9 NOV, 2022

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ELECTRICAL SCIENCE

100

- 25 internal
  - 15 internal ass
  - 10 quis, assignment
- 75 external theory + numericals.

SYLLABUS

Unit-1 DC circuits # Unit-2 AC circuits

Unit-3 Transformers & Machines (motors & Generators) # Unit-4 Measuring Instruments. (Analogue & Digital)

UNIT-1 DC Circuits

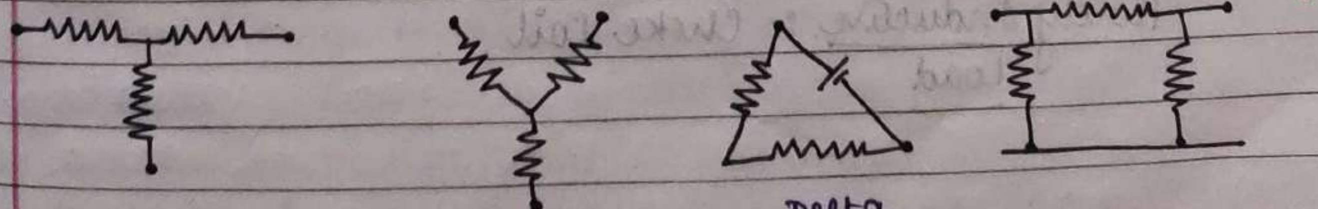
BASIC TERMS

(a) Circuit :- Any energized (Sources of energy) network through which current flows is called a circuit.

OR

A closed network or loop in which current flows.

(b) Network :- Combination or interconnections of circuit elements or parameters
→ R, L and C, voltmeter, battery



T network Star network Delta Network π network.

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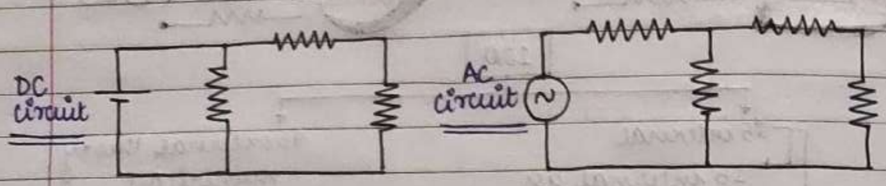
(c) Sources of Energy :- Battery, cell, Solar Cell, generator

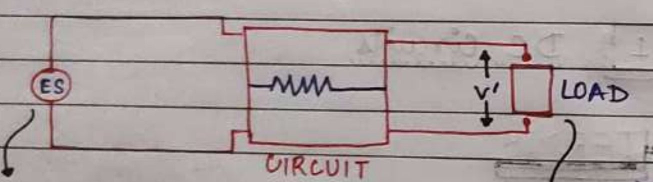
Photon → Elec. Mech → Elec



(d) Energy converter (LOAD) :- Anything which consumes electrical power. For eg:- Fan, oven

For us :- RLC → R, L for Real life ; C just enhances power factor.

CIRCUIT REPRESENTATION



SOURCE OF EMF
or
Open circuit voltage
(V)

Terminal ← pair of 2 points (port)
Voltage

$\boxed{V - IR = V'}$

QUESTIONS FOR VIVA :-

Q Purely Resistive Load :- Normal Tungsten 0 watt bulb

Purely Inductive Load :- Choke Coil

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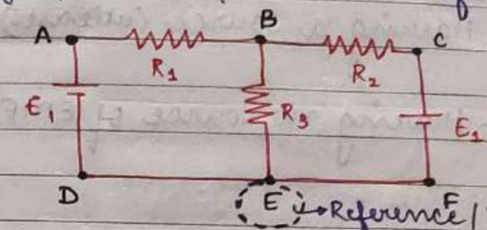
Circuit Diagram

A graphical representation of circuit elements



Characteristic having a reln b/w quantities

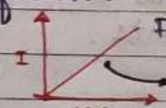
E ↳ Reference / Datum / ground node. (V=0)

TYPES OF CIRCUIT :-

*1. DC circuit :- Voltage & Current same with time.

*2. AC Circuit :- " " " changes " ".

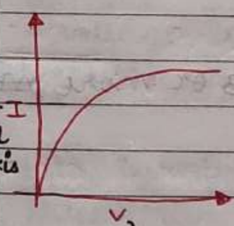
*3. Linear Circuit :- Which follows Ohm's Law, i.e purely resistive in nature.



Follows homo. & superposition.

St. line characteristic.

*4. Non-linear Circuit :- doesnot follow Ohm's Law. Eg:- Semiconductors. (or) which do not follow principle of Superposition & homogenity.



affected by x axis

changed by user

"Non linear circuit graphs"

Superposition

$x_1 + x_2 = y_1 + y_2$

$2x_1 + x_2 = 2y_1 + y_2$

(proportional change in o/p)

Homogenity :- $x_1 = y_1 \Rightarrow 5x_1 = 5y_2$

*5. Unilateral circuit :- characteristics of circuit changes with change in direction of current. Eg:- Diode, rectifiers.

*6. Bilateral circuit :- charateristic of circuit remains same irrespective of direction of current.

Eg:- Transmission line.

Type of Networks

*1. Active network :- Having a source (atleast one) of EMF

*2. Passive network :- Having no source of EMF. Eg:- only R, L, C

#1. Active Elements :- Sources of EMF. Eg :- Cell, battery.

#2. Passive elements :- which ~~stores~~ consumes & Dissipates energy. Only R dissipates energy.

★★ #3. Node :- A point or any interconnection of 2 or more elements.

A (E_1, R_1) D & F are not Nodes

B $(R_1\ R_2\ R_3)$

C (R_2, E_2)

E (E_1, R_3, E_2)

★★ #4. Juction :- Any interconnection of 3 or more circuit elements. (Current divides)

B and E are the 2 junctions

(KCL applied)

★★ #5. Branch :- A part of a circuit which lies b/w 2 junctions

For eg :- BADE, BE, BCFE (circuit diagram)

★★ #6. Loop :- Any closed path in a circuit is called loop in which no element or node is encountered more than one (KVL applied)

For eg :- ABED, BCFE, ABCFED

★★ #7. Mesh :- Smallest loop which doesnot contain a loop within it. (KVL applied)

For eg :- BCFE, ABED

[Ideal :- 100% η

Type of Sources :-

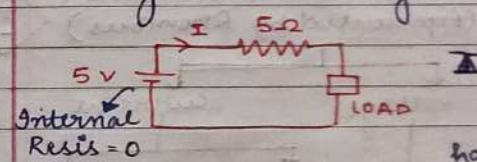
(Independent sources)

*1. Voltage Source :- Provides EMF (const V. wrt T).

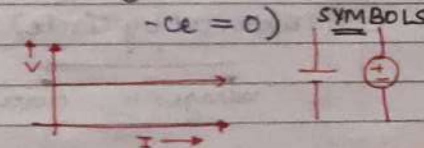
*2. Constant current source :- provides constant current Eg:- Solar panels, Metadine generators, certain Transis

Date :- 12 Nov, 2022

*1. Ideal voltage source :- It should provide a constant & designated voltage wrt time. (Internal Resista -ce = 0)



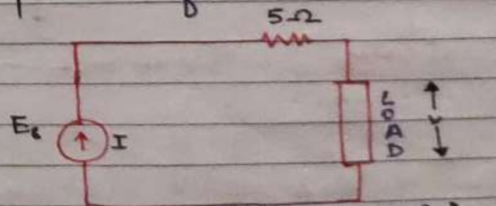
I = 1A



→ "An Ideal voltage Source has zero Internal Resistance"

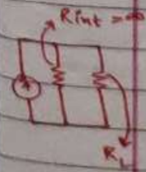
→ "A voltage source can be replaced by a short circuit because we need zero Resistance & infinite current"

*2. Ideal current source :- Provides constant current irrespective of load current



$E_s >>> V$ for flow of current. (High Pot → Lower Pot)

$E_s\uparrow \rightarrow R_{int}\uparrow$

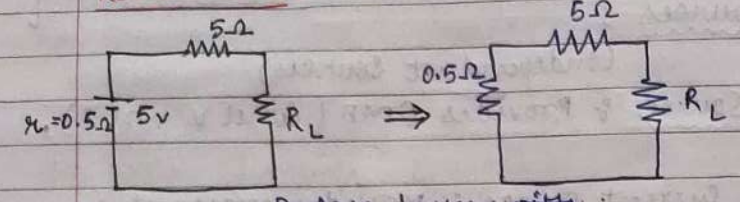


An Ideal current Source, which supply the same current to any Resistance connected across its terminats.

It has infinite internal Resistance to provide constt current.

→ An Ideal current source is Replaced by an open circuit bcz of infinite Resistance. (internal Resistance)

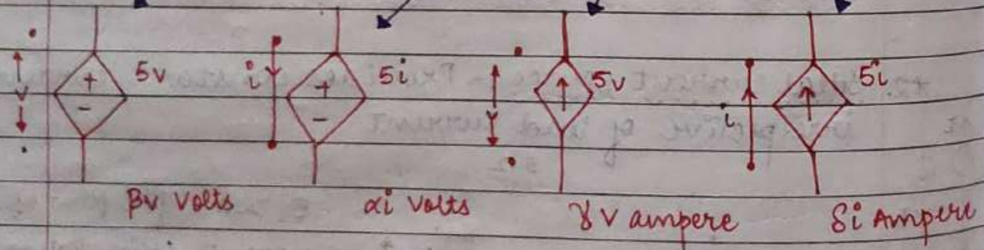
" ALL THE SOURCES (of EMF) ARE TO BE REPLACED BY THEIR INTERNAL RESISTANCES."



Replace battery

SOURCES

- Independent (Represented by circle)
  - voltage
  - current
- Dependent / controlled (Represented by Rhombus)
  - voltage
    - voltage controlled voltage source
    - current cont. voltage source
  - current
    - VCCS
    - CCCS

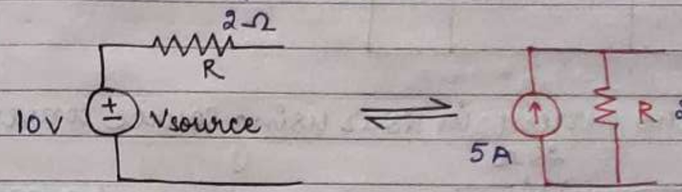


23rd November, 2022

SOURCE CONVERSION :-

(Independent Sources)

V source ⇌ C source



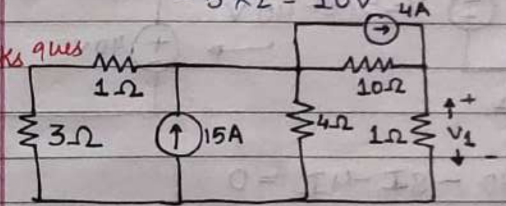
$V = IR$
$= 5 \times 2 = 10V$

$I = \frac{V}{R} = \frac{10}{2} = 5$ Ampere

25th Nov, 2022

3 marks ques

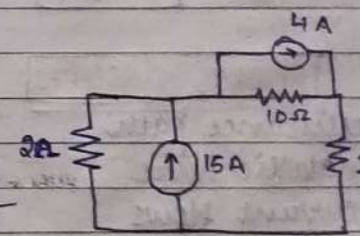
Q. Find V, using source conversion.

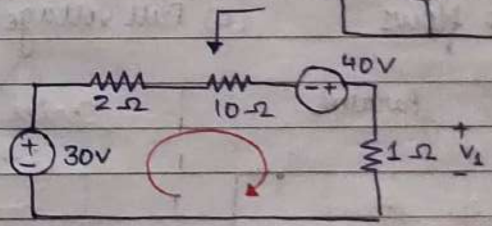


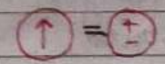
$(3\Omega + 1\Omega) \parallel 4\Omega$

$4\Omega \parallel 4\Omega$

$R_{eq} = 2\Omega$







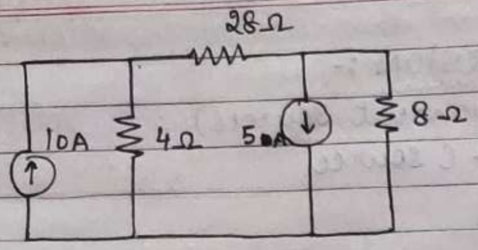
$V = IR = 15 \times 2 = 30V$

$30 - 12I + 40 - V_1 = 0$

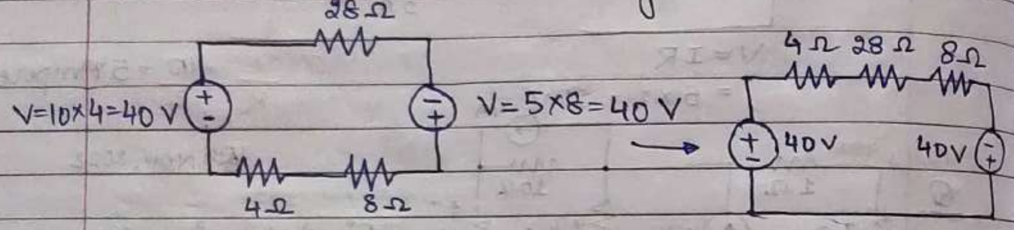
$30 - 12I + 40 - I(1\Omega) = 0$

$I = \frac{70}{13} A \Rightarrow V = \frac{70}{13} \times 1\Omega = \frac{70}{13} V$ Ans.

Q2



Find the current in 28Ω using source converter.

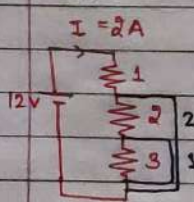
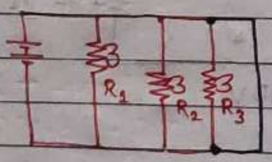
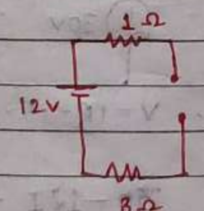


$+40V - 28I + 40 - 8I - 4I = 0$

$\boxed{I = 2A}$

$\boxed{\text{SHORT CIRCUITS}}$ v/s $\boxed{\text{OPEN CIRCUITS}}$

SHORT CIRCUITS	OPEN CIRCUITS
(A) Zero resistance path	(A) No continuity in ckt
(B) Thick metallic wire	(B) $R = \infty$, $I = 0 \rightarrow$ ⊗ V drop across R.
(C) Max^m current flows	(C) Full voltage across open Terminal.
(D) Dangerous	

Series	Parallel	Series
		
Step 1 ⇒ short ckt 3Ω $I_1 = \frac{12}{3} = 4A$ Step 2 ⇒ short ckt 2 & 3Ω $I_2 = \frac{12}{1} = 12A$	No bulb will glow	Voltage across each component = 0 voltage across open = Full voltage

In short ckt (Sn)

Zero Resistance $\Rightarrow V = IR \Rightarrow V = 0$

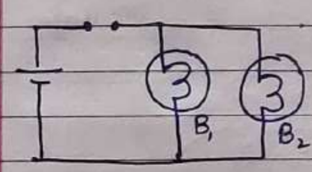
Zero voltage drop across terminals of short circuit.

In parallel short ckt.

Short across one branch = Short across all branches.

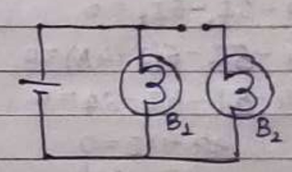
open ckt in parallel ckt.

Main line



No current & no bulb will glow.

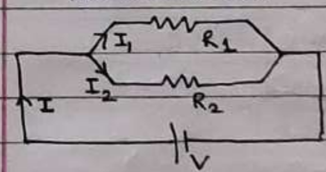
Branch line



B_1 will glow.

Current Division Rule and Voltage Division Rule

Parallel ckt



$$I_1 = I \cdot \left(\frac{R_2}{R_1+R_2}\right)$$

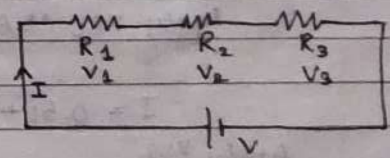
$$I_2 = I \cdot \left(\frac{R_1}{R_1+R_2}\right)$$

If $I = 4A$, $R_1 = 2\Omega$, $R_2 = 4\Omega$

$$I_1 = 4\left(\frac{4}{2+4}\right) = \frac{8}{3}A$$

$$I_2 = \frac{8}{6} = \frac{4}{3}A$$

Series ckt



$$V_1 = \frac{R_1 \cdot V}{R_{eq}}, \quad V_2 = \frac{V \cdot R_2}{R_{eq}}$$

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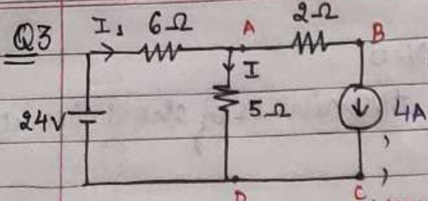
Q3

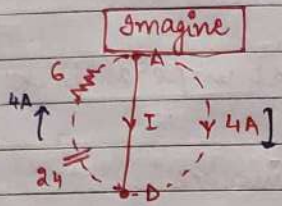


Find I ABCD has 4A current.

KCL at A

$I_1 = I + 4A$

$I_1 = \frac{24}{6} = 4A$



$I = 0A$

Using KVL

$24 - 6I_1 - 5I_1 = 0$

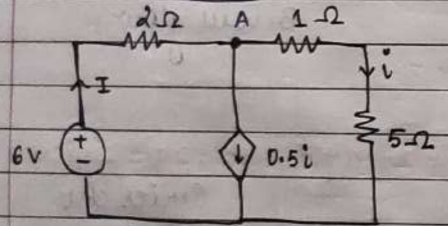
$24 - 5I - 6(I+4A) = 0$

$24 - 5I - 6I - 24 = 0$

$\cancel{44} - 11I = 0$

$\boxed{I = 0}$

Q4.



Find the current through 5Ω resistor.

Apply KCL at A

$I = 0.5i + i = 1.5i$

Apply KVL

$6V - 2I - 1i - .5i = 0$

$6 - 2(1.5i) - 6i = 0$

$6 - 9i = 0$

$\frac{6}{9} = i = \frac{2}{3} A$

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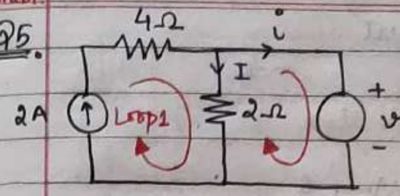
Doubt.

Q5.



find i for V=2V, 4V & 6V

For V = 2V

$2 = i + I$

KVL ⇒ $-2 + 2I = 0$

$+2 = 2I ⇒ I = +1A$

$2 = i + 1$

$i = 1A$ for $V = 2V$

$-4(2) - 2I = 0$ ⊗ $-2 + 2I$

$-4 - I = 0$ (KVL cannot be applied

$I = -4A$ on loop1 bcz of C.S)

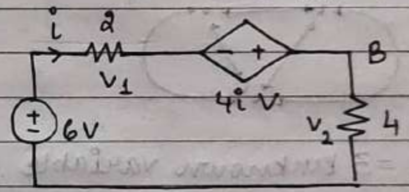
After 3 pages :-

for V=4V

$-4V + 2I = 0$

$I = 2A ⇒ i = 4A$

Q6.



find i, V_1, V_2

$-V_1 + 4i - V_2 + 6 = 0$

$V_1 = 2i \quad V_2 = 4i$

$-2i + 4i - 4i + 6 = 0$

$6 = +2i$

$\boxed{i = +3A}$

$V_1 = 2 \times 3 = 6V$

$V_2 = 4 \times 3 = 12V$

MESH ANALYSIS METHOD :-

We use mesh currents here based on KVL

STEP-1 Count no of meshes.

Step-2 for each mesh, assign a mesh current preferably in C.W direction.

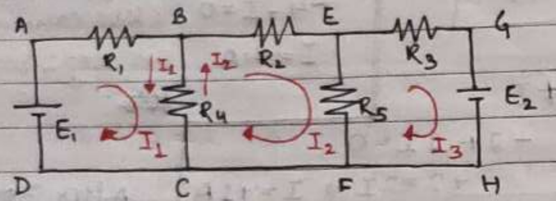
STEP-3 Write down KVL for each mesh.

no. of eqns = $(b - (j-1))$

b = no. of branches , j = no. of junctions.

We donot use branch current.
→ less eqns, less tedious
→ can use matrix method also.

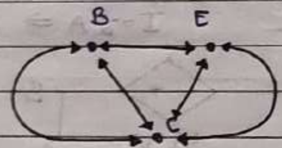
Q7.



Junctions :- B, E, C, F but C & F are at same potential. Hence

j :- B, E, C = 3

Branch :- 5



No. of eqn :- 5-(3-1)
= 3 eqns. = 3 unknown variable.

