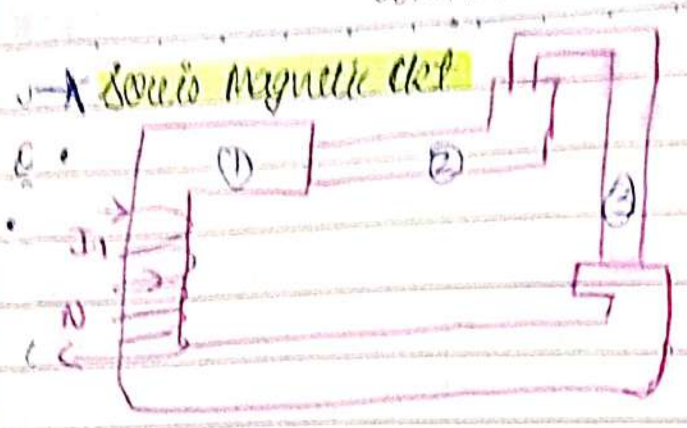
$\rightarrow \mu_r = \frac{B}{B_0} = \frac{\mu H}{\mu_0 H} = \frac{\mu}{\mu_0}$

DERIVATIONS

★ Series Magnetic Ckt



(1) MMF

★ • $MMF = MMF_1 + MMF_2 + MMF_3$

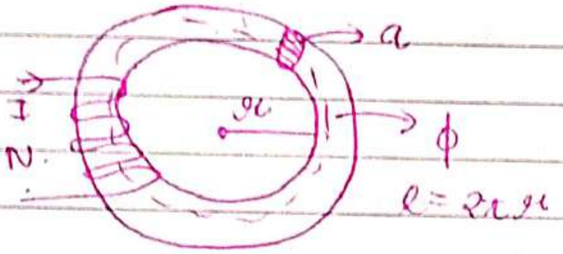
$= \phi S_1 + \phi S_2 + \phi S_3$

$= \phi S_{total}$

• (2) Reluctance $S_T = S_1 + S_2 + S_3$

$S_1 = \frac{1}{\mu_0 \mu_{r_1}} \cdot \frac{l_1}{a_1}$

(3) ★ FLUX IN TOROID



(2) • $B = \frac{\phi}{a}$ $\phi = B \cdot a$

$\phi = \mu \cdot H \cdot a$

$\phi = \mu_0 \mu_r \cdot H \cdot a$

$\phi = \mu_0 \mu_r \cdot \frac{NI}{l} \cdot a$

$\phi = \frac{NI}{\underbrace{\left(\frac{1}{\mu_r \mu_0}\right) \frac{l}{a}}_{Reluctance}} \rightarrow MMF$

$\phi = \frac{MMF}{Reluctance}$, unit of Flux is weber.

$H = \frac{NI}{L}$

$L = 2\pi r$

L = distance of

★ UNITS OF PARAMETERS

① Reluctance

• $S = \frac{MMF}{\phi}$, $S = \frac{1 \times l}{\mu_0 \mu_r a}$ (AT

② Flux - Weber

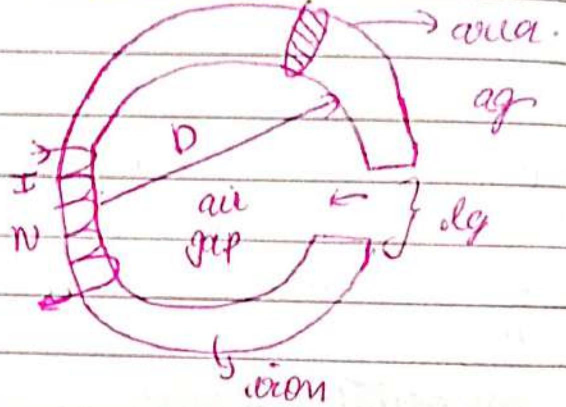
③ MMF = $\phi \cdot S$, NI, (AT

④ B - flux density = Tesla

⑤ Inductance - Henry.

⑥ Magnetic strength (H) = AT/m

★ IRON RING



• $a_g = a_i$,

$B_g = B_i$

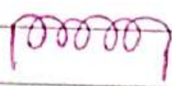
$S_i = \frac{1}{\mu_0 \mu_r} \times \frac{l_i}{a_i}$

$S_g = \frac{1}{\mu_0 \mu_r} \times \frac{l_g}{a_g}$

$S_T = S_i + S_g$

$l_i = \pi D$

★ SOLENOID

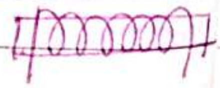


$H = \frac{NI}{L}$

B_1

Ap/m

Iron conductor



$H = \frac{NI}{L}$

B_2 con

$B_1 < B_2$.

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DERIVATION OF COEFFICIENT OF COUPLING

equations for e1

$$e_1 = -N_1 \frac{d\phi_1}{dt}$$

$$e_1 = \frac{-L_1 di_1}{dt}$$

$$e_1 = -\frac{M di_2}{dt}$$

where $L_1 = \frac{N_1 \phi_1}{I_1}$

$$M_1 = N_1 \frac{K_2 \phi_2}{I_2} \rightarrow (1)$$

equations for e2

$$e_2 = \frac{-N_2 d\phi_2}{dt}$$

$$e_2 = -\frac{L_2 di_2}{dt}$$

$$e_2 = -M \frac{di_1}{dt}$$

where $M_2 = \frac{N_2 K_1 \phi_1}{I_1} \rightarrow (2)$

- Multiply (1) x (2)

$$M_1 \times M_2 = \frac{N_1 K_2 \phi_2}{I_2} \times \frac{N_2 K_1 \phi_1}{I_1}$$

$$M^2 = \frac{K_1 K_2 N_1 N_2 \phi_1 \phi_2}{I_1 I_2}$$

$$M^2 = K_1 K_2 \frac{N_1 \phi_1}{I_1} \times \frac{N_2 \phi_2}{I_2}$$

$$M^2 = K_1 K_2 L_1 L_2$$

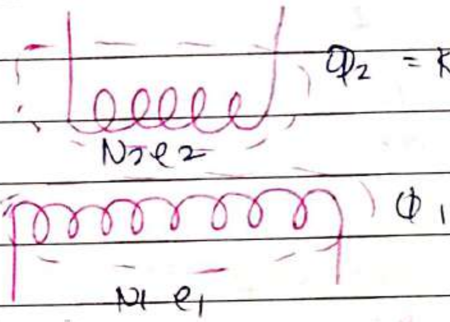
$$K_1 = K_2 = K$$

$$M^2 = K^2 L_1 L_2$$

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

- $K = \frac{M}{\sqrt{L_1 L_2}}$, K = 1 max value of mutual inductance

$$(M)_{max} = \sqrt{L_1 L_2}$$



$\phi_2 = K_1 \phi_1$

ϕ_1

- $L = \frac{N\phi}{I} = \frac{N}{I} \times \frac{NI}{S} = \frac{N^2}{S}$

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

$= L = \frac{N^2}{S}$.

- $M = \frac{N_1 \phi_2 K_2}{I_2} = \frac{N_2 K_1 \phi_1}{I_1}$

$$M = \frac{N_1 N_2}{S}$$

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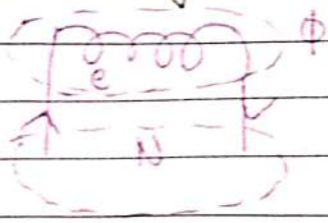
★ Electromagnetic INDUCTION.



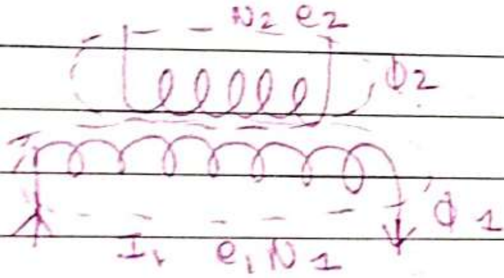
• $e = -\frac{N d\phi}{dt}$ = $e = -N\frac{d\phi}{dt}$.

• Multiply \ divide with I.

$e = -\frac{N d\phi}{dt} \times \frac{I}{I}$

$e = -\frac{N\phi}{I}\frac{di}{dt}$

★ MUTUAL INDUCTANCE



• $e_1 = -\frac{N_1 d\phi_1}{dt} = \cancel{-N_1 \frac{d \times di}{dt}}$

$= -\frac{N_1 d\Phi_1}{dt} \times \frac{I_1}{I_1} = -\frac{N_1 \Phi_1}{I_1} \times \frac{di}{dt}$

$= e = -(L_1) \times \frac{di_1}{dt}$

• $e_2 = -\frac{N_2 d\phi_2}{dt} = -\frac{\cancel{N_2}}{dt} \times d\Phi_2 \times \frac{I_1}{\cancel{I_1}}$

$\cancel{e_2} = -\frac{N_2\phi_2}{I_1} \times \frac{dI_2}{dt}$

$e = -N_2 \frac{d}{dt} k\phi_1$

$= e_2 = -N_2 k_1 \frac{d}{dt} \times \frac{\phi_1 I_1}{I_1}$

↳ multiply divide

$e_2 = \left(N_2 \frac{k_1\phi_1}{I_1}\right)\frac{dI_1}{dt}$

$e_2 = M\frac{di}{dt}$

where $M = N_2\frac{k_1\phi_1}{I_1}$

$L_1 = \frac{N_1\phi_1}{I_1}$

• $M = \frac{N_1 N_2}{S}$, $M = \frac{k N_1 N_2}{S}$.

★ FORMULAES.

① When I, li, lg, μr, B given and calculate MMF

• $MMF = H_i l_i + H_g l_g$.

$= \frac{B}{\mu_0\mu_r} \times l_i + \frac{B}{\mu_0\mu_r} \times l_g$.

use $MMF = B\left(\frac{l_i}{\mu_0\mu_r} + \frac{l_g}{\mu_0 \ldots}\right.$

in Ratio form.

or use MMF = NI To find

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) $N_1 N_2 N_3$ different coils,
l_i, l_g, μ_r, a_g, given and
flux is asked.

find S_i and S_g.

then $\phi = \dfrac{MMF}{S_i + S_g}$.

* **RIGHT HAND THUMB RULE** —

Hold current carrying conductor in the right hand such that thumb pointing in the direction of current and parallel to the conductor then tips of curled fingers point in the direction of MF.

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* MMF
- unit = NI = AT
- Quantity appearing in the equation for the magnetic flux in a magnetic circuit.
- Force produced by current through a coil of wire that gives rise to MF.
- Product of $\phi \times$ Reluctance.

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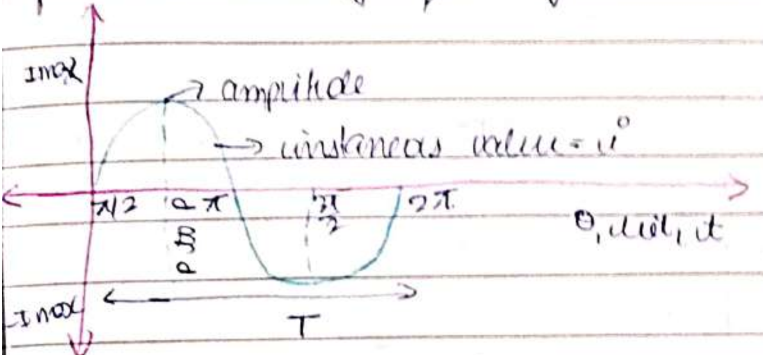
BEE - UNIT - 04 - AC FUNDAMENTALS

DEFINITIONS.

waveform

Pictorial form/ graphical representation of an alternating quantity.



$i = I_{max} \sin(\omega t)$ Amp

Cycle

set of all possible instaneous values obtained by that cycle

Instaneous value

value of that quantity at a given instant

Time period (T), $T = 2\pi/\omega$

Time required to complete one cycle (in seconds)

Frequency $f = \frac{1}{T}$

- Number of cycles completed in per second, Hertz.

Amplitude (A)

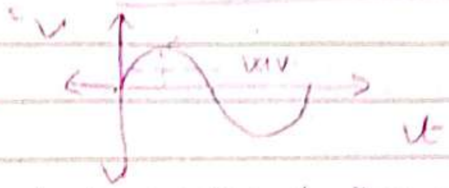
Maximum value obtained by alternating quantity.

- $m = A \sin \omega t + \phi$

↳ A is amplitude.

7) Average value

- If we convert the AC sine wave to DC sine wave through rectifier, then the converted value to the DC is known as average value.



- Average value of current $I_{av} = 0.637\, I_{max}$

8) Peak Factor

- It is the ratio b/w maximum value and RMS value of an alternating wave.
- $PF = \frac{\text{Max Value}}{\text{RMS}}$
- Also known as crest/ Amplitude factor.
- $PF = \frac{I_{max}}{0.707 I_{max}} = \boxed{1.414}$

9) Form factor

- Ratio b/w RMS value & average value of an Alternating quantity
- $\text{Form factor} = \frac{\text{RMS}}{\text{Average}}$
- $\frac{0.707}{0.636} = \boxed{1.11}$

10) RMS value - Square root of the mean of the squares of the instaneous voltages over a cycle.

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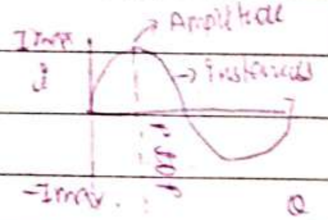
★ AVERAGE VALUE DERIVATION

• $I_{avg} = \frac{1}{\pi}\int_0^{\pi} i \, d\omega t$

$= \frac{1}{\pi}\int_0^{\pi} I_{max}\sin\omega t \, d\omega t$



$= \frac{I_{max}}{\pi}\left[-\cos\omega t\right]_0^{\pi}$

$= \frac{I_{max}}{\pi}\left(-\cos\pi + \cos 0\right)$

$\frac{I_{max}}{\pi} \quad -(-1)+(1)$

$I_{avg} = \frac{2 I_{max}}{\pi}$

$I_{avg} = \frac{2}{\pi} \times I_{max}$

$I_{avg} = 0.636\, I_{max}$

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★ RMS VALUE DERIVATION

• $I_{eff} = \sqrt{\frac{i_1^2 + i_2^2 + \dots i_n^2}{n}}$

→ Root mean of square of all instantaneous values in a cycle.

$i = I_{max}\sin\omega t$ Amp

squared i = $i^2 = I_{max}^2 \sin^2\omega t$

Σ of $i^2 = \int_0^{2\pi} i^2 \, d\omega t$

Mean of $i^2 = \frac{1}{2\pi}\int_0^{2\pi} i^2 \, d\omega t$

• I_{rms} = RMS of $i = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} i^2 \, d\omega t}$

$= \sqrt{\frac{1}{2\pi}\int_0^{2\pi} I_m^2 \, \cancel{d\omega t} \sin^2 d\omega t}$

$= \sqrt{\frac{I_m^2}{2\pi}\int_0^{2\pi} \frac{(1-\cos 2\omega t)}{2} \, d\omega t}$

$= \sqrt{\frac{I_m^2}{4\pi}\left[\omega t - \frac{\sin 2\omega t}{2}\right]_0^{2\pi}}$

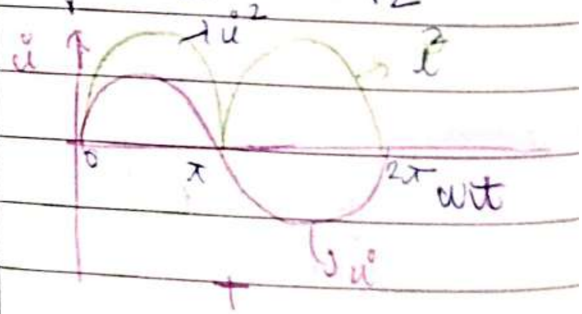
$= \sqrt{\frac{I_m^2}{4\pi}\left[\frac{2\pi}{1} - \frac{\sin 4\pi}{2} - 0 - \frac{\sin 0}{2}\right]}$

$= \sqrt{\frac{I_m^2}{4\pi}\left[2\pi - \sin 4\pi - 0 - 0\right]}$

$= I_{RMS} = \frac{I_{max}}{\sqrt{2}} = 0.707$

$= \sqrt{\frac{1}{4\pi} I_m^2 \left[2\pi - 0\right]}$

$= \sqrt{\frac{i_{max}^2}{2}} = \frac{i_{max}}{\sqrt{2}} = 0.707$



* **FORMULAES.**

$I_{avg} = 0.636\ I_{max}$

$I_{RMS} = 0.707 \times I_{max}$

$I_{RMS} = \frac{I_{max}}{\sqrt{2}}$

milli seconds $= 10^{-3}$

if $f = 50$ the $\omega = 314$.