Eqn-①

$E_1 - I_1R_1 - \underbrace{R_4(I_1 - I_2)}_{\star} = 0$ [R_4 (mesh no.1 - mesh no.2)]

$E_1 - I_1R_1 - R_4I_1 + R_4I_2 = 0$

$E_1 - I_1(R_1 + R_4) + R_4I_2 = 0$

Eqn-②

$-I_2R_2 - R_5(I_2 - I_3) - \underbrace{R_4(I_2 - I_1)}_{\star} = 0$

$-I_2R_2 - R_5I_2 + R_5I_3 - R_4I_2 + R_4I_1 = 0$

$-I_2(R_2 + R_4 + R_5) + R_5I_3 + R_4I_1 = 0$

Eqn-③ $-I_3R_3 \mp E_2 - R_5(I_3 - I_2) = 0$

$-I_3R_3 - E_2 - R_5I_3 + R_5I_2 = 0$

$-I_3(R_3 + R_5) - E_2 + R_5I_2 = 0$

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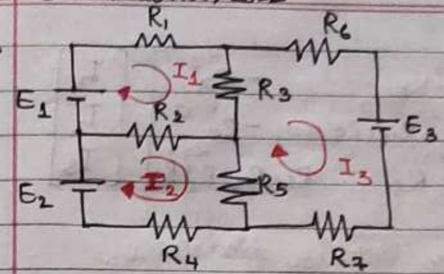
Q8.



find I_1, I_2, I_3

For mesh 1 :- $E_1 - I_1R_1 - R_3(I_1 - I_3) - R_2(I_1 - I_2) = 0$

$E_1 - I_1R_1 - R_3I_1 + R_3I_3 - R_2I_1 + R_2I_2 = 0$

$E_1 - I_1(R_1 + R_2 + R_3) + R_3I_3 + R_2I_2 = 0$ — (i)

For mesh 2 :- $E_2 - R_2(I_2 - I_1) - R_5(I_2 - I_3) - R_4I_2 = 0$

$E_2 - I_2(R_2 + R_5 + R_4) + R_2I_1 + R_5I_3$ — (ii)

For mesh 3 :- $-R_3(I_3 - I_1) - R_6I_3 - E_3 - R_7I_3 - R_5(I_3 - I_2) = 0$

$-E_3 - I_3(R_3 + R_6 + R_7 + R_5) + R_3I_1 + R_5I_2 = 0$ → (iii)

Using (i)
$E_1 = I_1(R_1 + R_2 + R_3) - R_3I_3 - R_2I_2$

Using (ii)
$E_2 = I_2(R_2 + R_5 + R_4) - R_2I_1 - R_5I_3$

Using (iii)
$E_3 = +I_3(R_3 + R_6 + R_7 + R_5) \mp R_3I_1 \mp R_5I_2$

$$\begin{bmatrix} E_1 \\ E_2 \\ E_3 \end{bmatrix} = \underbrace{\begin{bmatrix} & & \\ & & \\ & & \end{bmatrix}}_{R_m} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

$\boxed{[E_m] = [R_m][I_m]}$ → ohm's law in matrix form.
FOR CLOCKWISE DIR.

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$$\begin{bmatrix} E_1 \\ E_2 \\ E_3 \end{bmatrix} = \begin{bmatrix} \overset{R_{11}}{R_1+R_2+R_3} & \overset{R_{12}}{-R_2} & \overset{R_{13}}{-R_3} \\ \overset{R_{21}}{-R_2} & \overset{R_{22}}{R_2+R_4+R_5} & \overset{R_{23}}{-R_5} \\ \overset{R_{31}}{-R_3} & \overset{R_{32}}{-R_5} & \overset{R_{33}}{R_6+R_3+R_5+R_7} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

For clockwise direction.

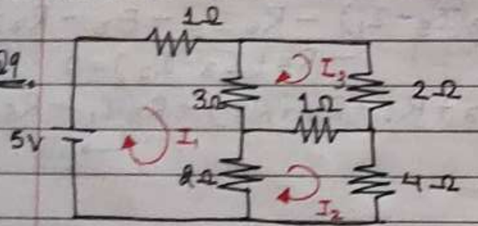
R_{11}, R_{22}, R_{33} = self Resis of each mesh (+ve)

R_{31} = Mutual Resistance b/w mesh 3 & mesh 1

all mutual Resistances are -ve.

$$\begin{bmatrix} E_1 \\ E_2 \\ E_3 \end{bmatrix} = \begin{bmatrix} R_1+R_4 & -R_4 & 0 \\ -R_4 & R_4+R_2+R_5 & \\ 0 & -R_5 & R_3+R_5 \end{bmatrix}$$

Q9.



$$\begin{bmatrix} E=5 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 6 & -2 & -3 \\ -2 & 4+1+2 & -1 \\ -3 & -1 & 2+3+1 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

$$\begin{bmatrix} 5 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 6 & -2 & -3 \\ -2 & 7 & -1 \\ -3 & -1 & 6 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

$; |A| = 6(42-1) - (-2)(-12-3) - 3(2+21)$
$= 6(41) + 2(-15) - 3(23)$
$= 246 - 30 - 69 = 147$

$\neq$ $6X_1 \cdot 2X$. Inverse of matrix

$A_{11} = 42-1$ $A_{21} = -12-3$ $A_{31} = 2+21$

$A_{12} = -12-3$ $A_{22} = 36-9$ $A_{32} = -6-6$

$A_{13} = 2+21$ $A_{23} = -6-6$ $A_{33} = 42-4$

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$C_{11} = 41$ $C_{21} = +15$ $C_{31} = 23$

$C_{12} = +15$ $C_{22} = 25$ $C_{32} = +12$

$C_{13} = 23$ $C_{23} = +12$ $C_{33} = 38$

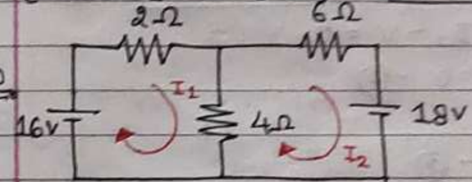
$$\frac{1}{147}\begin{bmatrix} 5 \\ 0 \\ 0 \end{bmatrix}_{3\times1} \begin{bmatrix} 41 & 15 & 23 \\ 15 & 27 & 12 \\ 23 & 12 & 38 \end{bmatrix}_{3\times3} = \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

$$\frac{1}{147}\begin{bmatrix} 41\times5 \\ 15\times5 \\ 23\times5 \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} \Rightarrow$$

$I_1 = \frac{205}{147}$ $I_2 = \frac{75}{147}$ $I_3 = \frac{115}{147}$

$\boxed{I_1 = 1.39A;\ I_2 = 0.51A;\ I_3 = 0.78A}$ Ans

Q10



Ans to crosscheck.
$I_2 = -1A$
$I_1 = 2A$

Method-1

$$\begin{bmatrix} 16 \\ -18 \end{bmatrix} = \begin{bmatrix} 6 & -4 \\ -4 & 10 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

$$adj = \begin{bmatrix} 10 & 4 \\ 4 & 6 \end{bmatrix}$$

$A = XB$

$AX^{-1} = B = A \times \frac{1}{|X|} adj X = B$

$$\frac{1}{44}\begin{bmatrix} 16 \\ -18 \end{bmatrix} \begin{bmatrix} 10 & 4 \\ 4 & 6 \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

$$\frac{1}{44}\begin{bmatrix} 10 & 4 \\ 4 & 6 \end{bmatrix} \begin{bmatrix} 16 \\ -18 \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

$$\frac{1}{44}\begin{bmatrix} 160 - 72 \\ 64 - 108 \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} \Rightarrow$$

$\boxed{I_1 = 2A;\ I_2 = -1A}$ Ans.

Method-2

$16 - 2I_1 - 4(I_1 - I_2) = 0$ → (i)

$-18 - 6(I_2) - 4(I_2 - I_1) = 0$ → (ii)

(i) $= 16 - 6I_1 + 4I_2 = 0$

(ii) $= -18 - 10I_2 + 4I_1 = 0$

from (i) $I_2 = \frac{6I_1 - 16}{4}$

Put I_2 in (ii)

$-18 - 10\left(\frac{6I_1 - 16}{4}\right) + 4I_1 = 0$

$-72 - 60I_1 + 160 + 16I_1 = 0$

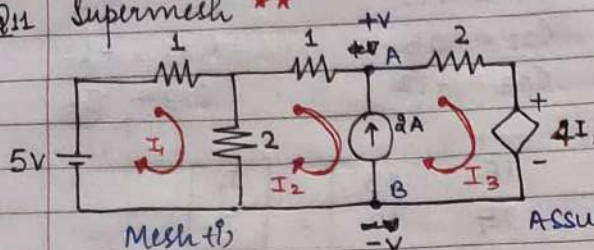
$88 - 44I_1 = 0$

$\boxed{I_1 = 2A}$ Ans

$I_2 = \frac{6(2) - 16}{4} = -1A$

$\boxed{I_2 = -1A}$ Ans.

Q11 Supermesh **



Assume voltage drop at A to be +V & B = -V

Mesh (i)

$5 - I_1(1) - 2(I_1 - I_2) = 0$

$5 - I_1 - 2I_1 + 2I_2 = 0 \Rightarrow 5 - 3I_1 + 2I_2 = 0$ — (1)

Mesh (ii) $I_3 - I_2 = 2 \Rightarrow \boxed{I_3 = 2 + I_2}$ — (5)

$-2(I_2 - I_1) - I_2 - V = 0$

$+2I_1 - 3I_2 - V = 0$ — (2)

Mesh (iii)

$4I_1 + 2I_3 = V$ — (3)

$4I_1 + 2I_3 - V = 0$ — (4)

Equating (4) & (2)

$2I_1 - 3I_2 = 4I_1 + 2I_3$

$2I_1 + 2I_3 + 3I_2 = 0$ — (6)

Putting (5) in (6)

$2I_1 + 2(2 + I_2) + 3I_2 = 0$

$2I_1 + 4 + 2I_2 + 3I_2 = 0$

$2I_1 + 4 + 5I_2 = 0$ — (7)

~~Equating (1) & (7)~~

$\cancel{5 - 3I_1 + 2I_2 = 4 + 5I_2}$

$2I_1 = -5I_2 - 4$

$I_1 = \frac{-5I_2 - 4}{2}$

$5 - 3\left(\frac{-5I_2 - 4}{2}\right) + 2I_2 = 0$

$10 + 15I_2 + 12 + 4I_2 = 0$

$19I_2 + 22 = 0 \Rightarrow \boxed{\frac{-22}{19} = I_2}$

$5 - 3I_1 + 2\left(\frac{-22}{19}\right) = 0$

$5 - 3I_1 - \frac{44}{19} = 0$

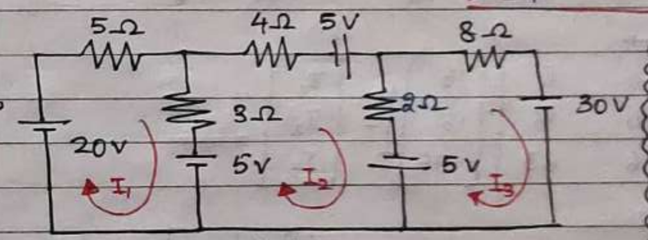
$95 - 57I_1 - 44 = 0$

$51 - 57I_1 = 0$

$\boxed{\frac{51}{57} = I_1} \Rightarrow \boxed{I_1 = \frac{17}{19} \text{ A}}$

$I_3 = 2 - \frac{22}{19} = \frac{38 - 22}{19} = \boxed{\frac{16}{19} = I_3}$

Q12.



Ans to crosscheck

$I_1 = \frac{1530}{598}$

$I_2 = \frac{1090}{598}$

$I_3 = \frac{-1875}{598}$

Mesh (i)

$20 - 5I_1 - 3(I_1 - I_2) - 5 = 0$

$15 - 8I_1 + 3I_2 = 0$

$15 = 8I_1 - 3I_2$

Mesh (ii)

$5 - 3(I_2 - I_1) - 4I_2 + 5 - 2(I_2 - I_3) + 5 = 0$

$15 - 9I_2 + 3I_1 + 2I_3 = 0$

$-15 = -9I_2 + 3I_1 + 2I_3$

Mesh (iii)

$-5 - 2(I_3 - I_2) - 8I_3 - 30 = 0$

$-35 - 10I_3 + 2I_2 = 0$

$$\begin{bmatrix} 15 \\ 15 \\ -35 \end{bmatrix} = \begin{bmatrix} 8 & -3 & 0 \\ -3 & 9 & -2 \\ 0 & -2 & 10 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

(care to polarity of I)

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$$A = \begin{bmatrix} 8 & -3 & 0 \\ -3 & 9 & -2 \\ 0 & -2 & 10 \end{bmatrix} = 8(90-4)+3(-30)$$
$$= 8(86)-90$$
$$= 688-90 = 598$$

$A_{11} = 90-4 = 86$ $\quad A_{21} = -30$ $\quad A_{31} = 6$

$A_{12} = -30$ $\quad A_{22} = 80$ $\quad A_{32} = -16$

$A_{13} = 6$ $\quad A_{23} = -16$ $\quad A_{33} = 72-9 = 63$

$C_{11} = 86$ $\quad C_{21} = +30$ $\quad C_{31} = 6$

$C_{12} = +30$ $\quad C_{22} = 80$ $\quad C_{32} = +16$

$C_{13} = 6$ $\quad C_{23} = +16$ $\quad C_{33} = 63$

$$\frac{1}{598}\begin{bmatrix} 86 & 30 & 6 \\ 30 & 80 & 16 \\ 6 & 16 & 63 \end{bmatrix}\begin{bmatrix} 15 \\ 15 \\ -35 \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

$$\frac{1}{598}\begin{bmatrix} (86)(15)+(30)(15)+(-35)(6) \\ (30)(15)+(80)(15)+(16)(-35) \\ (6)(15)+(16)(15)+(63)(-35) \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

$$\frac{1}{598}\begin{bmatrix} 1290+450-210 \\ 450+1200-560 \\ 90+240-2205 \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

Ans. $\boxed{\frac{1530}{598} = I_1}$; $\boxed{I_2 = \frac{1090}{598}}$; $\boxed{I_3 = \frac{-1875}{598}}$

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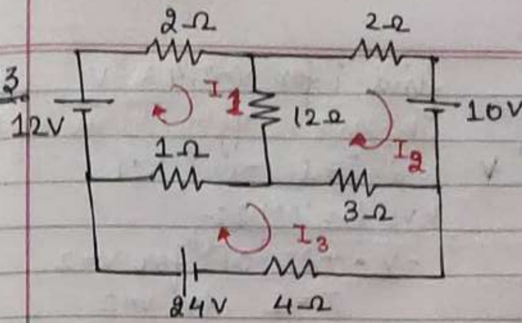
Q13.



$I_3 = 4.1A$
$I_1 = 2.72A$
$I_2 = 2.05A$

$$\begin{bmatrix} 12 \\ -10 \\ 24 \end{bmatrix} = \begin{bmatrix} 15 & -12 & -1 \\ -12 & 17 & -3 \\ -1 & -3 & 8 \end{bmatrix}\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

$A = 15(136-9)+12(-96-3)$
$-1(36+17)$
$= 15(127)+12(-99)$
-53
$= 1905 - 1188 - 53$
$= 664$

$A_{11} = 136-9$ $\quad A_{21} = -96-3$ $\quad A_{31} = 36+17$

$A_{12} = -96-3$ $\quad A_{22} = 120-1$ $\quad A_{32} = -45-12$

$A_{13} = 36+17$ $\quad A_{23} = -45-12$ $\quad A_{33} = 255-144$

$C_{11} = 127$ $\quad C_{21} = 99$ $\quad C_{31} = 53$

$C_{12} = 99$ $\quad C_{22} = 119$ $\quad C_{32} = 57$

$C_{13} = 53$ $\quad C_{23} = 57$ $\quad C_{33} = 111$

$$\frac{1}{664}\begin{bmatrix} 127 & 99 & 53 \\ 99 & 119 & 57 \\ 53 & 57 & 111 \end{bmatrix}\begin{bmatrix} 12 \\ -10 \\ 24 \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

$$\frac{1}{664}\begin{bmatrix} 127(12)-10(99)+24(53) \\ 99(12)-10(119)+24(57) \\ 53(12)-10(57)+24(111) \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

$$\frac{1}{664}\begin{bmatrix} 1524-990+1272 \\ 1188-1190+1368 \\ 636-570+2664 \end{bmatrix} = \begin{bmatrix} 1806 \\ 1366 \\ 2730 \end{bmatrix}\frac{1}{664} = \boxed{\begin{matrix} I_1 = 2.719A \\ I_2 = 2.05A \\ I_3 = 4.11A \end{matrix}}$$

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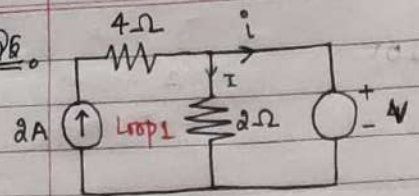
Q6.



find i for $V = 2, 4$ & $6V$

we cannot apply KVL in loop1

$2 = i + I$ — (i) KCL

KVL for loop2:-

$\boxed{-V + 2I = 0}$ (ii) for $V = 2$

$I = 1$ for $V = 2$

$2 = i + 1$

$\boxed{i = 1A}$

Putting $V = 4$ in (ii) $I = 2A$

Putting $I = 2$ in (i) $\boxed{i = 0A}$

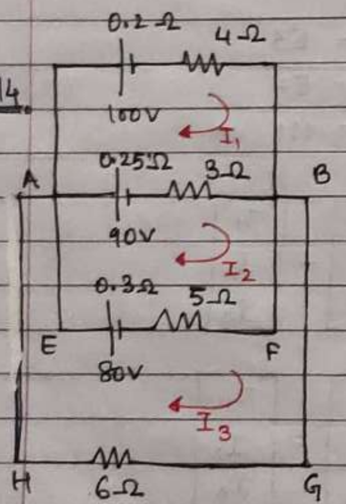
Putting $V = 6$ in (ii) $I = 3A$

Putting $I = 3A$ in (i) $\boxed{i = -3A}$

voltage	i
$V = 2V$	1A
$V = 4V$	0A
$V = 6V$	−1A

Ans.

Q14.



$I_3 = -12.339A$

$\cancel{A = 5.45[(8.55)(11) - (5.3)^2] + 3.25(-3.25)(11)}$

$\cancel{= 5.45[94.05 - 28.09] + 3.25(-35.75)}$

$= \cancel{359.48 - 116.18 = 243.3}$

$I_3 =$ AEFBGHA

$$\begin{bmatrix} -10 \\ -10 \\ -80 \end{bmatrix} = \begin{bmatrix} 4+3+0.2+0.25^{*} & -(3+0.25) & 0 \\ -(3+0.25) & 3+0.25+5+0.3 & -(0.3+5) \\ 0 & -(0.3+5) & 0.3+6+5^{*} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

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$$\begin{bmatrix} -10 \\ -10 \\ -80 \end{bmatrix} = \begin{bmatrix} 4+3+0.2+0.25 & -(3+0.25) & 0 \\ -(3+0.25) & 3+0.25+5+0.3 & -(0.3+5) \\ 0 & -(0.3+5) & 0.3+6+5 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

$= A$

$$A = \begin{bmatrix} 7.45 & -3.25 & 0 \\ -3.25 & 8.55 & -5.3 \\ 0 & -5.3 & 11.3 \end{bmatrix}$$

$|A| = 7.45[(8.55)(11.3) - (-5.3)(-5.3)] + (-3.25)(-3.25)(11.3)$

$= 7.45(96.615 - 28.09) - (119.35)$

$= 510.51 - 119.35 = 391.16125$

$A_{11} = 68.52$ $A_{21} = -36.72$ $A_{31} = 17.22$

$A_{12} = -36.72$ $A_{22} = 84.18$ $A_{32} = -39.48$

$A_{13} = 17.22$ $A_{23} = -39.48$ $A_{33} = 53.19$

$C_{11} = 68.52$ $C_{21} = 36.72$ $C_{31} = 17.22$

$C_{12} = 36.72$ $C_{22} = 84.18$ $C_{32} = 39.48$

$C_{13} = 17.22$ $C_{23} = 39.48$ $C_{33} = 53.19$

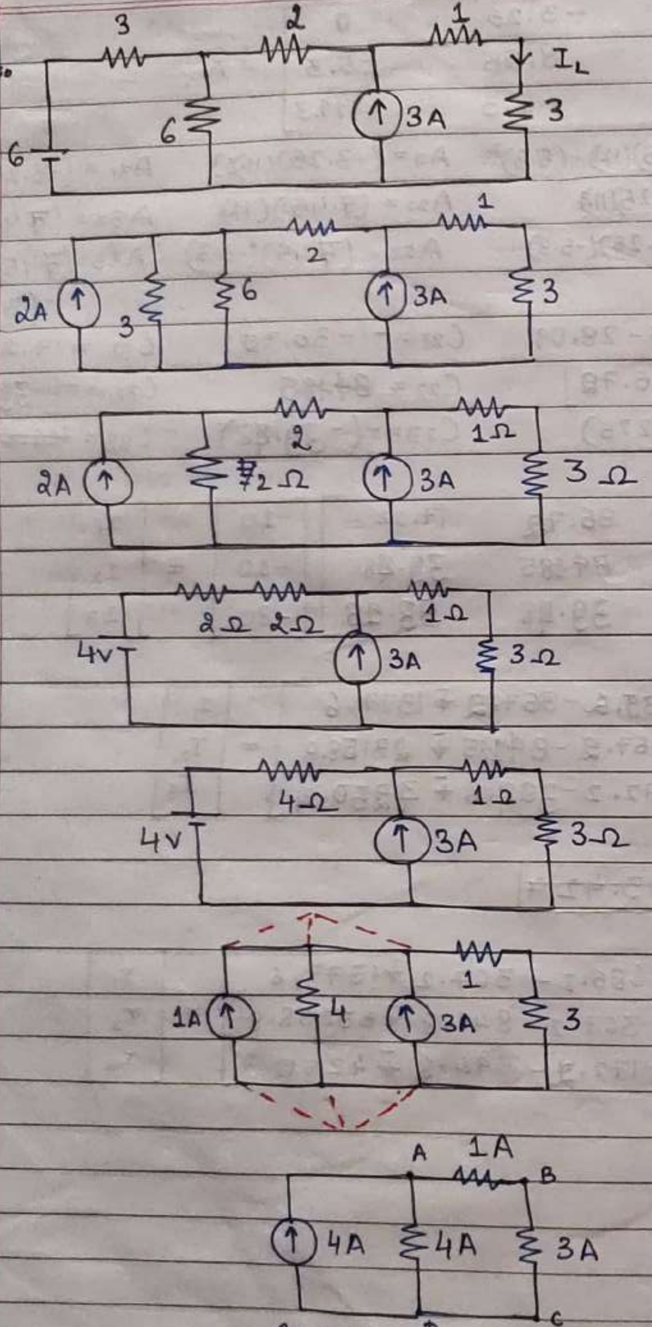
$$\frac{1}{391.16} \begin{bmatrix} 68.52 & 36.72 & 17.22 \\ 36.72 & 84.18 & 39.48 \\ 17.22 & 39.48 & 53.19 \end{bmatrix} \times \begin{bmatrix} -10 \\ -10 \\ -80 \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

$$\frac{1}{391.16} \begin{bmatrix} -685.2 - 367.2 - 1377.6 \\ -367.2 - 841.8 - 3158.8 \\ -172.2 - 394.8 - 4250.4 \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

$I_3 = -12.315$

Q16.