After what value time the current becomes 86.6 A

$I = I_{max} \sin \omega t$

when i is 86.6A, find t?

$i = 28 \sin 314 t$

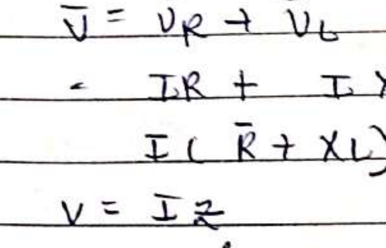
in calculator put → RADIAN.

$28 \times \sin \times 314 \times t$.

$\frac{14}{13} = \sin \times \omega t$

so $\frac{\sin^{-1}\left(\frac{14}{13}\right)}{\omega} = t$

* **SERIES R-L CIRCUIT**



$V = V_m \sin \omega t$

$\bar{V} = \bar{V}_R + \bar{V}_L$

$= IR + IX_L$

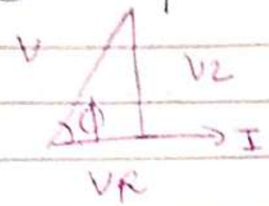
$I(\bar{R} + X_L)$

$V = IZ$

where Z is impedance (opposition to AC current)

- Applied voltage :- $V = V_m \sin \omega t$:
- current $= i = I_m \sin \omega t(-\theta)$

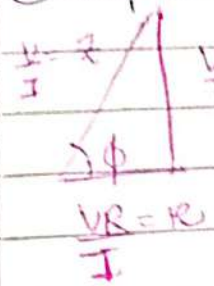
① Voltage Triangle



$V_L = V \sin \phi$

$V_R = V \cos \phi$

② Impedance Triangle (Dividing by I)

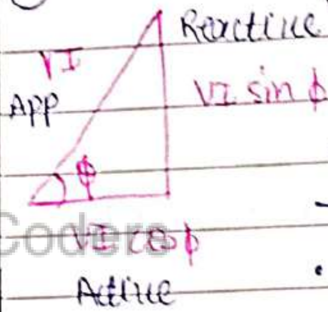


$X_L = Z \sin \phi$

$R = Z \cos \phi$

$\therefore Z\angle\phi$ or $R + jX_L$

③ Power Triangle (Multiply by I)

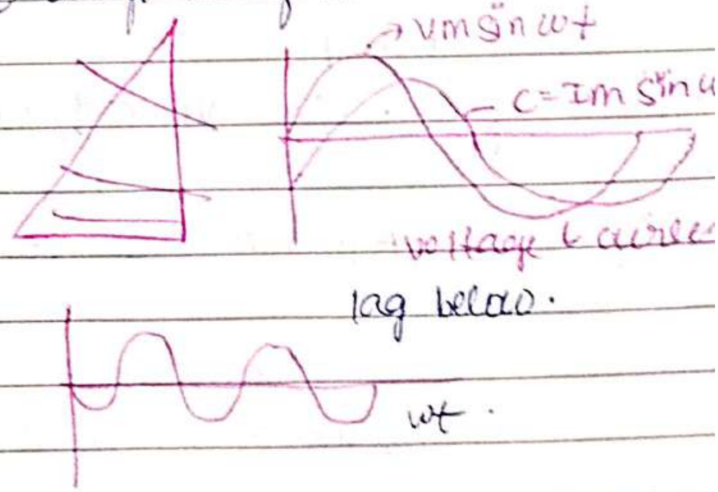


where
- Active Power → $VI \cos \phi$ VAR
- Reactive Power → $VI \sin \phi$ VAR
- Apparent power VI VA

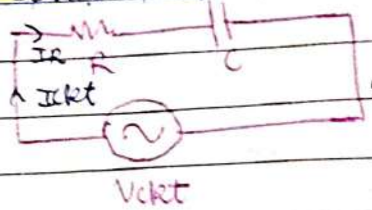
- where $\cos \phi$ is the power factor

→ Ratio of $\frac{\text{active power}}{\text{Apparent}}$

④ Waveform of Power



★ SERIES RC CIRCUIT:



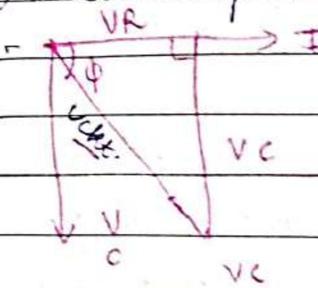
applied voltage

$v = V_m \sin \omega t$

• current circuit

$i = I_m \sin(\omega t + \phi)$

① Phasor diagram



$V_C = V \sin\phi$

$V_R = V \cos\phi$

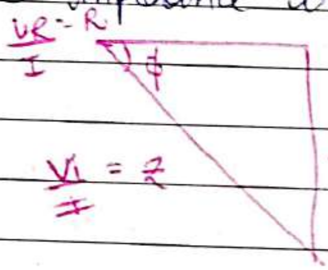
$\bar{V} = \bar{V}_R + \bar{V}_C$

$\quad = IR + \bar{I} X_C$

$\quad = I(R + X_C)$

$V = IZ$

② Impedance triangle (Divide by I)



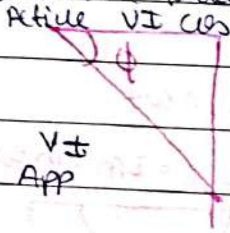
$X_C = Z \sin\phi$

$R = Z \cos\phi$

$\therefore Z \angle -\phi$ or

$R - jX_C$.

③ Power Triangle (multiply by I)



Active - $VI \cos\phi$ watt

Reactive = $VI \sin\phi$ VAR

Apparent = VI VA

• Instaneous power is given by

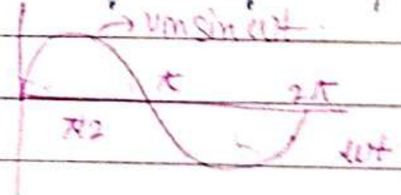
$p = v \cdot i = V_m \sin \omega t \cdot I_m \sin(\omega t + \phi)$

$= V_m I_m \sin \omega t \; \sin(\omega t + \phi)$

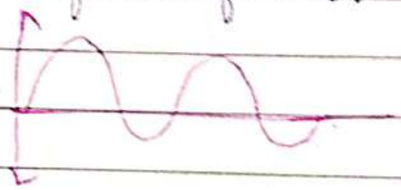
$= \frac{V_m I_m}{2} \cos\phi - \frac{V_m I_m}{2} \cos(2\omega t + \phi)$

$= \frac{V_m I_m}{2} \cos\phi - \frac{V_m I_m}{2} \cos(2\omega t + \phi)$

④ Waveform of voltage



⑤ Waveform of Power.



$v = V_m \sin \omega t$

$i = I_m \sin(\omega t + \phi)$

$P = VI \cos\phi$

* SERIES R-L-C CIRCUIT

$V = V_m \sin \omega t$

$V = \bar{V}_R + \bar{V}_L + \bar{V}_C$

$= IR + IX_L + IX_C$

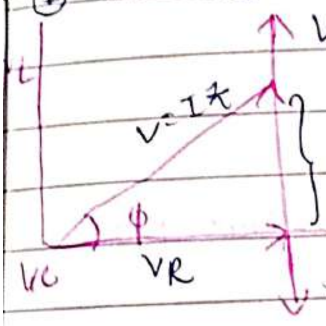
$= \bar{I}(\bar{R} + \bar{X}_L + \bar{X}_C)$

$V = IZ$

where Z is impedence

- X_L and X_C are in phase opposition so consider 3 conditions.

① $X_L > X_C$ ∴ $V_L > V_C$



$\boxed{\begin{aligned} V_L &= IX_L \\ V_C &= IX_C \end{aligned}}$

$V_L - V_C = I(X_L - X_C)$

$\rightarrow I_{ckt} = I_R = I_L = I_C$

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

- $\bar{V} = \bar{V}_R + (\bar{V}_L - \bar{V}_C)$

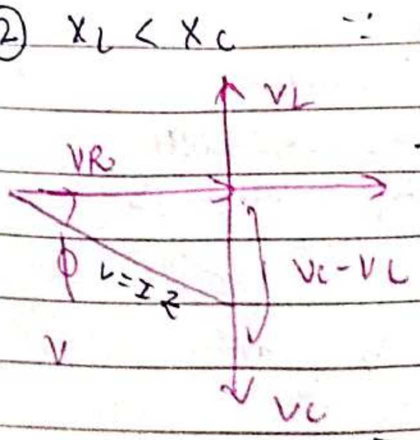
$I\bar{R} + (I\bar{X}_L - I\bar{X}_C)$

$I[\bar{R} + (X_L - X_C)]$

$\bar{V} = IZ$

where $Z = \sqrt{(R)^2 + (X_L - X_C)^2}$

② $X_L < X_C$ ∴ $V_L < V_C$



$\bar{V} = V_R + (\bar{V}_L - \bar{V}_C)$

$V = IR(X_L - X_C)$

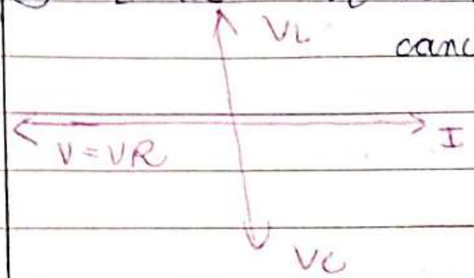
$[IR + (X_L - X_C)]$

$V = IZ$

where $Z = \sqrt{R^2 + (X_L - X_C)^2}$

- ϕ is $= \tan^{-1}\left(\frac{X_C - X_L}{R}\right)$

③ $X_L = X_C$ $V_L = V_C$ hence cancel eachother



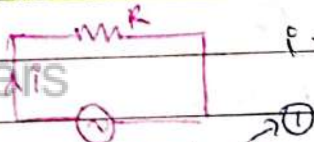
∴ $V = V_R$.

This is called series resonance

$I = I_R = I_L = I_C = I_{ckt}$

- write $\bar{Z}$ and $\bar{V}$ ___ + − + ___ in all conditions
- and write $V_L = IX_L$, $V_C = IX_C$

* AC FOR PURE RESISTANCE



$i = \frac{V_m}{R} \sin \omega t$

$V = V_m \sin \omega t$ → ①

$= i = I_m \sin \omega t$.

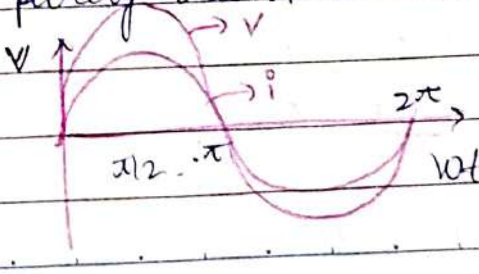
where $I_m = \frac{V_m}{R}$.

$i = \frac{V_m \sin(\omega t)}{R}$

$i = \frac{V_m}{R} (\sin \omega t)$

$i = I_{max} \sin(\omega t) \rightarrow$ ②

- from ① and ② V and I are in phase for purely resistive circuit.



SharkCoders

① Phasor

$\vec{I} \rightarrow \vec{V}$ ↑

② Equation of Power

$P = VI$

$= V_m \sin\omega t \cdot I_m \sin\omega t$

$V_m I_m \left(\frac{1 - \cos 2\omega t}{2}\right)$

∴ $P_{inst} = \frac{V_m I_m}{2} - \frac{V_m I_m}{2} \cos 2\omega t$

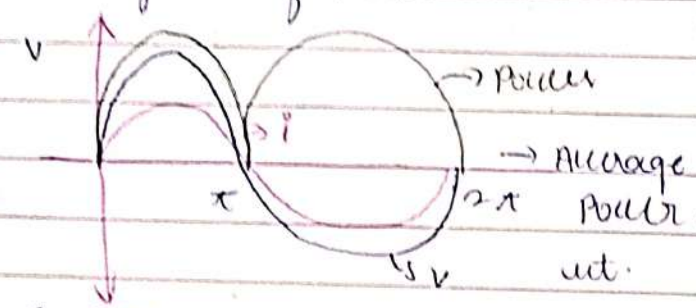
↳ instantaneous power

• Average power =

→ $P_{avg} = \frac{V_m I_m}{2} - 0$

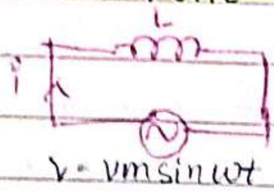
$P_{avg} = \frac{V_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}} = VI$

③ waveform of Power



$P = \frac{V_m I_m}{2} - \frac{V_m I_m}{2} \cos 2\omega t$.

★ AC TO PURE INDUCTANCE



self induced emf will always oppose applied voltage

• As per Lenz law

$v = -e$

$v = -e\ L \frac{di}{dt}$

• $V_m \sin\omega t = L \frac{di}{dt}$

$L\,di = V_m \sin\omega t\, dt$

$di = \frac{V_m}{L} \sin\omega t\, dt$

∴ Integrating both sides.

$i = \int \frac{V_m \sin\omega t\, dt}{L}$

$i = \frac{V_m}{L} \frac{(-\cos\omega t)}{\omega}\ dt$

$i = \frac{V_m}{\omega L} (-\cos\omega t)$

$i = \left(\frac{V_m}{\omega L}\right) \sin(\omega t - 90)$

$i = I_{max} \sin(\omega t - 90) \rightarrow ①$

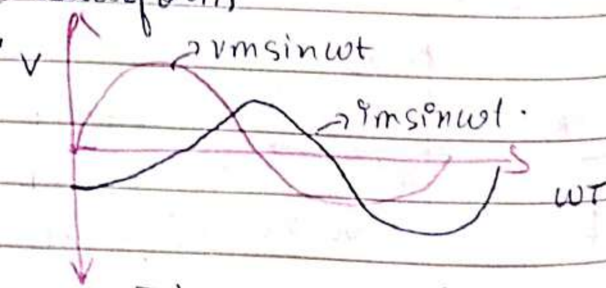
where $I_m = \frac{V_m}{\omega L} = \frac{V_m}{X_L}$.

$\frac{V_m}{X_L}$

↳ X_L is Reactance

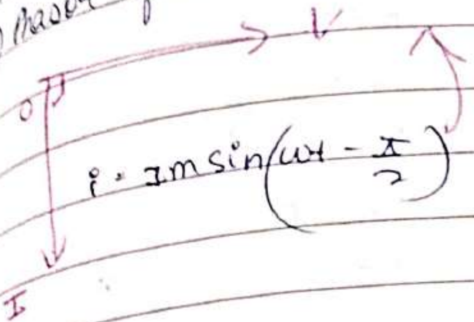
$X_L = \frac{V}{I}$

① waveform



I lags V by 90°

② Phasor of RL circuit



$i = I_m \sin\left(\omega t - \frac{\pi}{2}\right)$ where $I_m = \frac{V_m}{\omega L}$

③ Power

$P = VI$

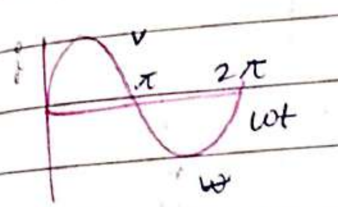
$P = V_m \sin \omega t \cdot I_m \sin(\omega t - 90)$

$V_m I_m \sin \omega t \,(-\cos \omega t)$

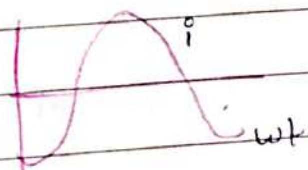
$P_{ins} = -\frac{V_m I_m}{2} \sin 2\omega t$

P_{avg} in RL circuit $= 0$.