$\boxed{2A = I_L}$



$= \frac{1}{3} + \frac{1}{6}$

$= \frac{6+3}{18} = \frac{9}{18} = \frac{1}{2}$

$V = IR$

$V/R = I$

$R_{eq} = 4A$ in ABCD, $\Rightarrow I = 4A \Rightarrow$

Since total current is 4A & resistance in both parallel branches is same, I in ABCD = 2A

$$\boxed{I_{ABCD} = 2A}$$

Methods of Matrix used in numericals.

(a) Matrix Multiplication

$A = \begin{bmatrix} a & b \\ c & d \end{bmatrix}$ $B = \begin{bmatrix} e & f & g \\ h & i & j \end{bmatrix}$ $\Rightarrow AB = \begin{bmatrix} ae+bh & af+bi & ag+bj \\ ce+dh & cf+di & cg+dj \end{bmatrix}$

(b) Determinant

$\Delta = \begin{vmatrix} a & b & c \\ d & e & f \\ g & h & i \end{vmatrix} = a(ei-hf) - b(di-gf) + c(dh-ge)$

(c) $adj\, A = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} = \begin{bmatrix} a_{22} & -a_{12} \\ -a_{21} & a_{11} \end{bmatrix}$

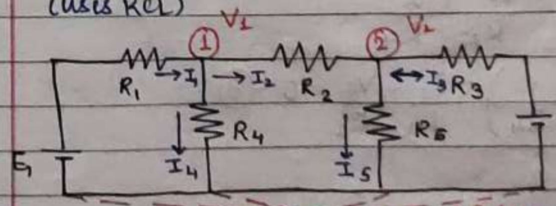
Sign ch. ~~interchange~~ Interchange

(d) $A^{-1} = \frac{1}{|A|} adj\, A$

Date :- 1 Dec 2022

NODAL ANALYSIS

(uses KCL)



③ $V_B = 0$ (Reference Node)

Step 1 :- find 'n' no. of junctions (node)

Step 2 :- no. of eq^ns = n-1 (n = no. of junc^ns)

Here n-1 = 2

Step 3 :- Take one node as datum node / reference node [V=0]

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Step 4 :- All other junctions, assign name & potential

Step 5 :- find V_1 & V_2

Step 6 :- On each junction write KCL equations by marking branch ~~eq~~ currents.

At node 1 :- $I_1 = I_2 + I_4$ — ①

At node 2 :- $I_5 = I_3 + I_2$ — ②

Step 7 :- write currents in the form of V/R

$I_1 = \frac{E_1 - V_1}{R_1}$ $\quad I_5 = \frac{V_2 - V_0}{R_5} = \frac{V_2}{R_5}$

$I_2 = \frac{V_1 - V_2}{R_2}$ $\quad I_3 = \frac{E_2 - V_2}{R_3}$ $\quad I_4 = \frac{V_1 - V_0}{R_4} = \frac{V_1}{R_4}$

Puts these expressions in eq ① & ②

$$\frac{E_1 - V_1}{R_1} = \frac{V_1 - V_2}{R_2} + \frac{V_1}{R_4} \quad — ③$$

$$\frac{V_2}{R_5} = \frac{E_2 - V_2}{R_3} + \frac{V_1 - V_2}{R_2} \quad — ④$$

Simplifying ③

$$\frac{E_1}{R_1} - \frac{V_1}{R_1} = \frac{V_1}{R_2} - \frac{V_2}{R_2} + \frac{V_1}{R_4}$$

$$V_1\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_4}\right) - \frac{E_1}{R_1} - \frac{V_2}{R_2} = 0 \quad — ⑤$$

Simplifying ④

$$\frac{V_2}{R_5} = \frac{E_2}{R_3} - \frac{V_2}{R_3} + \frac{V_1}{R_2} - \frac{V_2}{R_2}$$

$$V_2\left(\frac{1}{R_5} + \frac{1}{R_3} + \frac{1}{R_2}\right) - \frac{E_2}{R_3} - \frac{V_1}{R_2} = 0 \quad — ⑥$$

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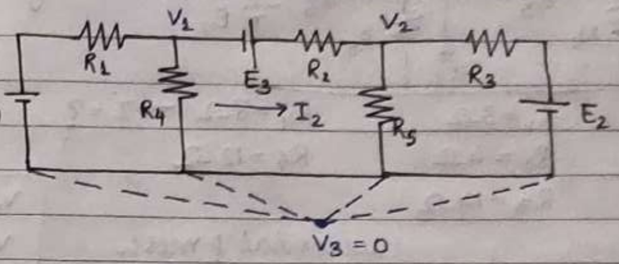
Application

(a) where ||el branches are connected at common ground

Q1.

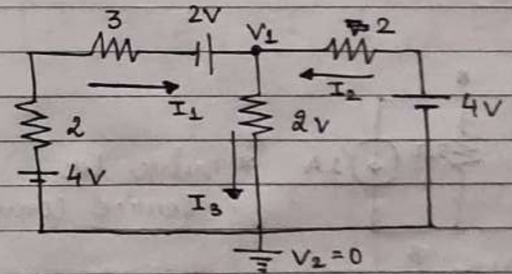


$I_2 = \frac{(V_1 + E_3) - V_2}{R_2}$ Rest all same.

2 $V_1\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_4}\right) - \frac{V_2}{R_2} - \frac{E_1}{R_1} + \frac{E_3}{R_2} = 0$

$V_2\left(\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_5}\right) - \frac{V_1}{R_2} - \frac{E_2}{R_3} - \frac{E_3}{R_2} = 0$

Q2.



Find current in 3 Ω resistance

$\boxed{V_1 = 8/3V}$

$I_3 = I_1 + I_2$

$I_3 = \frac{V_1 - V_2}{2} = \frac{V_1}{2} = \frac{4}{3}$; $I_1 = \frac{4 + 2 - V_1}{3 + 2} = \frac{6 - V_1}{5} = \frac{6}{5} - \frac{8}{15} = \frac{18 - 8}{15}$

$= 10/15$

$\boxed{= 2/3 A}$

$I_2 = \frac{4 - V_1}{2}$

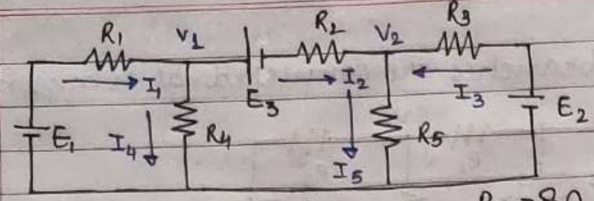
$\frac{V_1}{2} = \frac{6}{5} - \frac{V_1}{5} + \frac{2 - V_1}{2}$

$\frac{V_1}{2} + \frac{V_1}{2} + \frac{V_1}{5} = \frac{6}{5} + 2 \Rightarrow \frac{10V_1 + 2V_1}{10} = \frac{12 + 20}{10}$

$= 12V_1 = 32 \rightarrow \boxed{V_1 = 8/3V}$

HWQ1

Q2.



Using Nodal Analysis.

$E_1 = 10V$ $R_1 = 3\Omega$ $R_4 = 8\Omega \rightarrow I = ?$

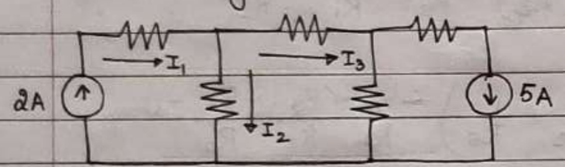
$E_3 = 3V$ $R_2 = 4\Omega$ $R_5 = 12\Omega$

$E_2 = 6V$ $R_3 = 14\Omega$

(use nodal & mesh analysis)

$\boxed{V_1 = 7.01V \quad V_2 = 3.537V \quad I_4 = 0.876A}$

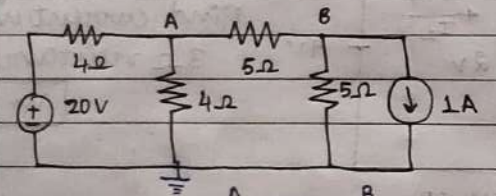
⟹ Nodal Analysis with Current source.



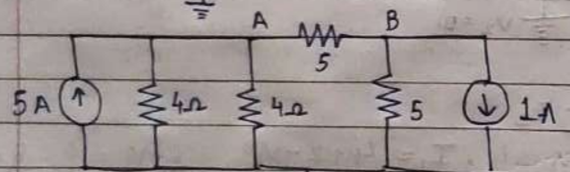
$I_1 = I_2 + I_3$

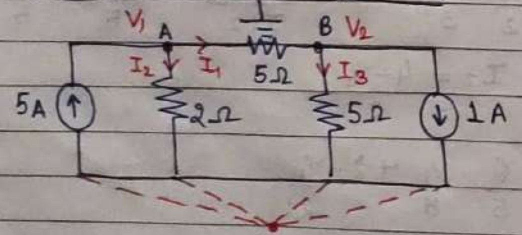
$2 = I_2 + I_3$

Q.



* Think for source conversions





$5 = I_2 + I_1$

$I_1 = I_3 + 1A$

$I_2 = \frac{V_1}{2} = \boxed{\frac{15}{4}}$; $I_1 = \frac{V_1 - V_2}{5} = \boxed{\frac{5}{4}}$; $I_3 = \frac{V_2}{5} = \boxed{\frac{1}{4}}$

$\frac{5}{1} = \frac{V_1}{2} + \frac{V_1}{5} - \frac{V_2}{5}$ & $\frac{V_1}{5} - \frac{V_2}{5} = \frac{V_2}{5} + 1$

$50 = 5V_1 + 2V_1 - 2V_2$ $V_1 - V_2 = V_2 + 5$

$\boxed{50 = 7V_1 - 2V_2}$ $\boxed{V_1 = 2V_2 + 5}$

$50 = 7(2V_2 + 5) - 2V_2$ $V_1 = \frac{5}{2} + 5 = \frac{15}{2} = \boxed{\frac{30}{4}}$

$50 = 14V_2 + 35 - 2V_2$

$50 = 12V_2 + 35$

$15 = 12V_2$

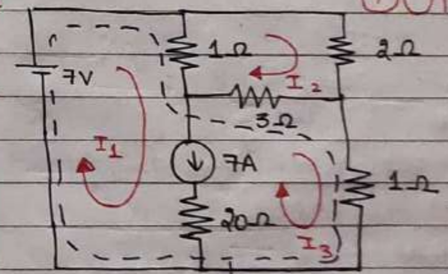
$\frac{15}{12} = V_2 = \boxed{\frac{5}{4}}$

SUPER MESH

↳ independent current source in b/w 2 meshes.

(15 marks)

Q. HWQ



Super mesh

$i_1 - i_3 = 7$

$-(I_2 - I_1) - 2I_2 - 3(I_2 - I_3) = 0$

$7 - 1(I_1 - I_2) - 3(I_3 - I_2) - I_3 = 0$

Ans :- $I_1 = 9A$
$I_2 = 2.5A$
$I_3 = 2A$

To crosscheck.

$I_1 - 4I_2 + 4I_3 = 7$

$6I_2 - 3I_3 - I_1 = 0$

$7 = I_1 - I_3 \Rightarrow \boxed{7 + I_3 = I_1}$

* If 7V is replaced by a current source (say 15A) then

$\boxed{I_1 = 15A}$

$6I_2 - 3I_3 - 7 - I_3 = 0$

$6I_2 - 4I_3 - 7 = 0$

$7 + I_3 - 4I_2 + 4I_3 = \cancel{0}7$

$\cancel{7} + 5I_3 - 4I_2 = \cancel{7}$

$I_3 = \frac{4I_2}{5}$

$6I_2 - 4\left(\frac{4I_2}{5}\right) - 7 = 0$

$30I_2 - 16I_2 - 35 = 0$

$\cancel{4KI_2}\ 14I_2 = 35$

$\boxed{I_2 = \frac{35}{14} = \frac{5}{2} = 2.5A}$

$\boxed{I_3 = \frac{4}{5}\left(\frac{5}{2}\right) = 2A}$

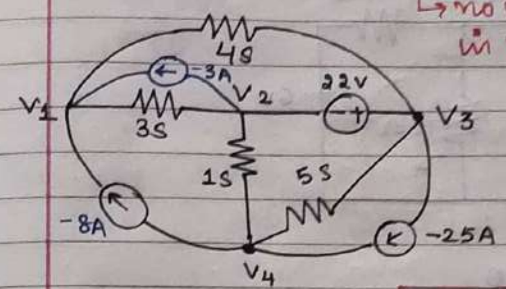
$7 + I_3 = \boxed{I_1 = 9A}$

SUPER NODE

* Siemens is inverse of ohms

$8\Omega = \frac{1}{8}S$

$8S = 1/8\,\Omega$



↳ no resistance in V_2 V_3 branch

$\boxed{V_2 + 22 - V_3 = 0 \quad -(i)}$

at node V_1, apply KCL ;

$(-3) + (-8) = (V_1 - V_2)(3) + (V_1 - V_3)4 \quad -(ii)$

at node V_2 , (+) at node V_3,

$3(V_1 - V_2) + 3 - V_2 = 0 \qquad 4(V_1 - V_3) = -25 + 5V_3$

$3V_1 + 4V_1 - 4V_2 + 3 - 4V_3 + 25 - 5V_3 = 0$

$\cancel{3}\ \boxed{7V_1 - 4V_2 - 9V_3 + 28 = 0} \quad -(iii)$

Simplifying (ii)

$-3 - 8 = \cancel{3V_2} \; 3V_1 - 3V_2 + 4V_1 - 4V_3$

$\boxed{-11 = 7V_1 - 3V_2 - 4V_3 \quad -(iv)}$

From (i) Put $V_2 + 22 = V_3$ in (iii) & (iv)

$7V_1 - 4V_2 - 9(V_2 + 22) + 28 = 0$

$7V_1 - 13V_2 - 9(22) + 28 = 0$

$7V_1 - 13V_2 - 198 + 28 = 0$

$7V_1 - 13V_2 - 170 = 0$

$-11 = 7V_1 - 3V_2 - 4(V_2 + 22)$

$-11 = 7V_1 - 3V_2 - 4V_2 - 88$

$77 = 7V_1 - 7V_2 \Rightarrow 11 = V_1 - V_2 \Rightarrow 11 + V_2 = V_1$

$\begin{array}{r} 22 \\ \times 9 \\ \hline 198 \end{array}$

$7(11 + V_2) - 13V_2 = 170$

$77 + 7V_2 - 13V_2 = 170$

$-6V_2 = 93 \Rightarrow \boxed{V_2 = -15.5}$

$7V_1 = 170 + 13V_2 = 170 - 13(15.5) = \boxed{-4.5 = V_1}$

$\boxed{V_3 = V_2 + 22 = 6.5}$

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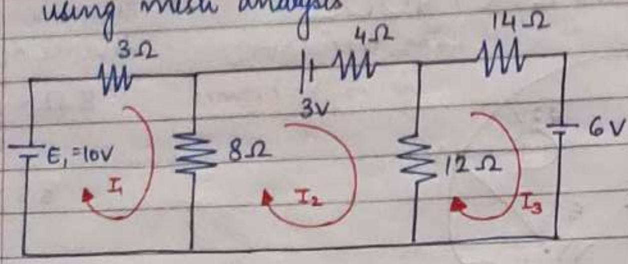
HWQ1 using mesh analysis



$10 - 3I_1 - 8(I_1 - I_2) = 0$

$-8(I_2 - I_1) - 3 - 4I_2 - 12(I_2 - I_3) = 0$

$-12(I_3 - I_2) - 14I_3 - 6 = 0$

$$\begin{bmatrix}10\\-3\\-6\end{bmatrix} = \begin{bmatrix}3+8 & 8 & 0\\ -8 & 8+4+12 & -12\\ 0 & -12 & 14+12\end{bmatrix}\begin{bmatrix}I_1\\I_2\\I_3\end{bmatrix}$$

$$\begin{bmatrix}10\\-3\\-6\end{bmatrix} = \underbrace{\begin{bmatrix}11 & -8 & 0\\ -8 & 24 & -12\\ 0 & -12 & 26\end{bmatrix}}_{A}\begin{bmatrix}I_1\\I_2\\I_3\end{bmatrix}$$

$|A| = 11[(24)(26) - (-12)(-12)] - (-8)[(-8)(26)]$

$= 11(624 - 144) + 8[(-8)(26)]$

$= 11(480) - 1664$

$= 5280 - 1664 = \cancel{4096}\ 3616$

$$\frac{1}{3616}\begin{bmatrix}10\\-3\\-6\end{bmatrix} \times \begin{bmatrix}480 & 208 & 96\\ 208 & 286 & 132\\ 96 & 132 & 200\end{bmatrix} = \begin{bmatrix}I_1\\I_2\\I_3\end{bmatrix}$$

$A_{11} = 624 - 144$ $\quad A_{21} = (-8)(26)$ $\quad A_{31} = (8)(12)$

$A_{12} = (26)(8)$ $\quad A_{22} = (26)(11)$ $\quad A_{32} = (11)(-12)$

$A_{13} = (8)(12)$ $\quad A_{23} = (11)(-12)$ $\quad A_{33} = 11(24) - (8)^2$

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$C_{11} = 480$ $\quad C_{21} = (+)208$ $\quad C_{31} = 96$

$C_{12} = (+)208$ $\quad C_{22} = 286$ $\quad C_{32} = (+)132$

$C_{13} = 96$ $\quad C_{23} = (+)132$ $\quad C_{33} = 200$

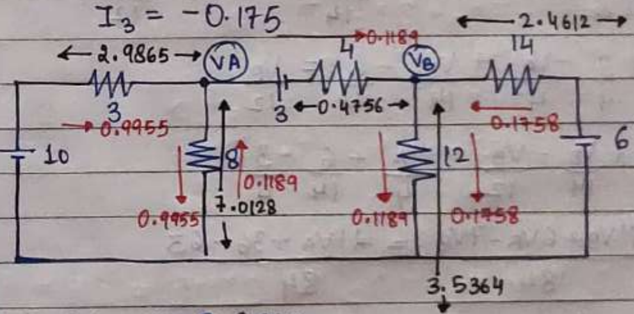
$$\frac{1}{3616}\begin{bmatrix}480 & 208 & 96\\ 208 & 286 & 132\\ 96 & 132 & 200\end{bmatrix}\begin{bmatrix}10\\-3\\-6\end{bmatrix} = \begin{bmatrix}I_1\\I_2\\I_3\end{bmatrix}$$

$$\frac{1}{3616}\begin{bmatrix}4800 - 624 - 576\\ 2080 - 858 - 792\\ 960 - 396 - 1200\end{bmatrix} = \begin{bmatrix}I_1\\I_2\\I_3\end{bmatrix}$$