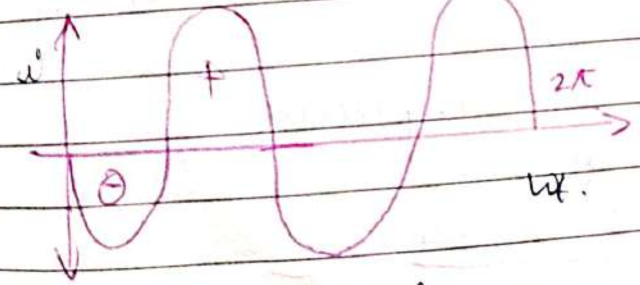
④ Voltage



⑤ current



⑥



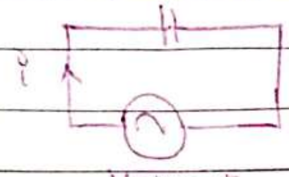
$P_{avg} = 0$ for 1 cycle.

$v = V_m \sin \omega t$

$i = I_m \sin(\omega t - \pi/2)$

$P_{ins} = \frac{V_m I_m}{2} \sin(2\omega t)$.

★ AC THROUGH PURE CAPACITANCE 06.



$q = CV$.

$V = V_m \sin \omega t$

$i = \frac{dq}{dt} = \frac{d}{dt} C V_m \sin \omega t$

$i = C V_m \frac{d}{dt} \sin \omega t$

$= C V_m \cos \omega t \cdot \omega$

$i = \omega C V_m \sin(\omega t + 90)$ → ②

where $I_m = \omega C V_m$

$i = I_m \sin(\omega t + 90^\circ)$

$I_m = \frac{V_m}{\sqrt{\frac{1}{(\omega C)}}}$

$X_C = \frac{1}{\omega C}$ → capacitive Reactance

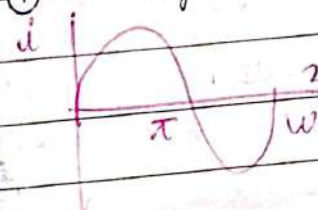
$I_m = \frac{V_m}{X_C}$

From ① and ②

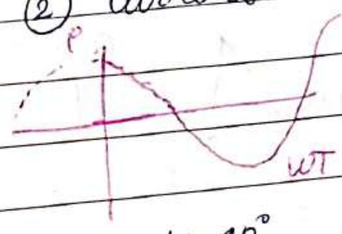
I leads V by 90°

④ waveform of R-C circuit

① Voltage

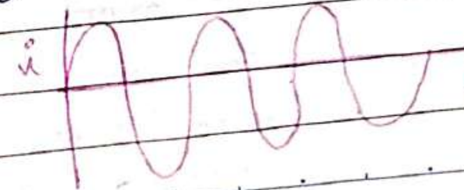


② current



lead by 90° current.

③ Power.



lead · lag - Before

FORMULA AND SUMMARY

(1) RLC

- $X_L = 2\pi f L$
- $X_C = \frac{1}{2\pi f C}$
- $V = IR$
- $I_{ckt} = \frac{V_{ckt}}{Z_{ckt}}$
- $V = IZ$
- $\phi_{ckt} = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$ (degree)

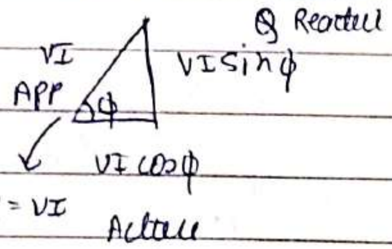
- $P = VI\cos\phi$ (Active Power) watt
- $S = V \times I$ VA (Apparent)
- $Q = VI\sin\phi$ VAR (Reactive)
- $Z_{ckt} = \sqrt{R^2 + (X_L - X_C)^2}$ or $(X_L)^2$
- Show arrow ↑ in phasor.
- Take rms value.

(2) Power Triangle in circuits.

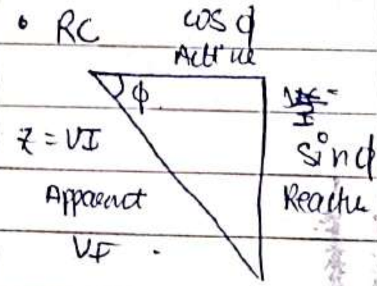
- BA - Base Active $\cos\phi$ (P)
- PR - Perpendicular Reactive $\sin\phi$ (Q)
- HA - Hypotenuse Apparent $S = VI$

By multiplying I.

- RL



- RC



~~$X_C = Z\sin\phi$~~

~~$R = Z\cos\phi$~~

$VI\cos\phi$ watt

$VI\sin\phi$ VAR.

Apparent = VI Va.

where $\cos\phi$ is power factor

$\frac{\text{Active}}{\text{Apparent}}$

(3) AC through

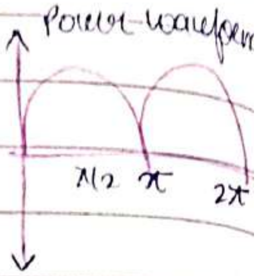
a. Pure Resistance.

- $P_{avg} = \frac{V_m I_m}{2} = 0$

$P_{avg} = \frac{V_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}} = VI$

write as $\frac{1 - \cos 2\omega t}{2}$.

Power waveform

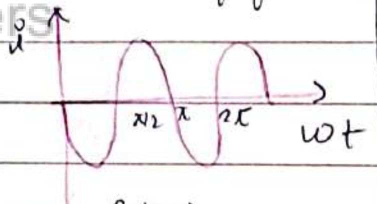


$\vec{V}$ $\vec{RI}$

b. Pure Inductance

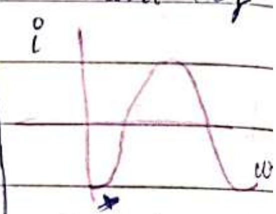
- $P_{avg} = 0$
- $P_{inst} = \frac{V_m I_m}{2} \sin 2\omega t$.
- Find Reactance $\frac{V_m}{X_L}$ → Reactance

- Power waveform



Below.

- current lag



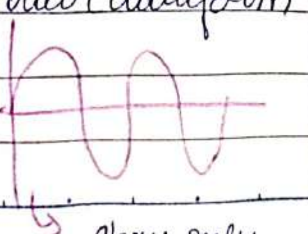
lead below

c. Pure Capacitance

- By $q = CV$.
- $I_m = \frac{V_m}{\frac{1}{\omega C}}$

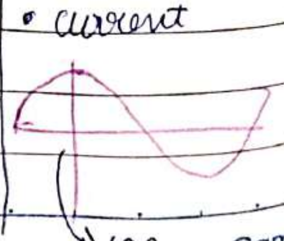
- $X_C = \frac{1}{\omega C}$ → capacitive Reactance.

- Power waveform



Above only

- current



LAG Before

Camlin

EFFECTIVE VALUE OF AC

Energy consumed by i_1 amp

$\to i_1^2 R \frac{T}{n}$ joule

$\to i_2^2 R \cdot \frac{T}{n}$ joule

Energy consumed by i_n amp -

$i_n^2 R \frac{T}{n}$ joule.