$I_1 = 0.9955$

$I_2 = 0.1189$

$I_3 = -0.175$

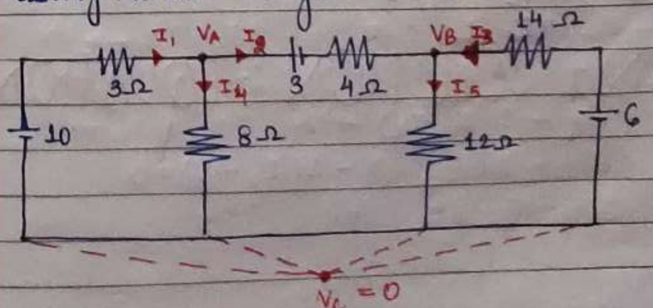


$V_A = 10 - 2.9865 = 7.0135\text{ V}$

$V_B = 6 - 2.4612 = 3.53\text{V}$

$I_{R_8} = 0.9955 - 0.1189 = 0.8766\text{ A}$

using Nodal Analysis



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$I_1 = I_2 + I_4$

$I_1 = \frac{10 - V_A}{3}$, $I_2 = \frac{V_A - 3 - V_B}{4} =$ $\boxed{I_4 = \frac{V_A}{8} = \frac{7.01}{8} = 0.876}$

$\frac{10}{3} - \frac{V_A}{3} = \frac{V_A}{4} - \frac{3}{4} - \frac{V_B}{4} + \frac{V_A}{8}$

$\frac{V_B}{4} = \frac{V_A}{4} + \frac{V_A}{3} + \frac{V_A}{8} - \frac{10}{3} - \frac{3}{4}$

$\frac{V_B}{4} = \frac{6V_A + 8V_A + 3V_A}{24} - \frac{40 - 9}{12}$

$\frac{6V_B}{24} = \frac{17V_A}{24} - \frac{49}{12} \Rightarrow 6V_B = 17V_A - 98$

$\Rightarrow \frac{6V_B + 98}{17} = V_A$

$I_2 + I_3 = I_5$

$\frac{V_A - 3 - V_B}{4} = I_2$; $I_3 = \frac{6 - V_B}{14} =$; $I_5 = \frac{V_B}{12}$

$\frac{V_A}{4} - \frac{3}{4} - \frac{V_B}{4} + \frac{6}{14} - \frac{V_B}{14} = \frac{V_B}{12}$

$\frac{V_A}{4} - \frac{3}{4} + \frac{6}{14} = \frac{V_B}{12} + \frac{V_B}{14} + \frac{V_B}{4}$

$\frac{21V_A - 63 + 36}{84} = \frac{7V_B + 6V_B + 21V_B}{84}$

$21V_A - 27 = 13V_B + 21V_B = 34V_B$

$21V_A - 27 = 34V_B$

$21\left(\frac{6V_B + 98}{17}\right) - 27(17) = 34V_B(17)$

$126V_B + 98(21) - 27(17) = 34(17)V_B$

$126V_B + 2058 - 459 = 578V_B$

$1599 = 452V_B$

$\boxed{V_B = 3.53V}$

$\frac{6(3.53) + 98}{17} = \boxed{V_A = 7.01V}$

Date :- 3 Dec, 2022

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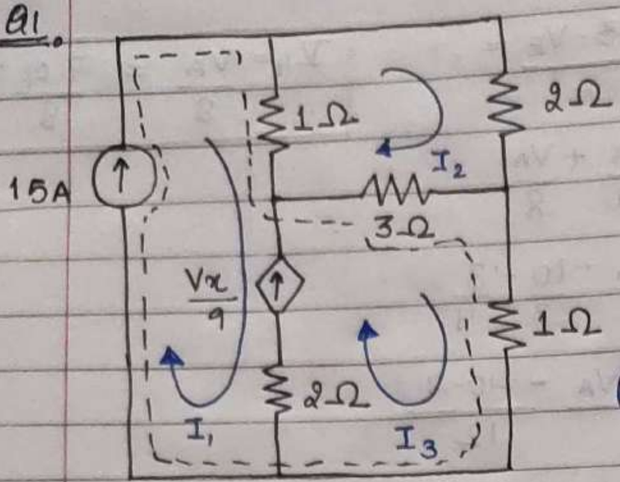
Q1.



Here $\boxed{15A = I_1}$

② $- I_3 - I_1 = \frac{Vx}{9}$ (Dependent source)

③ $-2I_2 - 3(I_2 - I_3) - 1(I_2 - 15) = 0$

④ $-1(15 - I_2) - 3(I_3 - I_2) - 1I_3 = 0$

② = $I_3 - 15 = \frac{Vx}{9}$

③ $-2I_2 - 3I_2 + 3I_3 - I_2 + 15 = 0$

$-6I_2 + 3I_3 + 15 = 0 \Rightarrow 3I_3 + 15 = 6I_2$

④ $-15 + 15I_2 - 3I_3 + 3I_2 - I_3 = 0$

$-15 + 18I_2 - 4I_3 = 0$

$-15 + 3(3I_3 + 15) - 4I_3 = 0$

$-15 + 9I_3 + 45 - 4I_3 = 0$

$30 + 5I_3 = 0$

$\boxed{I_3 = 7}$

$\frac{3(7) + 15}{6} = I_2 = \frac{21 + 15}{6} = \frac{36}{6} = 6 = I_2$

Since we have dependent source, so we cant use super mesh

$15A = I_1$ — (i)

$\frac{1}{9}Vx = I_3 - I_1 \Rightarrow Vx = 9I_3 - 9I_1 \rightarrow Vx = 9I_3 - 9(15)$

$Vx = 3(I_3 - I_2) \Rightarrow Vx = 3I_3 - 3I_2 \Rightarrow 9I_3 - 9(15) = 3I_3 - 3I_2$ — (ii)

2 $-2I_2 - 3(I_2 - I_3) - 1(I_2 - 15) = 0$

$3I_3 + 15 = 6I_2$ — (iii)

$9I_3$

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$$9I_3 - 9(15) = 3I_3 - 3I_2$$
$$3I_3 + 15 = 6I_2$$
$$3I_3 = 6I_2 - 15$$
$$3(6I_2 - 15) - 9(15) = 6I_2 - 15 - 3I_2$$
$$18I_2 - 45 - 135 = 6I_2 - 15 - 3I_2$$
$$18I_2 - 3I_2 = 135 + 45 - 15$$
$$15I_2 = 165$$
$$\boxed{\cancel{I_3 = 17A}} \quad \boxed{I_2 = 11A}$$

$$3I_3 = 6(11) - 15$$
$$3I_3 = \cancel{102-45}\ 66 - 15$$
$$I_3 = \frac{51}{3} = \cancel{27}\ 17A$$
$$\boxed{I_3 = 17A}$$
$$V_x = 3(17 - 11) = 18V$$

$$\boxed{V_x = 18V}$$

$-3I_2$ — (i)

Date :- 7 Dec, 2022

NETWORK THEOREMS

- → Superprositipn Theorem
- → Reciprocity
- → Thevenin
- → Norton

linear & bilateral
Active network.
(more than 1 source of emf)
* Only dependent sources ⊗ cannot use.
* Used for voltage

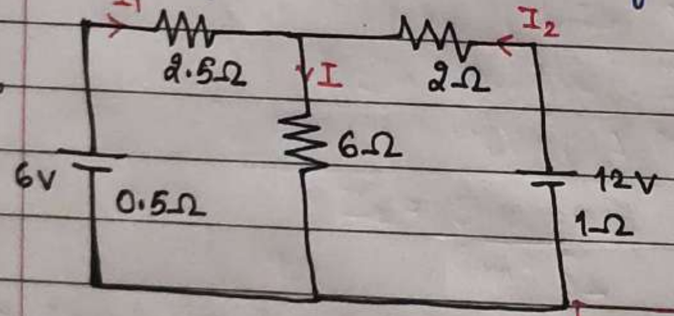
- → Max power transfer theorem (proof → 5 marks)

A. Superposition theorem

"according to this theorem, if there are no. of sources of EMF acting simultaneously in any linear bilateral network then each emf acts independently of the others i.e. as if other emfs didnot exist."

In other words, current or voltage across any conductor of network is obtained by superimposing the currents & voltages due to each emf in the network

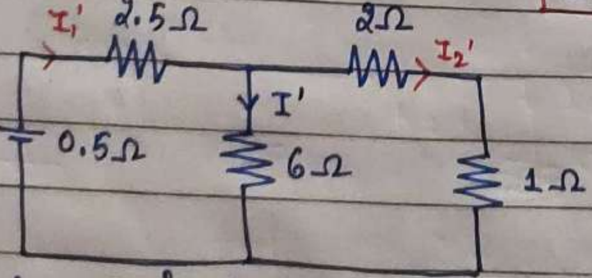
Q.



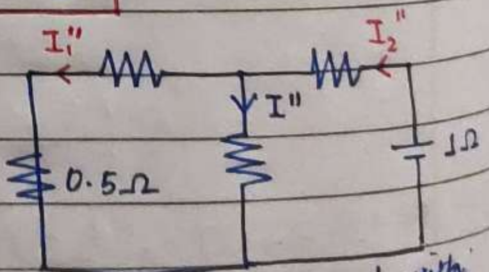
Linear:- follows ohm's law

Find I.

$$\boxed{I = I' + I''}$$



When E_2 is replaced with I.R

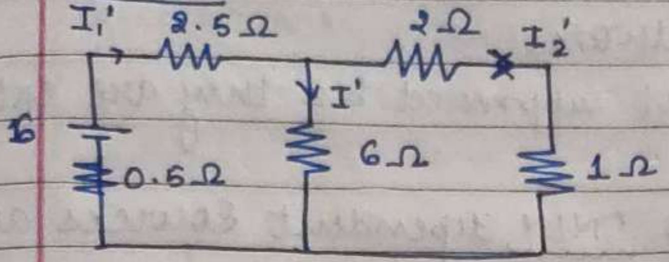


When E_1 is removed. with

$$\boxed{I_2 = -I_2' + I_2''}$$

* Dependent sources can never be deactivated / killed.

Case 1 :-



$$I_1' = \frac{6}{(3\|6)+(2.5+0.5)} = \frac{6}{5}\ A$$

Apply current div.

$$I' = (I_1')\frac{(2+1)}{(6+2+1)}$$

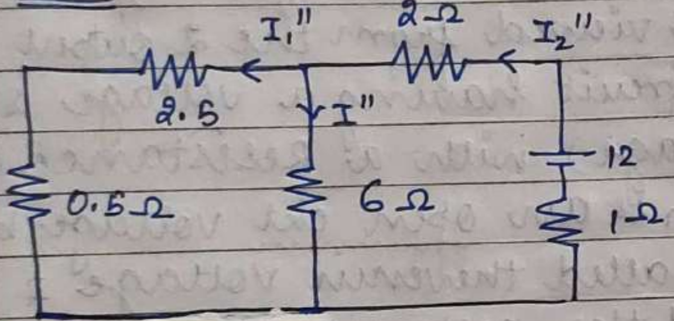
$$\boxed{I = I_T \frac{(\|\ Resis(+))}{(Sum\ of\ R + \|\ R)}}$$

$$I' = \frac{\cancel{6}^{2}}{5}\left(\frac{3}{\cancel{9}_{3}}\right) = \frac{2}{5}\ A$$

$$I_1' = I' + I_2'$$

$$\frac{2}{5} = \frac{6}{5} + I_2' \Rightarrow I_2 = -\frac{4}{5}\ A$$

Case 2 :-



$$Req = \{((0.5)+(2.5))\|(6)\} + (2+1)$$

$$= 5\Omega$$

$$\boxed{I_2'' = \frac{12}{5}\ A}$$

for I''

Apply current div rule

$$I'' = (I_2'')\frac{(2.5+0.5)}{(6+2.5+0.5)} = \frac{\cancel{12}^{4}}{5} \times \left(\frac{\cancel{3}}{\cancel{9}_{3}}\right) = \frac{4}{5}\ A$$

$$I_2'' = I_1'' + I''$$

$$\frac{12}{5} = I_1'' + \frac{4}{5}A \Rightarrow I_1'' = \frac{8}{5}\ A$$

$$\boxed{I = I' + I'' = \frac{4}{5} + \frac{2}{5} = \frac{6}{5}\ A.}$$

Limitations

(a) applied only in linear networks
(b) Dependent sources are not suppressed bcz they are externa controlled.
(c) It can't be applied where ONLY dependent sources are there.
(d) Power can't be determined DIRECTLY by superposition. (bcz Power is non linear quantity, it is not linearly related with V or I)

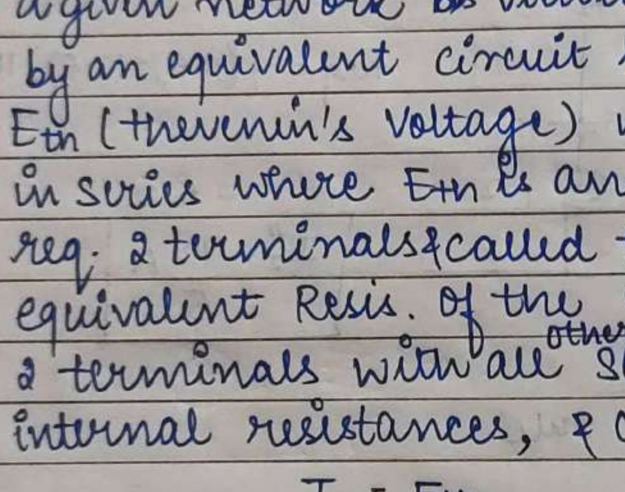
Date = 10 Dec, 2022

** (B) THEVENIN THEOREM:- (only independent sources are given)

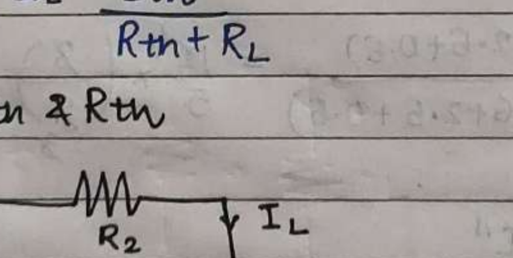
It is a mathematical technique for replacing a given network as viewed from the 2 output termin by an equivalent circuit having a voltage source E_{th} (thevenin's Voltage) with a Resistance (R_{th}) in series where E_{th} is an open ckt voltage b/w the req. 2 terminals & called thevenin voltage & R_{th} is equivalent Resis. of the network as seen from the 2 terminals with all other sources replaced by their internal resistances, & called thevenin's Resistan

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

⟹ How to find V_{th} & R_{th}



(a) Remove R_L & find V_{th}



$V_{open\,ckt} = V_{th} / E_{th}$

Here

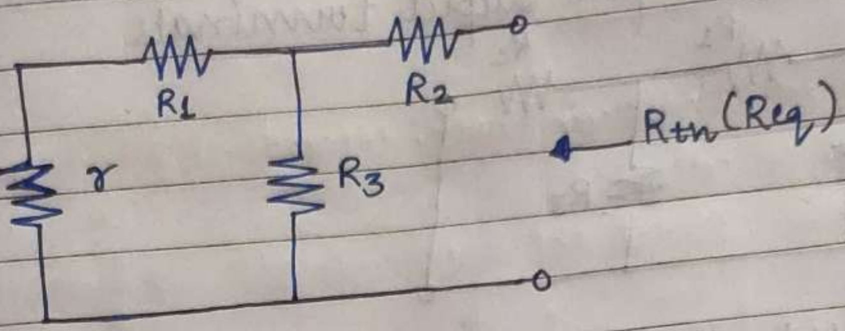
$V_{oc} = I \cdot R_3$

Date

(b) for R_{th}, replace all sources of emf by their internal resistances 'r'

V source = S.C

C. source = O.C

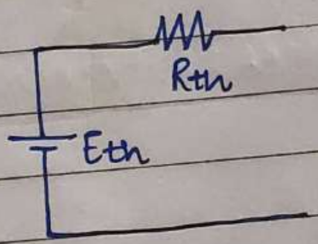


(c) find R_{th} from terminals

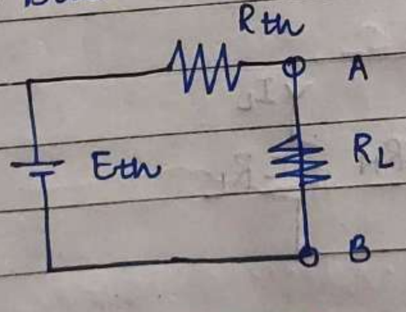
Here

$$((r+R_1) \parallel R_3) + R_2 = R_{th}$$

(d) Draw thevenin ckt



(e) Connect back R_t



(f) Find $\boxed{I_L = \dfrac{V_{th}}{R_{th}+R_L}}$

**

(c) NORTON THEOREM:- (Dual to Thevenin theorem)

It is a mathematical tech. for ---- having a current source in $\parallel$ el with an eq. Resis R_N

(I_N)

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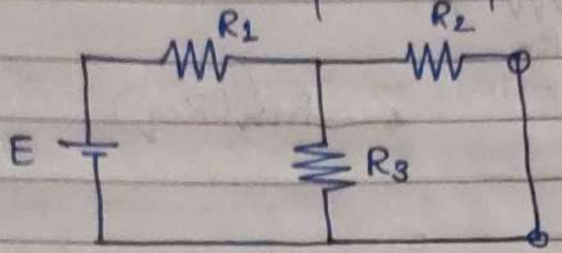
$R_{th} \rightarrow R_N$

HOW TO NORTANISE GIVEN CKT

Steps

(1) Remove R_L

(2) Short ckt 2 open output terminals



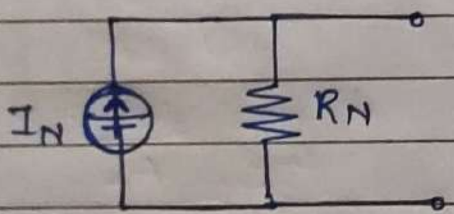
(3) find out Short ckt current I_N

$$R_{eq} = (R_2 \parallel R_3) + R_1 \quad ; \quad I = E/R_{eq}$$

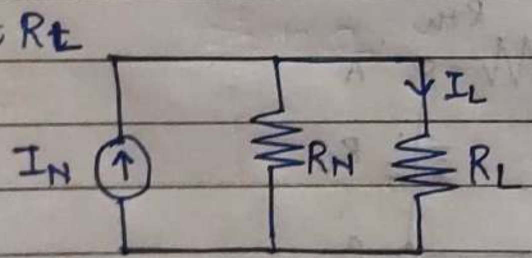
$$I_N = \frac{I \cdot R_3}{R_2 + R_3}$$

(4) $R_{TH} = R_N$

(5) Draw nortanised ckt

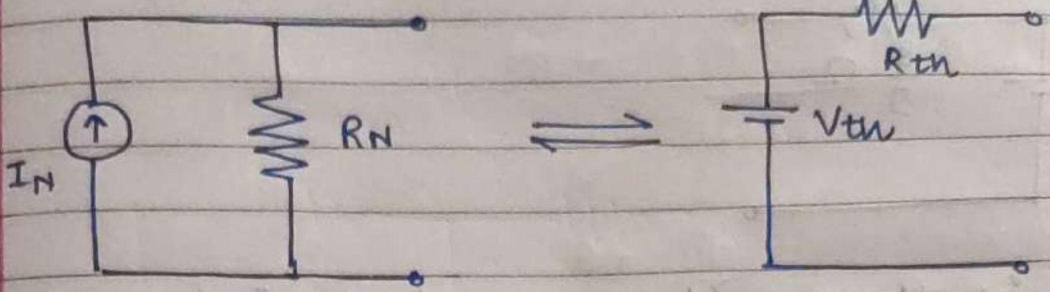


(6) Connect R_L



$$I_L = I_N \cdot \left(\frac{R_N}{R_N + R_L} \right)$$

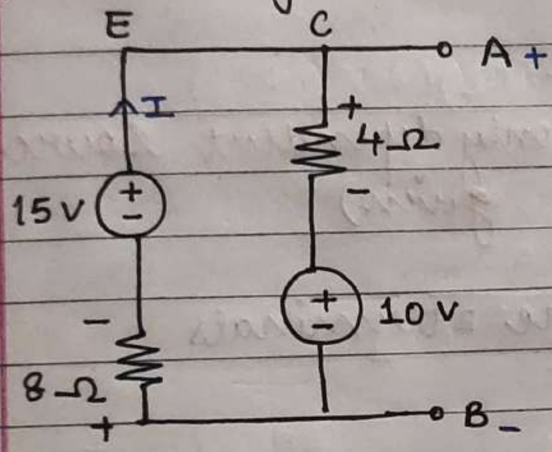
Q. How thevenin & Norton are Dual to each other



Source conversion

$$I_N = \frac{E_{th}}{R_{th}}, \quad R_N = R_{th}$$

Q1. Solve using thevenin, thevenise the ckt



Ans. V_{th} = Voltage across 4Ω or 8Ω branch

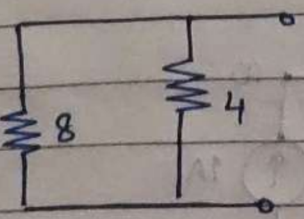
$$-4I - 10 - 8I + 15 = 0$$

$$-12I + 5 = 0$$

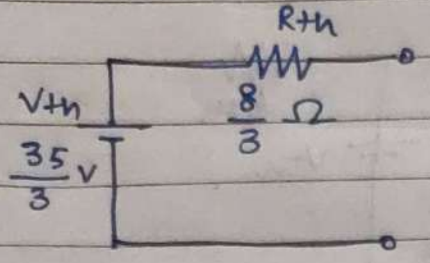
$$\boxed{I = \frac{5}{12}\,A}$$

for V_{th}, $V_{th} = 4I + 10$

$$= 4\left(\frac{5}{12}\right) + 10 = \frac{35}{3}$$

R_{th} =  $= \frac{8}{3}\,\Omega$

Thevenised ckt



Thevenin theorem (both dependent & independent Sources)

(1) V_{th} as usual

(2) for R_{th}, Short ckt 2 terminals, & find $I_{shortckt}$ (I_{s}

$$\boxed{R_{th} = \frac{V_{th}}{I_{sh}}}$$

Same for Nortans

Thevenin Theorem (when only dependent sources are given)

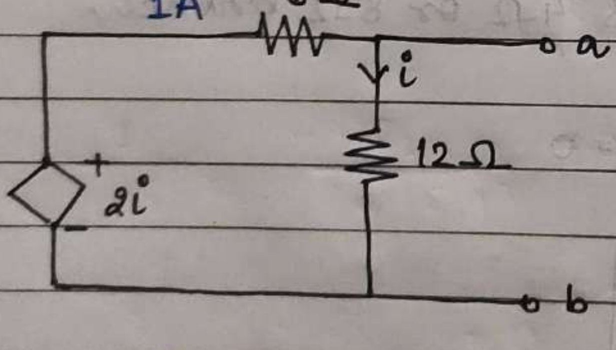
(1) $V_{oc} = 0$ / $V_{th} = 0$

(2) Connect 1A source to the 2 terminals

(3) Calculate V_{ab}

(4) $R_{th} = \frac{V_{ab}}{1A}$

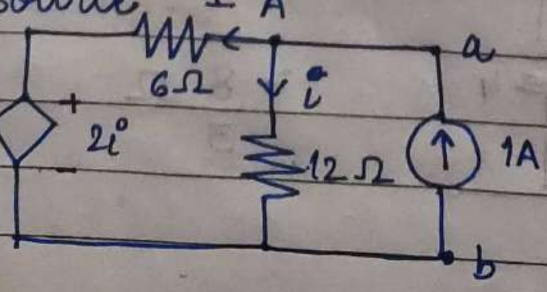
Q.