Total energy in a cycle

$$\left(i_1^2 \frac{RT}{n} + i_2^2 RT/n \dots i_n^2 \frac{RT}{n} \right) \to (1)$$

Energy given by direct current

$\to I_{eff}^2 \times RT$ joule $\to (2)$

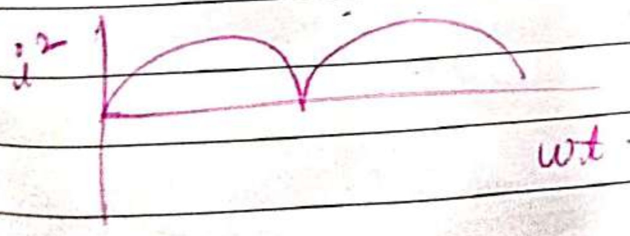
SharkCoders

$$I_{eff}^2 RT = \left[i_1^2 \frac{RT}{n} + i_2^2 \frac{RT}{n} \dots + i_n^2 \frac{RT}{n} \right]$$

$$I_{eff}^2 \cancel{RT} = (i_1^2 + i_2^2 + \dots i_n^2) \frac{\cancel{RT}}{n}$$

$$I_{eff} = \sqrt{\frac{i_1^2 + i_2^2 + \dots i_n^2}{n}}$$

I_{eff} = Root mean of square of instaneous values in a cycle.



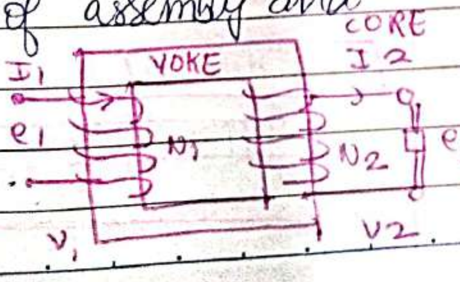
UNIT-05- TRANSFORMERS & POLYPHASE CIRCUITS

★ TRANSFORMER

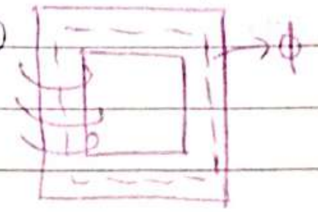
- Static device which transfers power from one circuit to another at same frequency but at different voltage levels.
- works on the principle of mutual induction
→ Two coils wound on the same magnetic core. The emf induced in one coil is due to the rate of change of flux in another coil
- Winding which is connected to the primary source of energy is called primary winding.
- The winding which plays the secondary role in transfer of power or the winding to which the load is connected is called secondary winding.
- The part of magnetic core on which winding is placed is called limb.
- The part of magnetic core which completes magnetic circuit through low reluctance path - yoke.

★ TYPES OF TRANSFORMER

- on the basis of assembly and winding
① core type
② shell type



★ CORE TYPE

①


- Internal - core
- outer - winding

② Structure
- core is surrounded by winding

③ Rating
- High

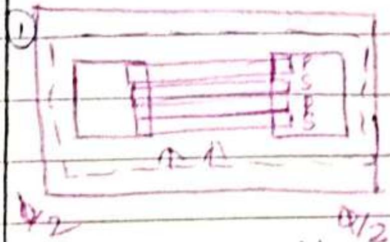
④ Repair/Maintenance
- easy

⑤ Flux - straight path

⑥ windings
- cylindrical

⑦ cooling - Better

SHELL TYPE

①


- Internal - winding
- outer - core

② Structure
- windings is surrounded by core

③ Rating
- Low

④ Repair/Maintenance
- Difficult

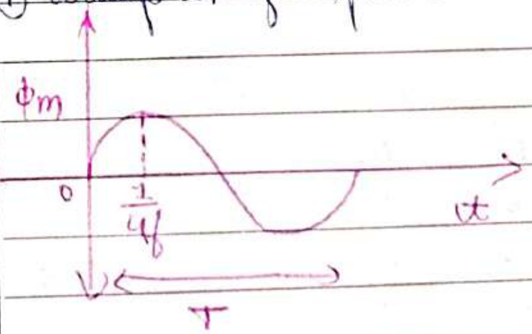
⑤ Flux - distributed

⑥ windings
- Sandwiched

⑦ cooling - Poor.

★ EMF EQUATION OF TRANSFORMER

① waveform of flux.



$\Delta t = \frac{t}{4}$

- Let $N_1, N_2, E_1, E_2, \phi_m$ = max value of flux
- Average induced emf is given by

$= \frac{d\phi}{dt}$

SharkCoders

$= \frac{\phi m}{\left(\frac{1}{4f}\right)}$ $|E_{Avg}| = \frac{N d\phi}{dt} = \frac{N\phi max - 0}{(T/4)}$

$(\Delta\phi = \phi_{max} \text{ to } 0), \Delta t = \frac{t}{4}$

$= \frac{N 4 \phi m}{T}$

- $|E_{Avg}| = 4 f \phi_m N$.
- For sinusoidal wave - form factor is 1.11.
- ~~RMS value = 4.4~~ $FF = \frac{E_{RMS}}{E_{AVG}} = 1.11$.
- $E_{Rms} = E_{avg}$

$E_{Rms} = 1.11 \times 4 f \phi m N$.

- $E_{Rms} = 4.44 f \phi m N$
- emf induced in primary $= 4.44 \phi_m f N_1$
- emf induced in secondary $= 4.44 \phi m f N_2$.

★ TRANSFORMER RATIO

- $P_1 = P_2$

$V_1 I_1 = V_2 I_2$

- $K = \frac{E_2}{E_1} = \frac{N_2}{N_1} = \frac{V_2}{V_1} = \frac{I_1}{I_2} = K$

$\frac{E_2}{E_1}$ → voltage Transformation Ratio; $\frac{N_2}{N_1}$ → Turn's Ratio; $\frac{I_1}{I_2}$ → current transformation Ratio.

- $K > 1$ - Step up transformer

$K < 1$ - Step down transformer

$K = 1$ - Isolation Transformer

★ TYPES OF LOSSES IN TRANSFORMER

1) Iron losses / core / constant losses

a. Hysteresis loss

- When MF is set up the molecules align in the direction of field, but if the field is changing / alternating they are reluctant to change direction, so energy spent in changing the direction is called hysteresis loss.
- $w_h = k_h \cdot B_m^{1.6} f \cdot V$ watt

k_h - hysteresis constant

f = frequency,

V = volume of core.

b. eddy current loss

- Due to linking of alternating to core, emf gets induced to the core giving rise to circulating currents in it.
- These currents - eddy current
- every path of circulating current produces I^2R losses, called as eddy current losses.
- $w_e = K_e \cdot B_m^2 \cdot f^2 t^2 V$ watt

B_m = max flux density

t - thickness of lamina.

- Flux density remains constant and supply frequency too, therefore called as constant losses.

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2) copper loss
- occurs in primary & secondary winding due to resistance of primary and secondary windings. (I^2R losses)
- Total copper losses = $I_1^2 R_1 + I_2^2 R_2$
  primary secondary
  $P_i + P_{cu}$

★ VOLTAGE REGULATION
- change in secondary voltage expressed as fraction of no load secondary voltage when primary voltage remains constant.
- Regulation : $\left.\dfrac{V_{2(0)} - V_2}{V_{2(0)}}\right|_{V_1 = const}$

★ EFFICIENCY OF TRANSFORMER
- efficiency $\eta = \dfrac{n \times VA \times P.f}{(n \times V_A \times P.f) + \text{losses}}$

① Output = $n \times V_A$ Rating $\times$ Pf
  n = % full load
  V_A = Rating / KVA → VA ✓ $\times 10^3$
  Pf = power factor value.

② losses - P_i = constant (given).
  $(P_{cu})_{FL}$ = ✓ given
  (P_{cu}) given load = $(P_{cu\,FL}) \times n^2$
  $(P_{cu})_{GL}$ = ✓

Total loss - $P_i + (P_{cu})$ given.

- n = loading fraction
  P_i ✓, P_{cu}, FL ✓

★ Solving efficiency numericals
- convert V_A into KVA → VA $\times 10^3$.
  S = Apparent Power = VAR.

★ POLYPHASE AC CIRCUIT.
① Symmetrical system (3ph)
- (Balanced system) - is the system in which all the three voltages of same frequency are equal in magnitude and are displaced from each other by equal 120° angle.

② Symmetrical load / Balanced load
- Load in which each phase is equal in magnitude and identified in nature.

③ Phase sequence
- The sequence in which three voltages achieve their positive max value.