$i = 0$ b/c no independ source

$\Rightarrow V_{th} = 12i = 0$ / $V_{oc} = 0V$

connect 1A source



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$I + i = 1A$ (Nodal analysis)

$\frac{2i - V_{ab}}{6} - \frac{V_{ab}}{12} + 1 = 0$ — (i)

$4i - 3V_{ab} = -12$

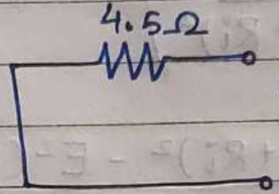
$i = \frac{V_{ab}}{12}$ — (ii)

Put (ii) in (i)

$\boxed{V_{ab} = 4.5}$

$R_{th} = \frac{V_{ab}}{1} = 4.5\ V$

Thevenin ckt



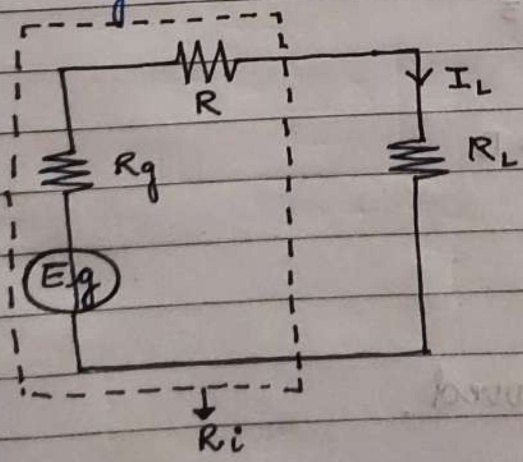
Ans.

Date = 12 Dec, 2022

(D) MAXIMUM POWER TRANSFER THEOREM :-
(application or extension of Thevenin theorem)

5 Marks important ques (Derivation + Graph)

A resistive load will abstract max power from a network when the load resistance is equal to the resistance of the network as viewed from the output terminals with all energy sources removed leaving behind their internal Resistances.



Let $R_i = R_g + R$

then $R_L = R_i$ for max power transfer.

(Transfer efficiency η) = 50%.

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$$I = \frac{E}{R_L + R_i}$$

$$P_L = I^2 R_L = \frac{E^2 \cdot (R_L)}{(R_L + R_i)^2} \quad \text{— (1)}$$

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

Put P from (i)

$$\frac{d}{dR}\left(\frac{E^2(R_L)}{(R_L + R_i)^2}\right)$$

$$= \frac{E^2(R_L + R_i)^2 - E^2(R_L)(2(R_L + R_i))}{(R_L + R_i)^4}$$

$$\frac{dP}{dR} = E^2 \left[\frac{1}{(R_L + R_i)^2} - \frac{2(R_L)}{(R_L + R_i)^3}\right]$$

either $E^2 = 0$ or $\left[\frac{1}{(R_L + R_i)^2} - \frac{2R_L}{(R_L + R_i)^3}\right] = 0$

$$\frac{1}{(R_L + R_i)^2} - \frac{2R_L}{(R_L + R_i)^3} = 0$$

$$\frac{R_L + R_i - 2R_L}{(R_L + R_i)^3} = 0$$

$$\boxed{R_i = R_L}$$

Hence Proved.

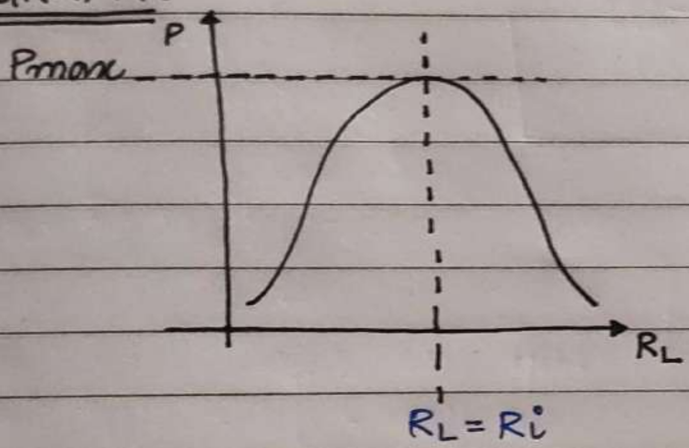
Put $R_L = R_i$ in (i)

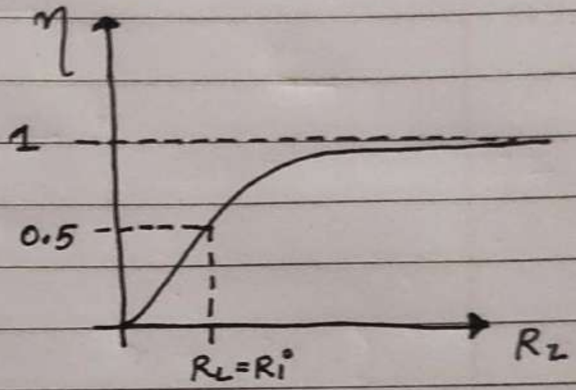
$$P_{max} = \left(\frac{E}{2R_L}\right)^2 (R_L)$$

$$= \frac{E^2}{4R_L^2} \cdot R_L$$

$$P_{max} = \frac{E^2}{4R_L} = \frac{(V_{TH})^2}{4R_L}$$

GRAPH:-





\# Proof of $\eta = \frac{P_L}{P_T}$ (from book)

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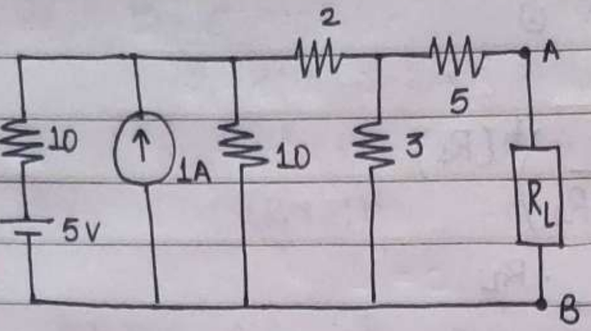
Date:- 14Dec, 2022

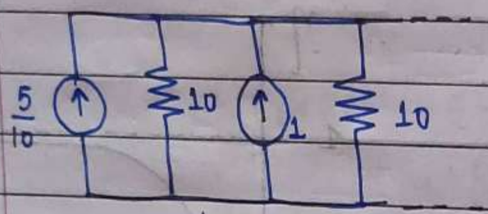
Q1.

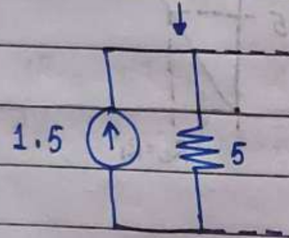


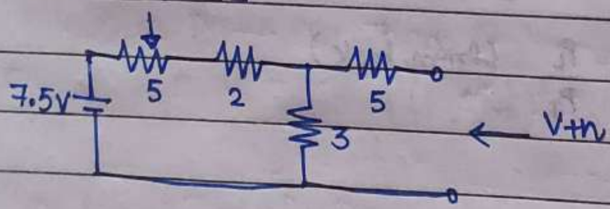
Find R_L for max power

Ans. For max power $R_L = R_{th}$

$$P_{max} = \frac{V_{th}^2}{4R_L}$$



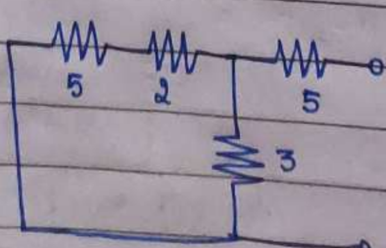


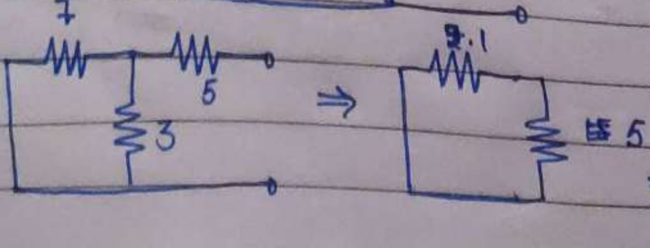


V_{th} = voltage drop across 3Ω resistance

voltage division $= \frac{3(7.5)}{10} = 2.25V$

For R_{th}





$\frac{1}{5} + \frac{1}{3}$

$\frac{8}{15}$

$= 7.1\Omega$

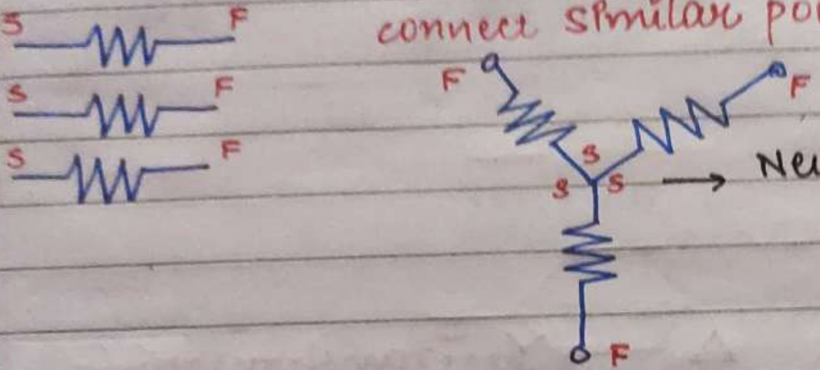
$$P_{max} = \frac{(2.25)^2}{4(7.1)} = \frac{5.0625}{\cancel{1.775}\ 28.4} = 0.178\ W$$

$R_{th} = R_L = 7.1\,\Omega$

DELTA-STAR TRANSFORMATION :-

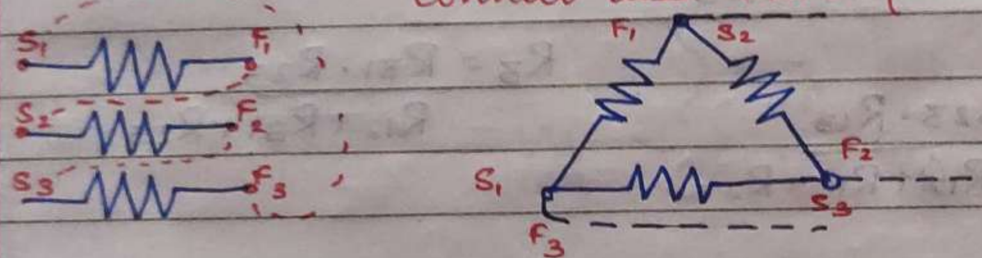
STAR FORMATION

connect similar points

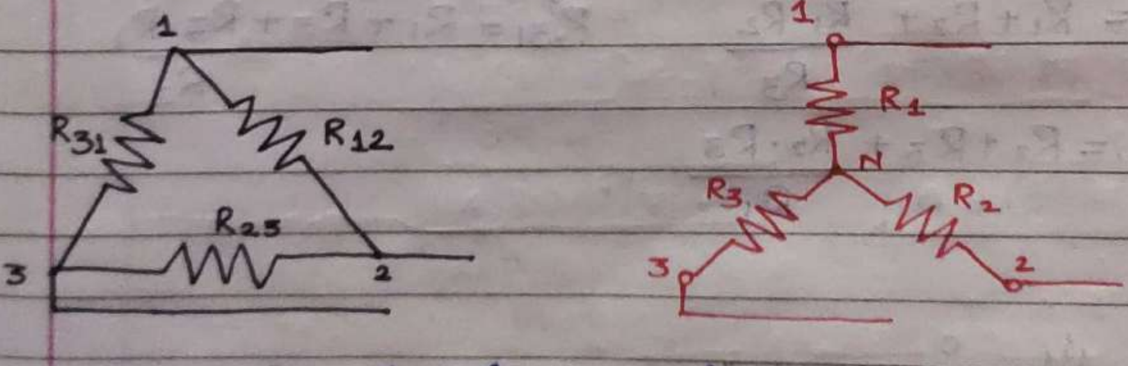


DELTA FORMATION

connect dissimilar points



TRANSFORMATION



For electrically equivalent

⇒ Resistance b/w any pair of terminals is same

for δ connection :- Resis b/w 1 & 2 ⇒ $R_{12} \parallel (R_{31} + R_{23})$

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

↳ ②

for star connection

$$\text{Res b/w } 1 \,\&\, 2 = R_1 + R_2 \longrightarrow (1)$$

for electrically equivalent

$$1 = 2$$

Final ans :-

$\Delta \longrightarrow Y$ Transformation

$$R_1 = \frac{R_{12} \cdot R_{13}}{R_{12} + R_{13} + R_{23}}$$

$$R_2 = \frac{R_{23} \cdot R_{13}}{R_{12} + R_{13} + R_{23}}$$

$$R_3 = \frac{R_{31} \cdot R_{23}}{R_{12} + R_{31} + R_{23}}$$

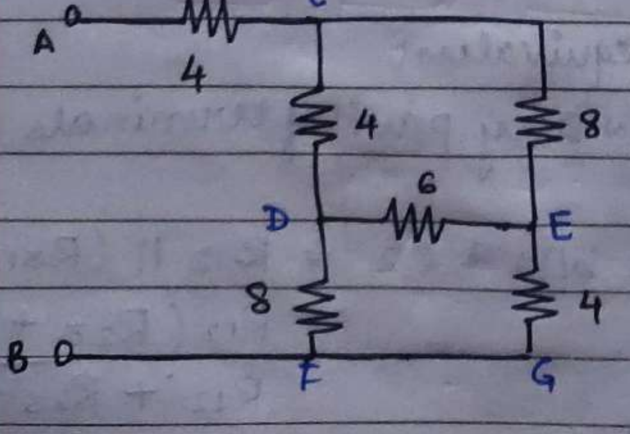
$Y \rightarrow \Delta$ Transformation

$$R_{12} = R_1 + R_2 + \frac{R_1 \cdot R_2}{R_3}$$

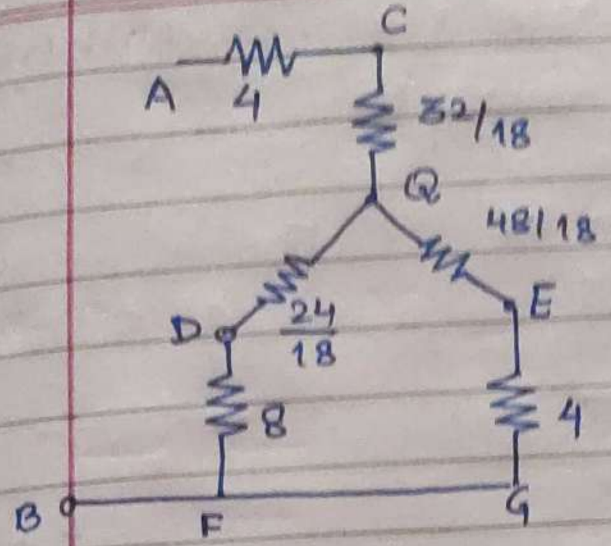
$$R_{31} = R_1 + R_3 + \frac{R_3 \cdot R_1}{R_2}$$

$$R_{23} = R_2 + R_3 + \frac{R_2 \cdot R_3}{R_1}$$

Q.



$R_{eq} = ?$

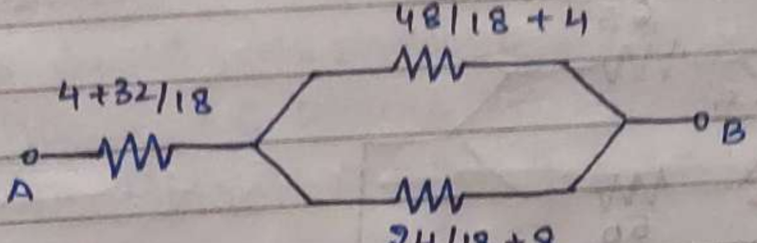


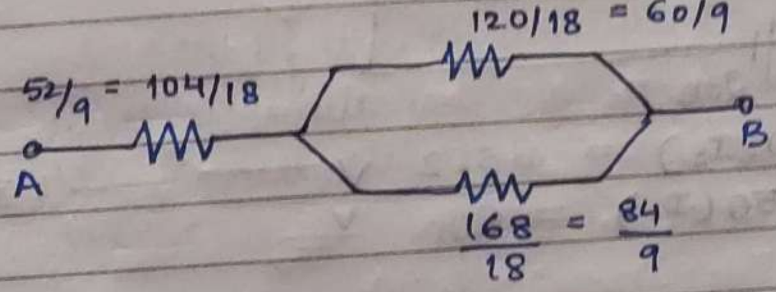
$$R_C = \frac{R_{CD} \cdot R_{CE}}{R_{CD} + R_{CE} + R_{DE}}$$

$$= \frac{32}{18}$$

$$R_D = \frac{24}{18} \qquad R_E = \frac{48}{18}$$

$$\begin{array}{r} 72 \\ +32 \\ \hline 104 \end{array}$$





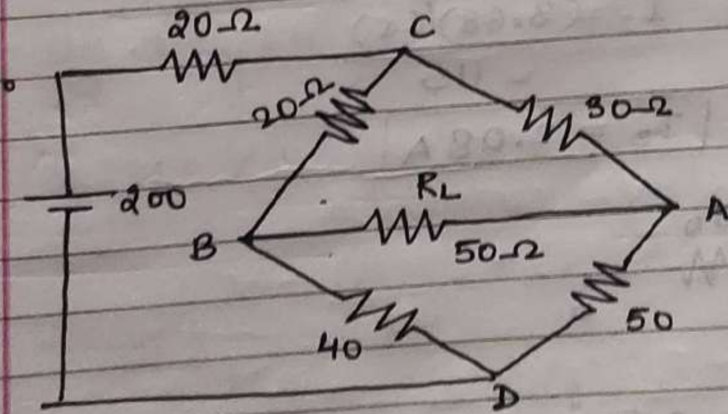
$R_{AB} = \frac{87}{9}\,\Omega$

$$\begin{array}{r} 18 \\ \times 8 \\ \hline 144 \\ 24 \\ \hline 168 \end{array} \qquad \begin{array}{r} 48 \\ 72 \\ \hline 120 \end{array}$$

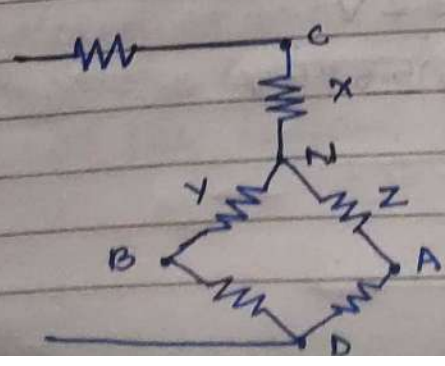
$$R_{AB} = \frac{52}{9} + \left(\frac{60}{9} \parallel \frac{84}{9}\right) = \frac{87}{9}\ \Omega \text{ Ans.}$$

Find I_{RL}

Q2



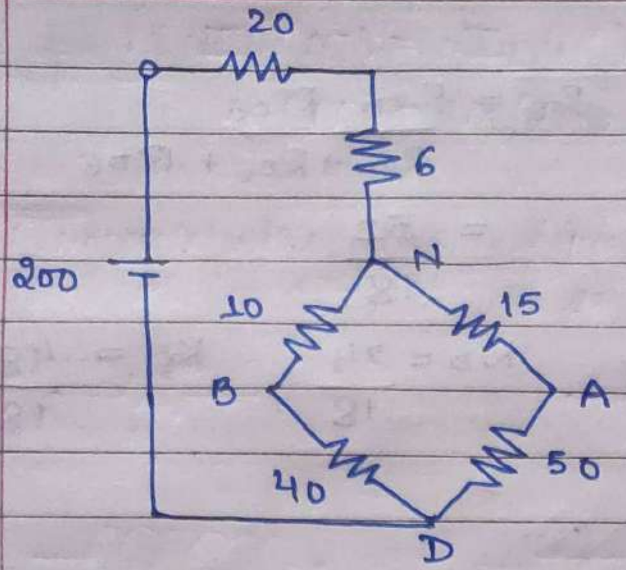
$$I_{RL} = (\cancel{50})(V_{AB})/(50)$$



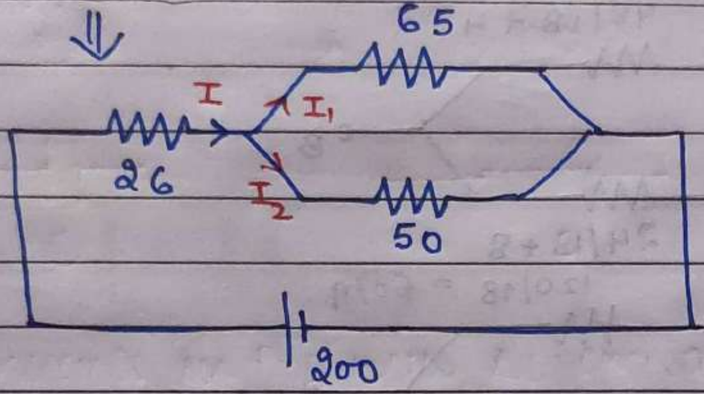
$$X = \frac{20 \cdot 30}{100} = 6\,\Omega \qquad Z = 15\,\Omega$$

$$Y = \frac{1000}{100} = 10\,\Omega$$

Ans:- 0.65V



⇓



$\frac{1}{65} + \frac{1}{50}$

$\frac{10+13}{650}$

$\frac{650}{23}$

$= 28.26$

$I = \frac{200}{26+28.26}$

$= \frac{200}{54.26}$

$= 3.68$

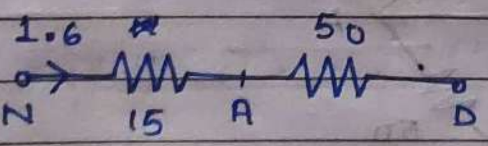
Pot at B = $40(I_2)$ = 83.2 V

Pot at A = $50(I_1)$ = 80 V

$I_1 = \frac{I(50)}{65+50}$ $\qquad$ $I_2 = \frac{I(65)}{65+50}$

$I_1 = \frac{3.68(50)}{115}$ $\qquad$ $I_2 = \frac{(3.68)(65)}{115}$

$\boxed{I_1 = 1.6\,A}$ $\qquad$ $\boxed{I_2 = 2.08\,A}$



** Pot diff b/w A & B is 3.2 V

$I_{RL} = 50 \times 3.2 = \cancel{160\,A}$ 15.625 V

Date :- 23 Dec, 2022

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AC FUNDAMENTAL

AC :- Magnitude & Direction changes wrt time.

IMPORTANCE OF AC

Power System :-

Generation → 11KV

Transmission → 132 KV, 66 KV

Distribution → Primary (11KV / 440V) → output (step down; 440V → 3φ)

→ Secondary 11KV 3φ → 220 V 1φ / 440 V 3φ

(a) $P = VI\cos\theta$ (V, I → Constt; $\cos\theta$ → Vary)

$I \propto$ load

$\frac{P}{V} = $ const $\Rightarrow V \propto \frac{1}{I}$

$\boxed{V\uparrow \rightarrow I\downarrow \rightarrow \text{LOSSES}\downarrow}$

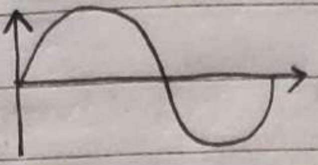
(b) less cost & wt of wire bcs these quantities $\propto I$

wt of wire $\propto$ tower size $\propto$ ckt breaker $\propto$ Rating of appliances. I

$I\downarrow$ hence these things are less.

(c) Induction motor works on AC. as DC motors cannot do heavy work. Induction motors are robust (no heating on heavy work)

(d) Natural zero break :- Shock prevention.



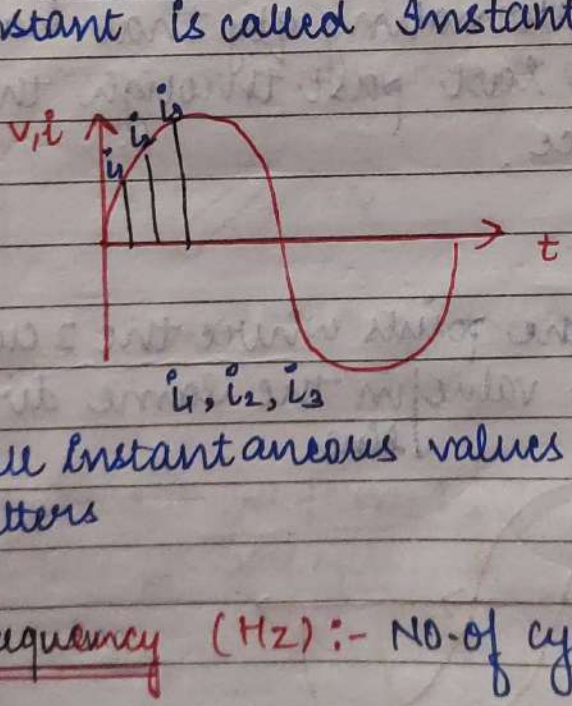
Adv of choosing sinosidal wave form over other

(a) produces less losses
(b) ↓ Harmonics :- less Freq (undesireable)
(c) ↓ Interferences with communication ckt.
(d) ↓ Noise

Important Terms.

(a) Waveform :- Shape of the curve (V or I) when plotted against time.

(b) Instantaneous Value :- Value of quantity at any particular instant is called Instantaneous value



all Instantaneous values are written in small letters

(c) Frequency (Hz) :- No. of cycles in 1 sec.

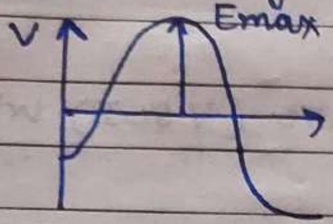
$$\boxed{f = \frac{1}{T}}$$

(d) Time Period (sec) :-
Time taken to complete one cycle

(e) Cycle :- Set of all +ve & -ve instantaneous value is 1 cycle.

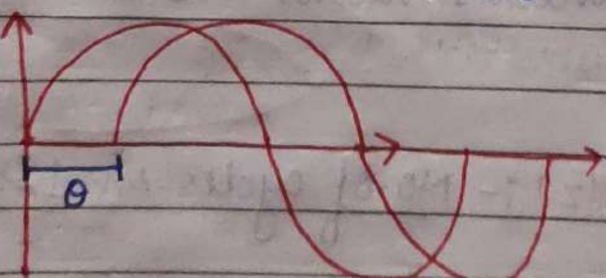
(f) Half cycle / Alternation :- Set of all +ve values → +ve half cycle
Set of all -ve values → -ve half cycle.

(g) Amplitude / Peak value / crest value / Max value :-
The max mag (+ve / -ve) which an alternating qty attains during one cycle.



(h) Phase / Phase Angle :-
Fraction of T.P of alternating qty that has elapsed since the current last past through the zero position of refrence.

(i) Phase difference :-
Angular dis b/w the points where the 2 curves cross the refrence value / line in the same dir.



(j) Avg value :-
~~Sum of all instantaneous~~
Arithmatic avg of all inst. values considered of an alternating qty over one cycle.

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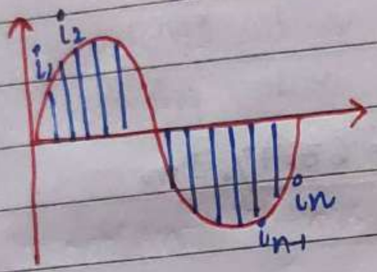
I_{av}, V_{av} → Representation

(k) Symmetrical Alt-qty :-
where +ve half cycle = −ve half cycle.

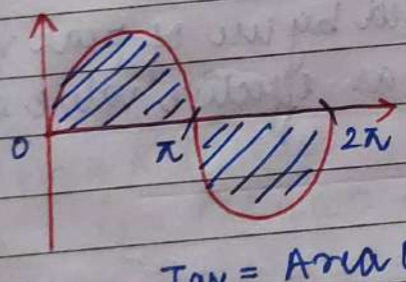
For sym. alt. qty, avg value = 0.



$$avg = \frac{i_1 + i_2 + \cdots - i_{n-1} - i_n}{n} = 0$$

For unsymmetrical alt. qty, avg value ≠ 0

⇒ Integral Calculus Method for Avg value.



= Area under graph
2π = base

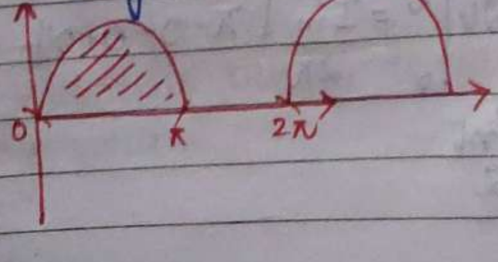
$$I_{av} = \frac{\text{Area of alternation}}{\text{base}}$$

Integration at home

For pure wave form :- we take for half cycle.
↳ base half cycle

$$\boxed{I_{av} = \frac{\int_0^{\pi} I_m \sin\theta}{\pi} = \frac{2I_m}{\pi} = 0.637 I_m}$$

For unsymmetrical



$$I_{avg} = \frac{\int_0^{\pi} I_m (\text{wave eq}^n)}{2\pi}$$

Limit :- where we see actual waveform

base :- when next cycle start.

Q. Derivation of avg value of current

$$I_{av} = \int_0^{\pi} \frac{I_0 \sin\theta \, d\theta}{\pi}$$

$$= \frac{I_0 (-\cos\theta)\Big|_0^{\pi}}{\pi}$$

$$= \frac{2 I_0}{\pi} = 0.637 I_m = 63.7\% \, I_m$$

Date 24 Dec, 2022

(2) Root mean square value :.

(written in capital letters)

$$V = V_m \sin\theta$$

All instruments, Ammeter, Voltmeter measure RMS value. It is used for calculations.

(1) Protective devices all calculated by use of peak values.

(2) RMS value are also known as effective value & virtual value.

$$I_{rms} = \sqrt{\frac{1}{\pi} \int_0^{\pi} i^2 . d\theta}$$

$$I_{rms}^2 = \frac{1}{\pi} \int_0^{\pi} I_m^2 \sin^2\theta \, d\theta = \frac{I_m^2}{\pi} \int_0^{\pi} \sin^2\theta \, d\theta$$

$$= \frac{I_m^2}{\pi} \int_0^{\pi} \left(\frac{1 - \cos 2\theta}{2} \right) . d\theta = \frac{I_m^2}{2\pi} \int_0^{\pi} (1 - \cos 2\theta) d\theta$$

$$= \frac{I_m^2}{2\pi} \left| \theta - \frac{1}{2} \sin 2\theta \right|_0^{\pi} = \frac{I_m^2}{2\pi} \left| \pi - 0 - 0 + 0 \right|$$

$$I_{rms}^2 = \frac{I_m^2}{2}$$

$\therefore I_{rms} = \frac{I_m}{\sqrt{2}} = 0.707 I_m$

(m) Form factor :-

It is the ratio of RMS value of AC to Avg value of AC for pure sinosidal wave.

$$F.F = \frac{\text{RMS value}}{\text{Avg value}} = \frac{0.707\, I_m}{0.637\, I_m}$$

$$\boxed{K_f = F.F = 1.1}$$

(n) Peak factor / crest factor / Amplitude factor :-

It is the ratio of peak value of AC qty to RMS value of AC qty

$$K_p = \frac{\text{Peak value}}{\text{RMS value}} = \sqrt{2} = 1.414$$

Q1 Find RMS value

$$i_2 = 12 \sin \omega t + 5(\sin \omega t - 3\pi/2) + 8 + 24(\sin \omega t - 5\pi/6$$

Ans $I_{rms} = \sqrt{\left(\frac{12}{\sqrt{2}}\right)^2 + \left(\frac{5}{\sqrt{2}}\right)^2 + 8^2 + \left(\frac{24}{\sqrt{2}}\right)^2}$

$= \sqrt{\frac{973}{2}} = \sqrt{486.5}$

Q2 A sinosidal varying current AC of 50 Hz max value of 15A. write eqn for instantaneous value.

(2) current after 1/200 sec.

(3) Find time taken to reach 10 A for 1st time.

(4) Avg value.

A2:- $\nu = 60 Hz$

$I_m = 15A$

$\omega = 2\pi\nu = 120\pi$

(ii) $I_{1/200} = I_m \sin\omega t = 15 \sin(120\pi)\left(\frac{1}{200}\right) = 15 \sin\left(\frac{3}{5}\right)$

$= 15 \sin(0.6) = 14.266$

(iii) $I_t = 10 = 15 \sin 120\pi t$

$\sin^{-1}\left(\frac{2}{5}\right) = 120\pi t = \frac{\sin^{-1}(2/5)}{120\pi} = t$

(iv) Avg value $= \frac{2(15)}{\pi} = 9.55 A$.

(i) Instantaneous current $= i = 15 \sin 120\pi t$

Q3. An AC source sinosidal has current RMS value of 40A at 50Hz frequency. Write the expression of
(i) Instantaneous Current
(ii) current at 0.02 sec after passing through max +ve value.

A3. $I_{RMS} = 40 A$; $\nu = 50 Hz$

$\frac{I_m}{\sqrt{2}} = I_{RMS} \Rightarrow I_m = \sqrt{2}\, I_{rms} = \sqrt{2}(40) = 40\sqrt{2} A$

$\omega = 2\pi\nu = 100\pi$

$i = I_m \sin\omega t$

$= 40\sqrt{2} \sin 100\pi t$

HW ques → Half wave Rectifier Form factor: 1.57 (Derivation)

Q. Half wave Rectifier Form factor.

Q2. Peak form factor for half wave.

$8 \times 0.15 \quad 3$

$\frac{100}{20} \quad 4$

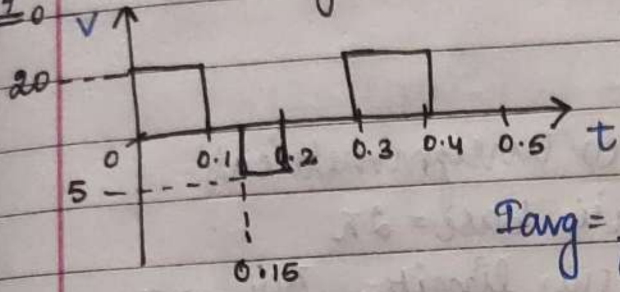
$40\sqrt{2} = 40\sqrt{2} \sin 100\pi t$

$\pi/2 = 100\pi t \qquad t = 1/200$

$t = 1/200 + 0.02 = 0.07$

$40\sqrt{2} \sin 7\pi = I_{req} = 0$

Q4. Find Average & RMS value.



$$I_{avg} = \frac{1}{0.3}\left[\int_0^{0.1} 20\,dt + \int_{0.15}^{0.2} -5\,dt\right]$$

$$I_{avg} = \frac{1}{0.3}\left[20t\Big)_0^{0.1} + (-5t\Big]_{0.15}^{0.2}\right]$$

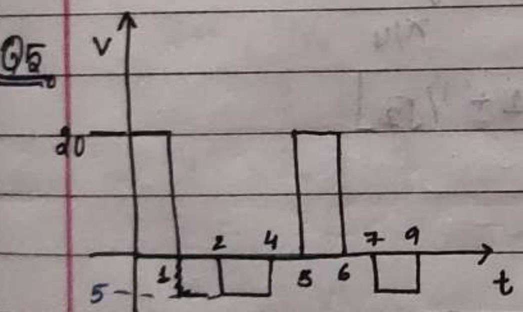
$$= \frac{10}{3}\left[20.(0.1) - (5.(0.2) - 5.(0.15))\right]$$

$$= \frac{10}{3}\left[2 - (1 - 0.75)\right] = \frac{10}{3} \times 1.75 = \frac{17.5}{3} = I_{avg}$$

-: Irms at end :-

Date :- 28 Dec, 2022

Q5. Find Avg. & RMS value.



$$V_{avg} = \frac{1}{5}\int V(t)\,dt$$

$$= \frac{1}{5}\left[\int_0^1 (20.dt) + \int_2^4 (-5dt)\right]$$

$$= \frac{1}{5}\left[20t\Big]_0^1 - 5t\Big]_2^4\right]$$

$$= \frac{1}{5}\left[20(1) - 20(0) - (5(4) - 5(2))\right]$$

$$= \frac{1}{5}\left[20 - 10\right] = 2$$

$$RMS = \sqrt{(V_{avg})^2} = \sqrt{\frac{1}{5}\left[\int V(t)\right]^2}$$

$$= \sqrt{\frac{1}{5}\left[\int_0^1 (20^2 dt)^2 + \int_2^4 (5^2 dt)\right]}$$

$\frac{\theta}{t} = \omega$

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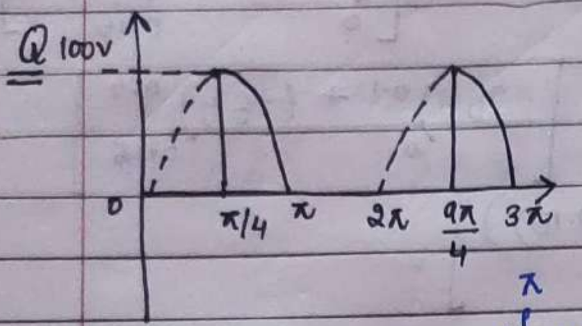
$$\sqrt{\frac{1}{5}\left(\int_0^1 400(t) + 25t\Big]_4^2\right)}$$

$$= \sqrt{\frac{1}{5}\left(400+50\right)} = \sqrt{\frac{450}{5}} = \sqrt{90}$$

Q



(i) unsymmetrical
(ii) base $= 2\pi$
(iii) limit $= \pi/4 \rightarrow \pi$

$$V_{avg} = \frac{1}{2\pi}\int_{\pi/4}^{\pi} 100 \sin \omega t \, dt$$

$\omega t \rightarrow \theta$
$dt \rightarrow d\theta$

$$= \frac{1}{2\pi}(100)\left(-\cos\theta\right)_{\pi/4}^{\pi}$$

$$= \cancel{50}\, \frac{-50}{\pi}\left[-1 + 1/\sqrt{2}\right]$$

$$= 27.18$$

$$V_{rms} = \sqrt{\frac{1}{2\pi}\int (100)^2 (\sin\theta)^2 d\theta}$$

$2\sin^2\theta = 1 - \cos 2\theta$

$$= \sqrt{\frac{10000}{2\pi}\int_{\pi/4}^{\pi} \sin^2\theta \, d\theta}$$

$$= \sqrt{\frac{10000}{4\pi}\int_{\pi/4}^{\pi}\left(1 - \cos 2\theta\right) d\theta}$$

$$= \sqrt{\frac{2500}{\pi}\left[\theta - \frac{\sin 2\theta}{2}\right]_{\pi/4}^{\pi}}$$

put $\pi = 3.14$

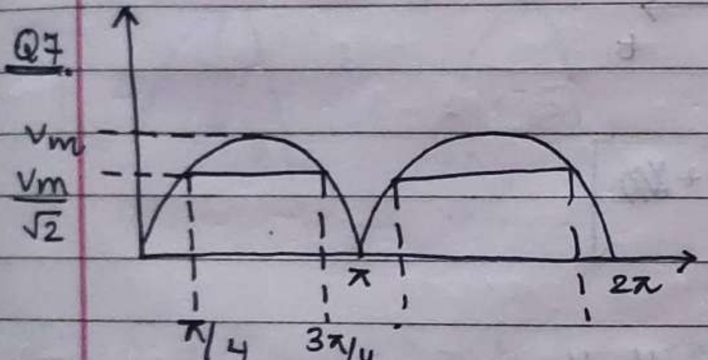
$$= \sqrt{\frac{2500}{\pi}\left[\pi - \frac{\cancel{\sin 2\pi}^{\,0}}{2} - \frac{\pi}{4} + \frac{\sin 2(\pi/4)}{2}\right]}$$

$$= \sqrt{\frac{2500}{\pi}\left[\frac{3\pi}{4} + \frac{1}{2}\right]}$$

$$= \sqrt{\frac{3(25)(\cancel{100})^{25}}{\cancel{4}} + \left(\frac{2500}{\pi}\right)\left(\frac{1}{2}\right)}$$

$$= \sqrt{1875 + 398.08} = \sqrt{2,273.08} = 47.67$$

Q7.