★ RATIO NUMERICAL
- Tx Ratio = $\dfrac{N_2}{N_1} = \dfrac{E_2}{E_1} = \dfrac{V_2}{V_1} = \dfrac{I_1}{I_2}$
- $\dfrac{E_1}{N_1} = \dfrac{E_2}{N_2}$ ✓ voltage per Turn

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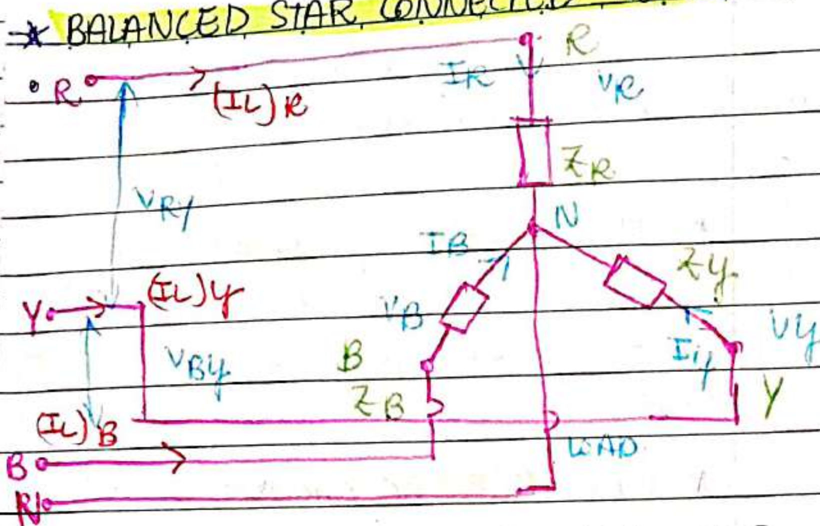
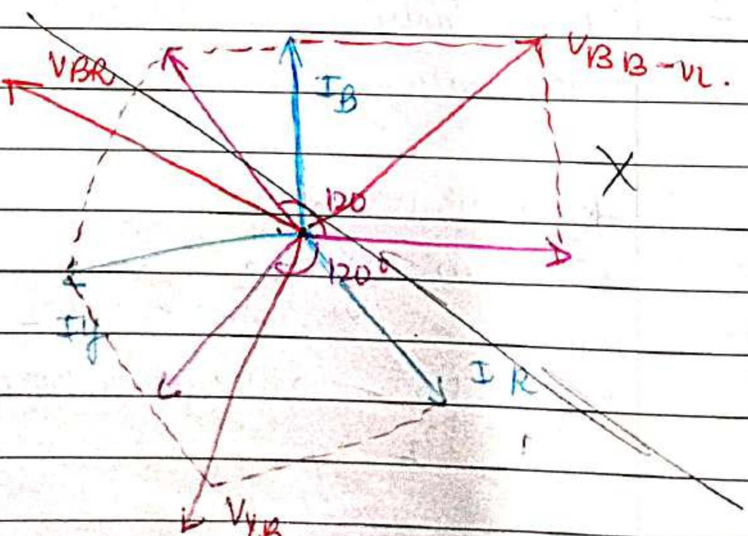
* BALANCED STAR CONNECTED LOAD

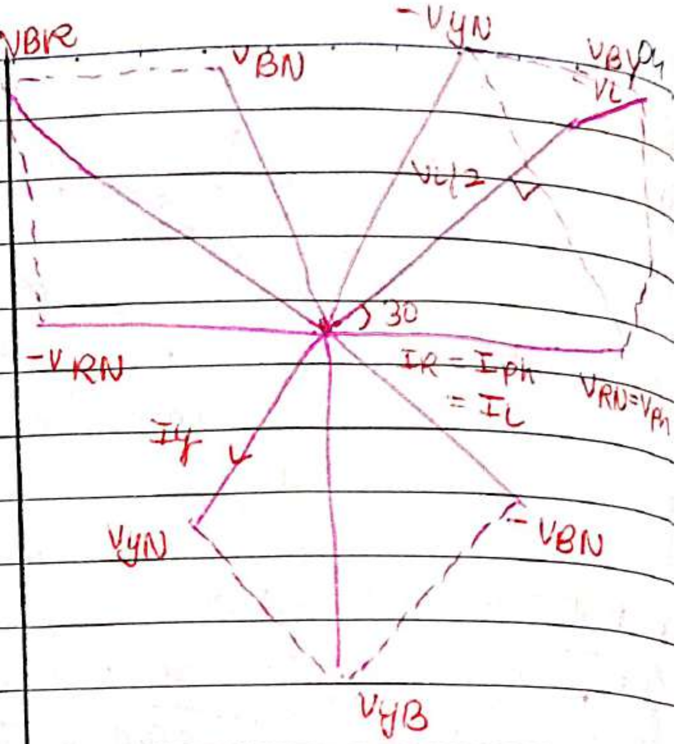


- Line voltage $V_L = V_{RY} = V_{YB} = V_{BR}$
- Line currents: $I_L = I_R = I_Y = I_B$
- Phase voltages $= V_{ph} = V_{RN} = V_{YN} = V_{BN}$
- Phase current $= I_{ph} = I_R = I_Y = I_B$
- Since the phase arm and line conductor form series circuit, hence $I_L = I_{ph}$ but

- $V_L = V_{RY} = V_{RN} + V_{NY} = V_{RN} + (-V_{YN})$
- V_{YB}: $V_{YN} + V_{NB} = V_{YN} + (-V_{BN})$
- V_{BR}: $V_{BN} + V_{NR} = V_{BN} + (-V_{RN})$

hence





Notes.

- $\cos 30° = \dfrac{V_L/2}{V_{ph}}$

$\dfrac{\sqrt{3}}{2} = \dfrac{V_L}{2V_{ph}}$

$\therefore V_L = \sqrt{3}\, V_{ph}$

$I_L = I_{ph}$.

- 3 phase Active power = $3 V_{ph} I_{ph} \cos\phi = \sqrt{3} V_L I_L \cos\phi$ watt
- Reactive power → $3 V_{ph} I_{ph} \sin\phi = \sqrt{3} V_L I_L \sin\phi$ VAR
- Apparent Power → $3 V_{ph} I_{ph} = \sqrt{3} V_L I_L$ VAR

* PHASOR - STAR - equations

$V_{RY} = V_R - V_Y$
$V_{YB} = V_Y - V_B$
$V_{BR} = V_B - V_R$
} line voltages

- $I_R\ I_Y\ I_B$ → current.

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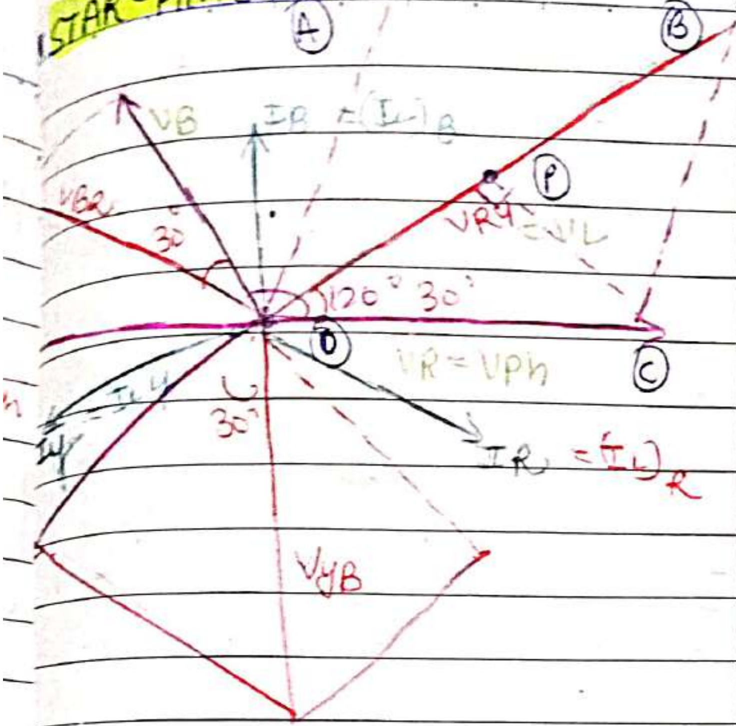
STAR-PHASOR