A full Rectified Sinosidal voltage clipped at $1/\sqrt{2}$ of ~~at~~ its max value.

$$V_{avg} = \frac{1}{\pi}\left[\int_0^{\pi/4} V_m \sin\theta \, d\theta + \int_{\pi/4}^{3\pi/4} V_m \, d\theta + \int_{3\pi/4}^{\pi} V_m \sin\theta \, d\theta\right]$$

$$= \frac{1}{\pi}\left[V_m\left[-\cos\theta\right]_0^{\pi/4} + \frac{V_m}{\sqrt{2}}\left[\theta\right]_{\pi/4}^{3\pi/4} + V_m\left[-\cos\theta\right]_{3\pi/4}^{\pi}\right]$$

$$= \frac{1}{\pi}\left[-V_m\left[\cos\frac{\pi}{4} - \cos 0\right] + \frac{V_m}{\sqrt{2}}\left[\frac{3\pi}{4} - \frac{\pi}{4}\right] + V_m\left[\cos\pi - \cos\frac{3\pi}{4}\right]\right]$$

$$= \frac{1}{\pi}\left[-V_m\left[\frac{1}{\sqrt{2}} - \frac{\sqrt{2}}{\sqrt{2}}\right] + \frac{V_m}{\sqrt{2}}\left[\frac{\pi}{2}\right] - V_m\left[-1 - \left(-\frac{1}{\sqrt{2}}\right)\right]\right]$$

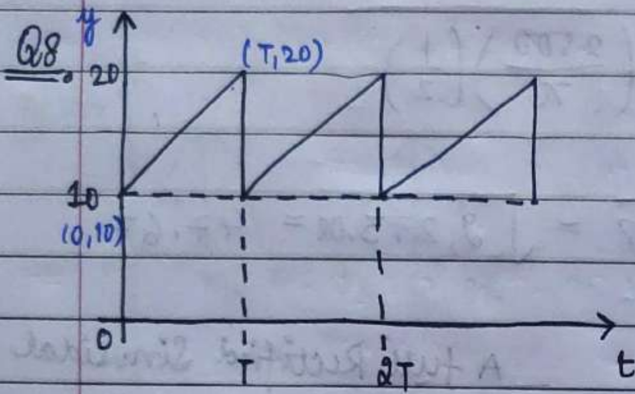
$$= \frac{1}{\pi}\left[-V_m\left[\frac{1-\sqrt{2}}{\sqrt{2}}\right] - V_m\left[\frac{\cancel{1}+1}{\sqrt{2}}\right] + \frac{V_m \pi}{2\sqrt{2}}\right]$$

$$= \frac{1}{\pi}\left[-2V_m\left[\frac{1-\sqrt{2}}{\sqrt{2}}\right] + \frac{V_m \pi}{2\sqrt{2}}\right] = V_m\left[-\frac{2}{\pi}\left(\frac{1-\sqrt{2}}{\sqrt{2}}\right) + \frac{1}{2\sqrt{2}}\right]$$

$$V_m\left(\frac{(-0.636)(-0.414)}{1.414} + 0.353\right)$$

$$V_m\left(0.186 + 0.353\right) = V_m\,(0.54)$$

Q8.



Ans = 15

$$y_{avg} = \frac{1}{T}\int_0^T \left[y_{line} + \cancel{10}\right]$$

eqⁿ of line ⇒ $\dfrac{y_2-y_1}{x_2-x_1} = \dfrac{y-y_1}{x-x_1}$

$$\frac{20-10}{T-0} = \frac{y-10}{x-0}$$

$$\frac{10}{T} = \frac{y-10}{x}$$

$$10x = yT - 10T$$

$$10(t) = yT - 10T \qquad (x=t)$$

$$\frac{10(t)+10(T)}{T} = y$$

$$y = \frac{10t}{T} + 10$$

$$y_{avg} = \frac{1}{T}\left[\int_0^T \left(\frac{10t}{T} \cancel{+10}\right)dt + \int_0^T 10\,dt\right]$$

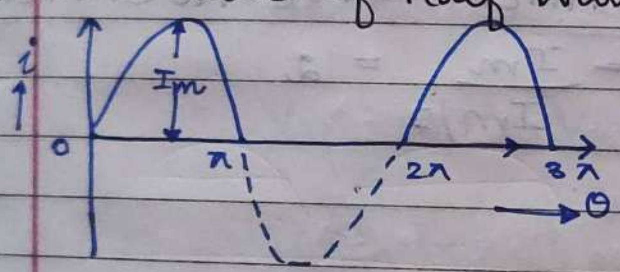
$$\frac{1}{T}\left[\int_0^T \left(\frac{10t}{T}\right) + \int_0^T 10\right]$$

$$\frac{1}{T}\left[\frac{10}{T}\left(\frac{t^2}{2}\right)_0^T + 10T\right]$$

$$\frac{1}{T}\left[\frac{10}{\cancel{T}}\left(\frac{T^{\cancel{2}}}{2}\right) + 10T\right]$$

$$5 + 10 = 15$$

RMS value of Half Wave Rectifier.



$$I_{RMS} = \sqrt{\frac{1}{2\pi}\int_0^\pi Im^2 \sin^2\theta \, d\theta}$$

$$= \sqrt{\frac{Im^2}{2\pi}\int\left[\frac{1-\cos 2\theta}{2}\right]_0^\pi d\theta}$$

$$= \sqrt{\frac{Im^2}{2\pi}\left(\frac{\theta}{2} + \frac{\sin 2\theta}{4}\right)_0^\pi}$$

$$= \frac{Im}{2}\sqrt{\frac{1}{\pi}\left(\pi - \frac{\cancel{\sin 2\pi}^{0}}{2} - 0 - \frac{\cancel{\sin 0(2)}^{0}}{2}\right)}$$

$$I_{RMS} = \frac{Im}{2}$$

AVERAGE VALUE OF HALF WAVE RECTIFIER :-

$$I_{av} = \frac{1}{2\pi}\int_0^{\pi} I_m \sin\theta \, d\theta$$

$$= \frac{I_m}{2\pi}\Big[-\cos\theta\Big]_0^{\pi} = \frac{I_m}{\pi}$$

FORM FACTOR OF HALF WAVE RECTIFIER :-

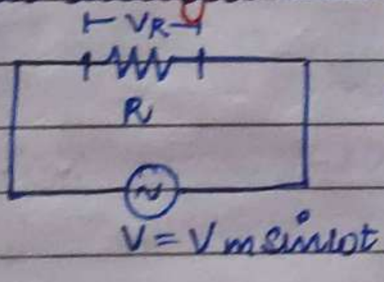
$$F.F = \frac{\text{RMS value}}{\text{~~Peak~~ Avg value}} = \frac{I_m/2}{I_m/\pi} = \frac{\pi}{2} = 1.57$$

PEAK FORM FACTOR OF HALF WAVE RECTIFIER

$$P.F = \frac{\text{Peak value}}{\text{RMS value}} = \frac{I_m}{I_m/2} = 2$$

Date :- 29 Dec, 2022.

AC through Pure RESISTIVE CIRCUIT



Voltage = $V_m \sin\omega t = v$ — 2

Instantaneous current $= i$

V drop across R is $V_R = iR$ — 1

for equilibrium 1 = 2

$$V_R = iR = V_m \sin\omega t$$

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

for $\sin\omega t = 1$ $\quad i = \frac{V_m}{R} = I_m$

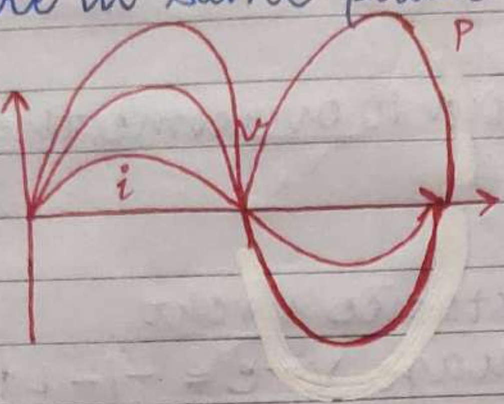
$$i = I_m \sin\omega t \quad — 3$$

comparing 2 & 3

for $v = V_m \sin\omega t$

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

v, i are in same phase. for only R ckt



Instantaneous power $= vi = P$

$= (V_m \sin\omega t)(I_m \sin\omega t)$

$= V_m I_m \sin^2\omega t$

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

$= \frac{V_m I_m}{2} - \frac{V_m I_m}{2}\underbrace{\cos 2\omega t}_{\text{variable}}$ —(4)

For average power.
over complete cycle, the variable part in 4 is zero. We are left with only $\frac{V_m I_m}{2}$

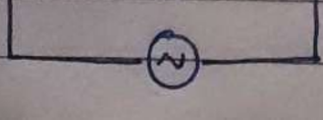
$$P = \frac{V_m I_m}{2} = \frac{V_m}{\sqrt{2}} \frac{I_m}{\sqrt{2}} = V_{rms} \cdot I_{rms}$$

$$P_{avg} = V \cdot I$$

(a) Power is always +ve and the expression of Power is $V_{rms} I_{rms}$. Unit = Watts

(b) No part of power cycle becomes -ve at any time. and power is never zero in purely resistive ckt.

AC through purely INDUCTIVE CIRCUIT



$V = V\sin\omega t$

~~when an~~ alternating voltage

all this voltage is used to overcome the self induced emf. $e = -L\frac{di}{dt}$.

As there is no resistance in ckt.
Hence applied voltage $V = -e = -\left(-L\frac{di}{dt}\right) = L\frac{di}{dt}$

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

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

$$I = \frac{V_m}{\omega L} \sin(\omega t - \pi/2)$$

$$I = \frac{V_m}{X_L} \sin(\omega t - \pi/2)$$

$\omega L = X_L$ = Inductive reactance = Ω
Inductive reactance is the resistance offered by Inductor to alternating current

for $\sin(\omega t - \pi/2)$

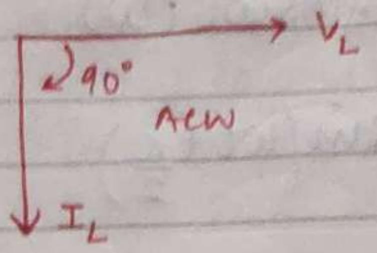
$$i = \frac{V_m}{X_L} = I_m$$

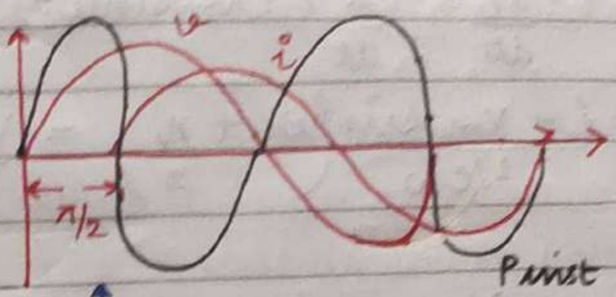
In a L ckt

$V = V_m \sin\omega t$

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

current lags the applied voltage by $\pi/2$





(Jiska Max phle vo leading)

Instantaneous Power $= v.i$

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

$= -V_m I_m \sin\omega t \cos\omega t$

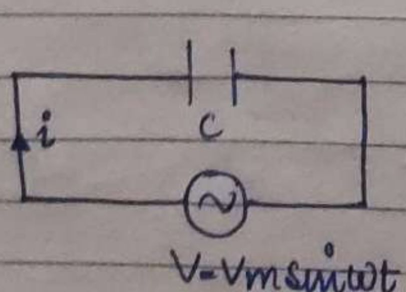
$= -\frac{V_m I_m}{2} \sin 2\omega t$ → fluctuating (variable)

Avg Power = 0

In a pure Inductive & capactive ckt, average power across full cycle is zero. (NO consumption of Power in pure L & C in avg but at instant it consumes power).

Power system :-

AC through Pure Capacitive Alone



Let $V = V_m \sin\omega t$

V = pot diff across plates

q = charge on plates

$q = CV$

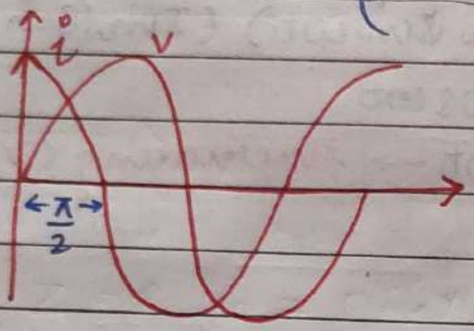
$= C V_m \sin\omega t$

$$i = \frac{dq}{dt} = \frac{d}{dt}(CV_m \sin\omega t) = CV_m \cos\omega t\,(\omega)$$

$$i = \frac{V_m}{1/C\omega}\sin\left(\omega t + \frac{\pi}{2}\right) = \frac{V_m}{X_c}\sin\left(\omega t + \frac{\pi}{2}\right)$$

$$X_c = \frac{1}{\omega C} \quad ; \quad I_m = \frac{V_m}{X_c}$$

$$i = I_m \sin\left(\omega t + \frac{\pi}{2}\right)$$



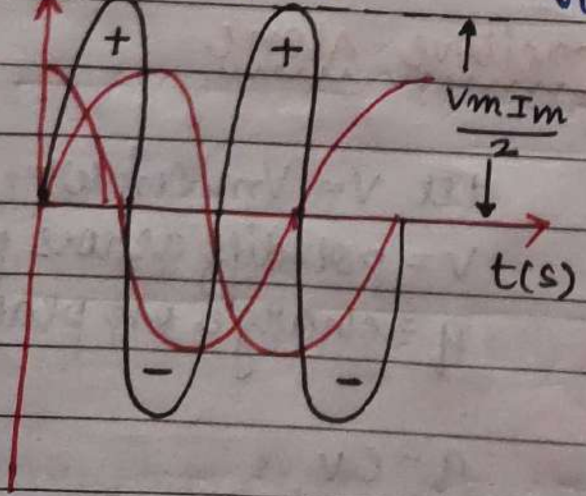
Instantaneous Power

$$p = vi = (V_m \sin\omega t)(I_m \sin(\omega t + 90^\circ))$$

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

$$= \frac{1}{2} V_m I_m \sin 2\omega t$$

$$\text{Power}_{avg} = \frac{1}{2} V_m I_m \int_0^{2\pi} \sin 2\omega t \, dt = 0$$



1 Horse power = 786 Watt

CLASSTIME Pg. No.
Date / /

POWER SYSTEM

(i) Apparent Power (S)

It is given by the product of rms values of applied voltage and circuit current.

$$\therefore S = VI = (IZ) \cdot I = I^2 Z = \text{Volt amperes (VA)}$$

(ii) Active/Real Power (P)

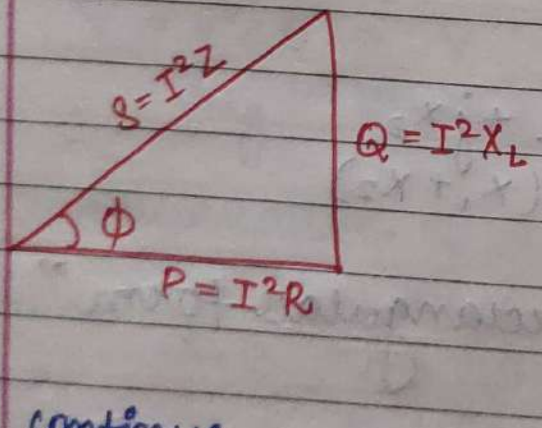
It is the power which is actually dissipated by circuit Resistances.

$$P = I^2 R = VI\cos\phi = \text{Watt}$$

(iii) Reactive Power (Q)

It is the power developed in the inductive reactance of the circuit / capacitance reactance
(consume in one half cycle, give back in other half cycle)

$$Q = I^2 X_L = I^2 . Z\sin\phi = I.(IZ)\sin\phi = VI\sin\phi$$
$$= \text{volt-amperes-reactive.}$$



$$S^2 = P^2 + Q^2$$
$$S = \sqrt{P^2 + Q^2}$$
$$\cos\phi = \frac{P}{S}$$

Q4. continue

$$I_{rms} = \sqrt{\frac{10}{3}\left[\int_0^{0.1} 400\,dt + \int_{0.15}^{0.2} 25\,dt\right]}$$

$$= \sqrt{\frac{10}{3}\left(\frac{400 \times 0.1}{10} + 25\left(\frac{0.2}{10}\right) - 25\left(\frac{0.15}{100}\right)\right)}$$

$$= \sqrt{\frac{10}{3}\left(40 + 5 - 3.75\right)}$$

$$= \sqrt{137.5}\ A$$

Date :- 30 Dec, 2022

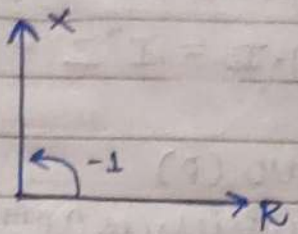
Mathematical Representation of Phasors

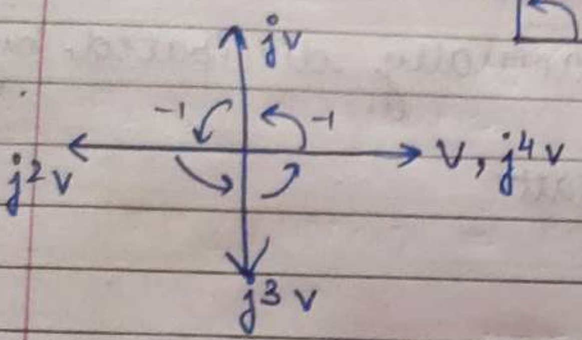
(A) Rectangular form

$j^2 = -1$

$j = \sqrt{-1}$

$Z = R + jX$





$Z = a + jb = R + jX$

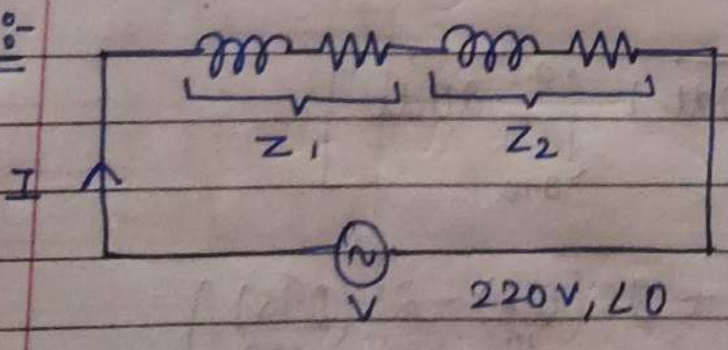
a = Real part
b = Imaginary part

$Z_1 = R_1 + jX_1$; $Z_2 = R_2 + jX_2$

$Z_1 + Z_2 = (R_1 + R_2) + j(X_1 + X_2)$

"Add / Sub we go it in Rectangular form"

g:-



net Impedence $= Z_1 + Z_2$

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

(B) TRIGONOMETRICAL FORM

Real part $= a = V\cos\phi$

Img. part $= b = V\sin\phi$

$$\vec{V} = V\cos\phi + Vj\sin\phi$$
$$\vec{V} = V(\cos\phi + j\sin\phi)$$

(C) Exponential form

$$e^{j\phi} = \cos\phi + j\sin\phi$$
$$e^{-j\phi} = \cos\phi - j\sin\phi$$
$$e^{j(\phi+\theta)} = \cos(\theta+\phi) + j\sin(\theta+\phi)$$