STAR- Relation b/w V_L & V_{ph}

In parallelogram $\square OABC$

$l(OC) = V_R = V_{ph}$

$l(OB) = V_{RY} = V_L$

$l(OP) \quad V_L/2$

In ΔOPC

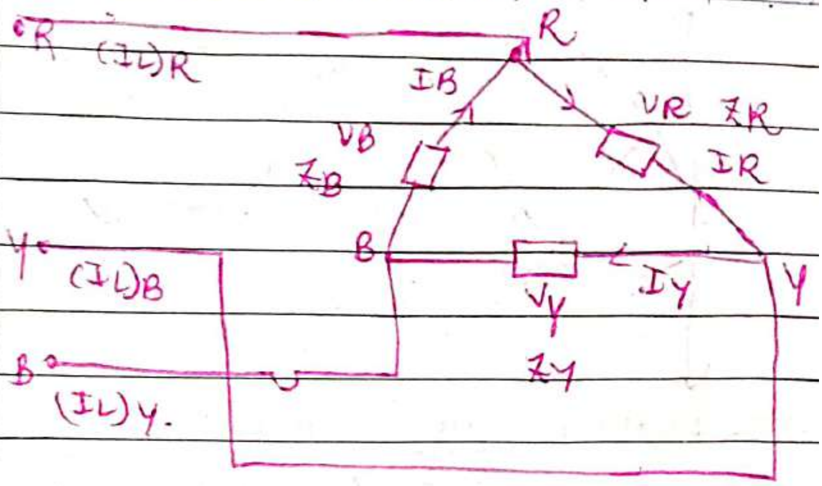
$$\cos 30^\circ = \frac{l(OP)}{l(OC)} = \frac{V_L/2}{V_{ph}}$$

$$\frac{\sqrt{3}}{2} = \frac{V_L/2}{V_{ph}}$$

$$\frac{V_L}{2} = \frac{\sqrt{3}}{2} V_{ph}$$

$$V_L = \sqrt{3}\, V_{ph}.$$

★ DELTA CONNECTION



- $V_L = V_{ph}$ Delta
- $l(OA) = I_R = I_{ph}$

$l(OB) = (I_L)_R = I_L$

$\Delta OAP, \ \angle P = 90^\circ$

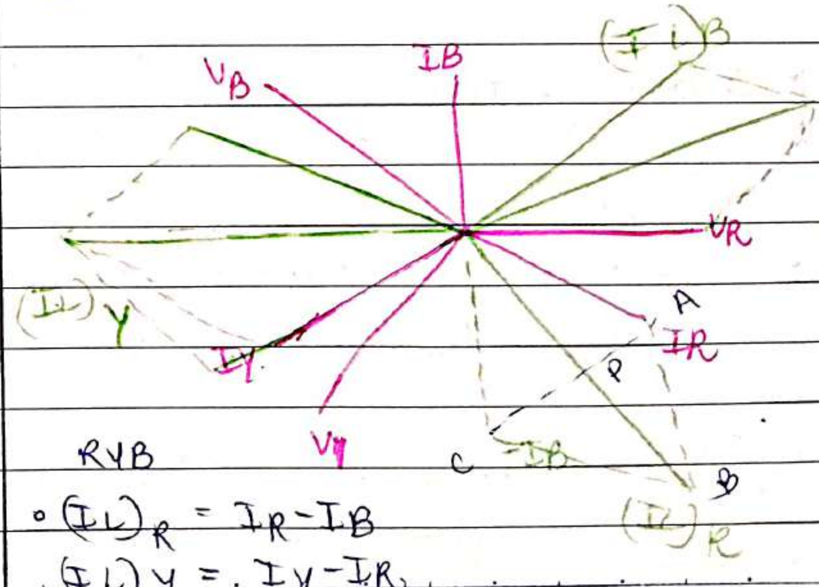
$l(OP) = l(PA) = \frac{1}{2} I_L$

$$\cos 30^\circ = \frac{l(OP)}{l(OA)} = \frac{1/2\, I_L}{I_{ph}}$$

$$\frac{\sqrt{3}}{2} I_{ph} = \frac{I_L}{2}$$

- $I_L = \sqrt{3}\, I_{ph}$

★ DELTA PHASOR



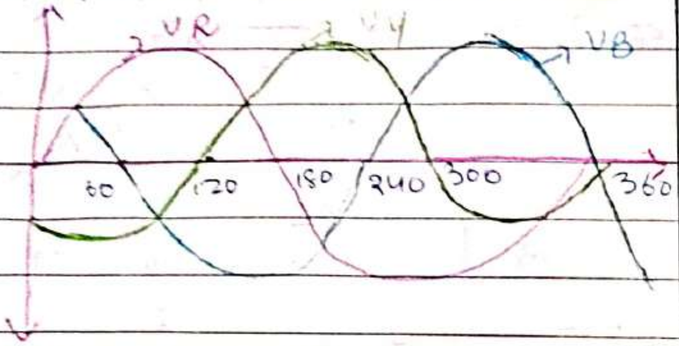
RYB

- $(I_L)_R = I_R - I_B$

$(I_L)_Y = I_Y - I_R$

- $(I_L)_B = I_B - I_Y$

★ WAVEFORM OF 3PHASE AC CIRCUIT:



★ SOLVING STAR/DELTA NUMERICALS

① $Z_{ph} = \sqrt{R^2 + X_L^2}$ or $\sqrt{(Real)^2 + (imag)^2}$

- $X_L = \omega \times L$
  $X_C = \frac{1}{\omega C}$

② $\phi = \tan^{-1}\left(\frac{X_L}{R}\right)$ degree $\frac{imag}{Real}$.

③ $I_{ph} = \frac{V_{ph}}{Z_{ph}}$, Always given → V_L

- For star $I_L = I_{ph}$ $V_L = \sqrt{3} V_{ph}$
- For delta $V_L = V_{ph}$ $I_L = \sqrt{3} I_{ph}$

④ Active 3ϕ power $P = V_L I_L \cos\phi \times \sqrt{3}$
Reactive Q $\sqrt{3} \times V_L \times I_L \sin\phi$
Apparent $S = V_L \times I_L \times \sqrt{3}$

★ 3 PHASE ACTIVE POWER

- $I_L = I_{ph}$ $3\phi P = 3 \times (1\phi P)$
  $V_L = \sqrt{3} V_{ph}$
- $3\phi P = 3 \times (V_{ph} \times I_{ph} \times \cos\phi)$
  $\left(3 \times \frac{V_L}{\sqrt{3}} \times I_L \cos\phi\right)$

$3\phi P = \sqrt{3} V_L I_L \cos\phi$ watt
- $3\phi Q = \sqrt{3} V_L I_L \sin\phi$ VAR
- $3\phi S = \sqrt{3} . V_L I_L$ VA

STAR	DELTA
① 4 wired connection (4th wire - optional)	① 3 wired connection
② Two Types → 3 Phase 4 wire → 3 phase 3 wire	② only 3 phase 3 wire connection possible
③ $V_L = \sqrt{3} V_{ph}$	③ $V_L = V_{ph}$
④ $I_L = I_{ph}$	④ $I_L = \sqrt{3} I_{ph}$
⑤ Line & Phase voltage is different	⑤ Line and Phase voltage are same.
⑥ Common point of star connection is called neutral/star point	⑥ There is no neutral in Delta connection
⑦ used for long distances	⑦ used for shorter distances
⑧ often used in application which require less starting current	⑧ often used in application which require high starting torque

★

- $\phi = B \cdot a$
- $\frac{N_2}{N_1} = \frac{E_2}{E_1}$
- emf equation, To find N_1
  → $4.44 f \phi_m \cdot N_1$
  N_1
- Now use Tx Ratio, get N_2.
- Primary current
  $I_1 = \frac{VA}{V_1} \rightarrow kVA \times 10^3$.

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