(D) Polar form

$$\vec{V} = \underbrace{V}_{\text{mag}}\angle\underbrace{\theta}_{\text{Phase }\angle.} = V\angle-\theta$$

"multiplication of phasors" "Divide of phasors"

$$A\angle\theta, \; B\angle\alpha$$
$$A\cdot B = AB\angle(\theta+\alpha)$$
$$\frac{A}{B} = \frac{A}{B}\angle(\theta-\alpha)$$

Q. $Z = 3 + j5$; $V = 220V, \angle 0$; $I = ?$

Ans. $$I = \frac{V}{Z}$$

$$|Z| = \sqrt{3^2+5^2} = \cancel{4}Y \qquad \theta = \tan^{-1}\left(\frac{5}{3}\right)$$

$$Z = \cancel{4}\angle\theta \quad , V = 220\angle 0$$

coil = $r + X_L$

Lead & lag

$$I = \frac{220}{Y} \angle(0-\theta)$$

$A\angle\theta \rightarrow$ nth power

$A^n \angle n\theta$

nth root $A^{1/n} \angle \frac{\theta}{n}$

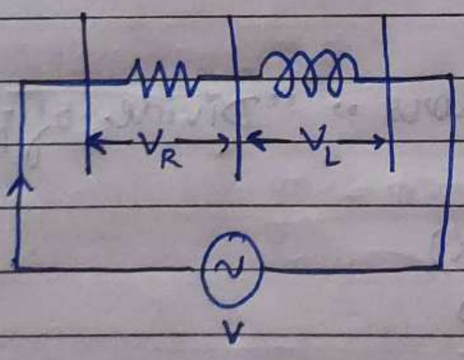
Eg:- $5\angle 60$, 4th power

$$5^4 \angle (4)(60) = 625\angle 240$$

$$\text{4th root} = (5)^{1/4} \angle \frac{60}{4} = \sqrt{5} \angle 15$$

R-L-Series Circuit :-

R-L-series :- coil



$$V = \sqrt{V_R^2 + V_L^2} = \sqrt{(IR)^2 + (IX_L)^2}$$

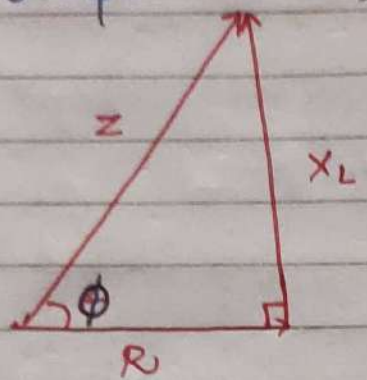
$$V = I\sqrt{R^2 + X_L^2}$$

$$\frac{V}{I} = Z = \sqrt{R^2 + X_L^2}$$

Impedence = $\sqrt{R^2 + X_L^2}$

$\tan\theta = \dfrac{X_L}{R} = \dfrac{\omega L}{R}$

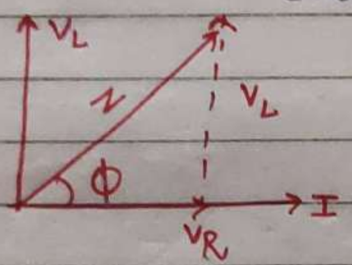
Impedence Δ,



$\cos\phi = \dfrac{R}{Z} = \dfrac{\text{Resistance}}{\text{Impedence}}$

$0 \leq \cos\phi \leq 1$

bcs base ckts are pure Resistive ($\cos\phi = 1$) and pure Inductive/Capacitive ($\cos\phi = 0$)



Applied V & I are not in phase
I is lagging is by ϕ with V.

If $V_m \sin\theta = V$
$I = I_m \sin(\theta - \phi)$

$$p = vi = V_m \sin\theta \times I_m \sin(\theta - \phi)$$
$$= V_m I_m \sin\theta \sin(\theta - \phi)$$

$$= \underbrace{\frac{V_m}{\sqrt{2}} \frac{I_m}{\sqrt{2}} \cdot \cos\phi}_{\text{Constt}} - \frac{V_m}{\sqrt{2}} \frac{I_m}{\sqrt{2}} \underbrace{\cos(2\omega t - \phi)}_{\text{fluctuating}}$$

$P = P_{avg} =$
$$\frac{V_m}{\sqrt{2}} \frac{I_m}{\sqrt{2}} \cos\phi = V_{rms} I_{rms} \cos\phi$$

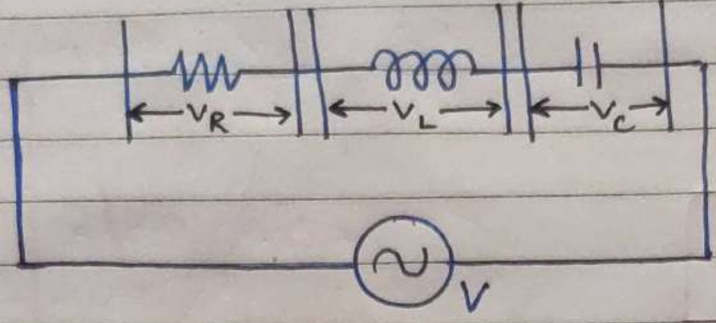
$P = VI\cos\phi = VI.\frac{R}{Z} = \frac{V}{Z}.I.R = I^2R$ Watt.

power is only consumed by ckt.

R-C series circuit

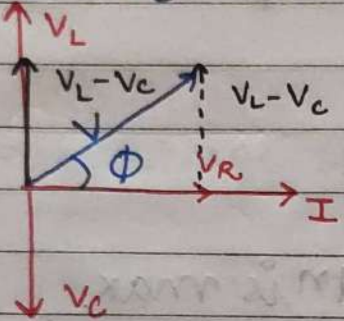
Date :- 8 Dec, 2022

R-L-C Series Circuit



$V_L > V_C \Rightarrow$ Inductive ckt

$V_L < V_C \Rightarrow$ capacitive ckt



FOR $V_L > V_C$

I lags applied voltage by ϕ angle

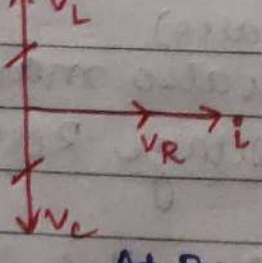
$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

SERIES RESONANCE :-

condition :- $X_L = X_C$ or $V_L = V_C$

Resonance :- Any ac circuit when behaves like purely resistive circuit i.e. V & I are in same phase. i.e net reactive component of circuit is zero.

$V_L - V_C = 0$



Total voltage is around resistive part of ckt.

V is in phase with I.

$V_R = V$

At Resonance

$V_L = V_C$

$I X_L = I X_C$

$$\boxed{X_L = X_C}$$

$$\omega L = \frac{1}{\omega C}$$

$$\omega^2 = \frac{1}{LC}$$

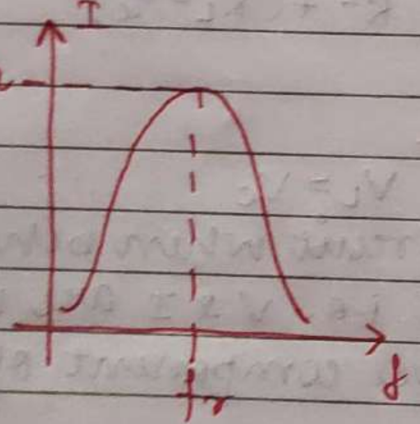
$$\boxed{f = \frac{1}{2\pi\sqrt{LC}}}$$

→ As V_R is in phase with I → $\cos\phi = 1$

→ $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$$\boxed{Z = R}$$

→ Current at Resonating condn is max.



Radio & Communication Ckt Applications.

(Voltage Magnification ckt)

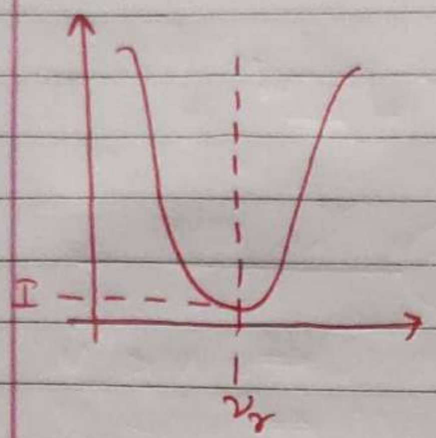
Series Resonance is also called Voltage Resonance & acceptor circuit.

(L, C also)

Voltage across each component is also maximum with current hence called Voltage Resonance

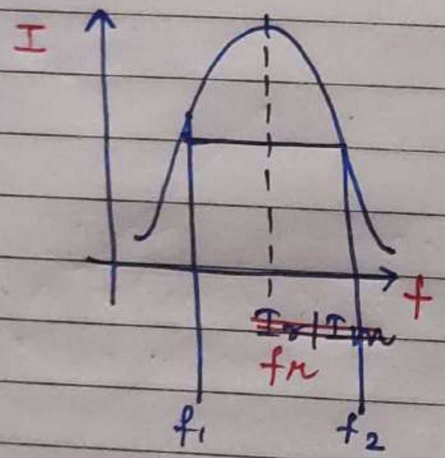
As ~~ckt~~ R accepts max current from the ckt It is acceptor circuit.

Parallel Resonance (current/ rejector resonance)



BANDWITH :-

The range of freq where $I = 70.7\%\ I_r$



$BW = f_2 - f_1$

f_1 & f_2 are half power points

Power drawn is half at these points.

$$f_r = \sqrt{f_1 f_2}$$

Q-Factor (Quality factor of coil) :-

$$\frac{V \text{ developed across } L \text{ or } C}{\text{Applied voltage}} = \frac{I_r X_L}{I_r R} = \frac{1}{R}\sqrt{\frac{L}{C}}$$ Der.

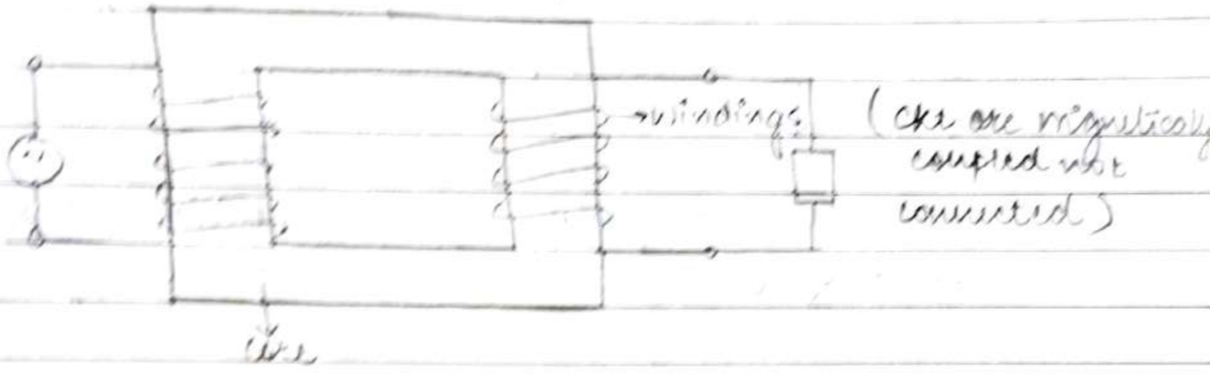
$$Q_{res} = \frac{\text{Resonating frequency}}{\text{Bandwidth}}$$

Q factor decides designing of coil
It doesnot depend upon frequency.

Date :- 25 Jan 2023

unit-3

TRANSFORMER



(Electrical)
Transformer (Transfer) :- E. Energy from one ckt to another ckt w/o changing v.

→ Static device :- no rotating part as in motors.

→ Device :- no effective work, hence its not a machine

→ machine :- effective work using power.

Power is transferred from primary to secondary.

→ No rotating part → no change in frequency.

Tasks of transformer

(a) voltage up down (potential transformers)

(b) same voltage transfer

(c) current up down (current transformers)

(d) same Power transfer

$$P_{I/P} = P_{O/P}$$

$$V_1 I_1 \cancel{\cos\phi} = V_2 I_2 \cancel{\cos\phi}$$

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

If $V_1 \uparrow$, $I_1 \downarrow$

Types of transformers

(A) INSTRUMENT TRANSFORMERS
(connected before measuring inst.)

- CT
  current transformer
  (step up of voltage)
- PT
  Potential Transformer
  (stepdown of voltage)

(B) Basis of Rating of Transformer

- Power transformer
  (3-φ)
- Electronics Transformer)
  (5-10V)
- Distribution transformer
  (3-φ)

(C) Stepup - stepdown transformers

- Stepup V↑
- Stepdown V↓

(D) Phase

PHASE

- 1-φ
- 3-φ
  Primary, Secondary
  or tertiary windings

Input Y / Δ output
Δ / Δ
Δ / Y
Y / Y

Primary side :- Input side (1°)
Secondary side :- Output side (2°)

$V_1, I_1, N_1, E_1 \rightarrow$ Primary $V_2, I_2 \rightarrow$ Secondary

$V_0, I_0 \rightarrow$ No load $\Rightarrow$ secondary current = 0

(G) 11 KV
(T) 132 KV (Distribution / Transmission)

CONSTRUCTION OF TRANSFORMER (Power transformer)

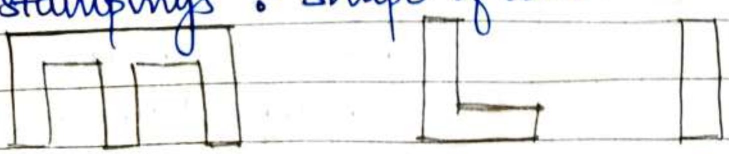
(i) core :- Mag material $\Rightarrow$ flux transfer (soft Iron) / CRGO ✓ / silicon steel
(ii) Winding :- Cu $\Rightarrow$ current transfer
(iii) Tank ~~(conservator)~~ (vi) conservator tank
(iv) Coolant / Insulating oil
(v) Bushings

Electronics Transformer
(i) core
(ii) winding

(A) CORE :- Iron core
Q Why not cast Iron $\rightarrow$ Hysteris losses.
core losses $\Rightarrow$ Hysteris & ~~Iron losses~~ Eddy losses

CRGO $\rightarrow$ Manufacturing Process
(Cooled Rolled Grained Oriented) $\Longrightarrow$ leakage flux ↓
Hysteris losses ↓

Stampings :- Shape of core



E   L   I   Silicon sheet

Shape.

Motor 80% η

(G) 60-90% η

CLASSTIME Pg No
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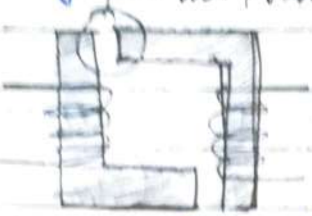
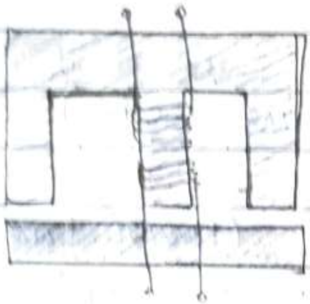
Q. Why E, I, I → ↓ Eddy current losses
→ air / vaccum → doesnot allow current



(no joints, only pressed together)
→ break the ckt of Eddy currents

core type transformer



Q. Why transformer is highly efficient device?

Less losses → friction losses ×
→ core construction
→ Hysteris loss ↓, due to Silicon.

Hysteris :- To lag behind (Greek word)

B Lags H → Number of turns × I ($n \times I$) ⇒ setsup ϕ
Mag-field

$H \times I$ ⇒ Magnetisum force

Q Eddy losses & Hysteris losses are const in nature. Explain. How to reduce

Date :- 27 Jan 2023

CONSTRUCTION OF TRANSFORMER :-

(i) core :- core loss → eddy + hysteresis loss
→ constant core
→ depend upon V, ν } O.C Test

(ii) Winding :- copper (conductor) → copper losses → I^2R losses
→ depends on current

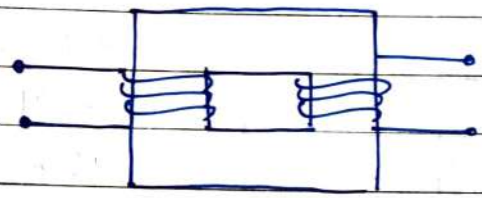
S.c Test { load, variable losses

Formula for Eddy losses :-

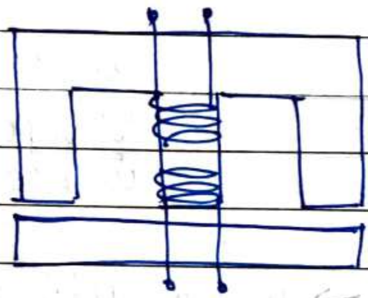
Hysteresis losses :-

Q. On the basis of construction, classify ~~core~~ transformer.

A:- core type :-



Shell type :-



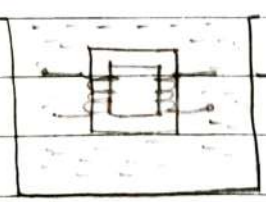
Q. Eddy losses are constant

It depends upon input supply V & ν ⇒ φ.
which is constant hence V & ν are constant in nature.

Stampings enhance Eddy losses.

open ckt test (No load test)

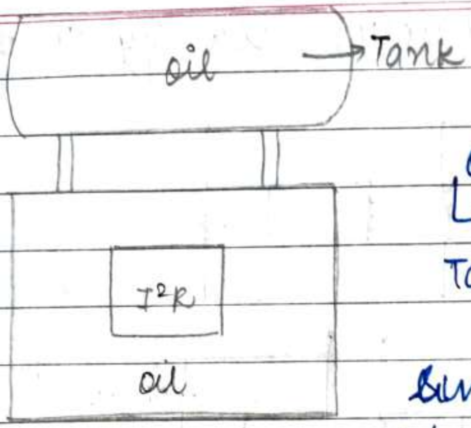
⇒ Conservator Tank (Insulating oil)



→ Al, Fe box / Tank

Insulation b/w Tank & TRM is req bcz eddy loss will transfer to Tank and hence loss ↑.
We use TFM oil (Insulating oil) ⇒ also provide cooling property

Heat losses) }
Ohmic losses)



oil heatup through I^2R losses
↳ vapours → go to conservator Tank ($T\downarrow$ than Tank) → liquify

Since V is same
V(vapour) = V(liq into tank)
into conservator tank.

In Hot region ⇒ forced cooling ⇒ fan (forced air draw cooling)
54°C ⇒ water sprinkler on fan.

Bushings
connecting insulating rings in output wires
no. of rings × 11 KV = output voltage.

Breathers (Dehydrator)
contains Si gel (Originally Blue colour) in duct to take oil samples (Blue → Pink either change oil or change oil).

Losses

The wattmeter reading gives total losses
but at no load, current losses are negligible
bcz I_0 = 0.2% of full load ckt.
$I\downarrow$ ⇒ SC losses$\downarrow$ ⇒ neglect them.
i.e open ckt test.

(W) → core + Cu
O.C cond^n → Cu losses ≈ zero → core losses measure

short
core
loss.

EMF

flux

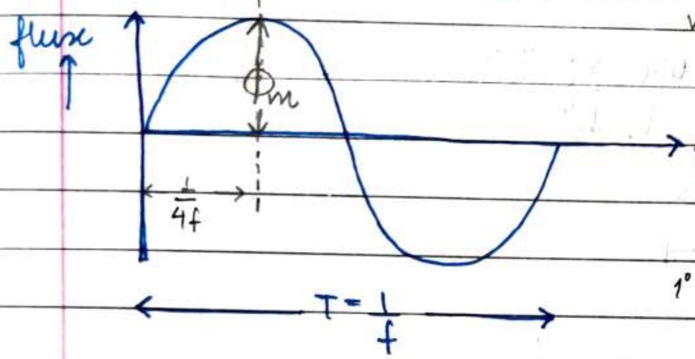
Avg
indu
Avg. e
for si
RMS V
of N_1
RMS V
of N_2

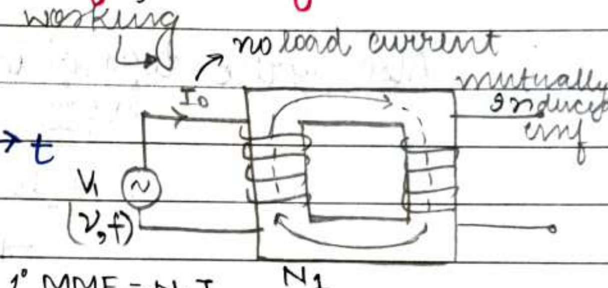
Transfor

Short ckt $\Rightarrow$ max I $\Rightarrow$ min voltage
core losses depends upon voltage $\approx$ negligible loss.

EMF ---- Equation of Transformers.

Derivation Imp 5-marks.





1° MMF = $N_1 I_0$
$\hookrightarrow$ Φ setup in core

Avg rate of change of flux $= \frac{0 - \Phi_m}{0 - 1/4f} \Rightarrow 4f\Phi_m$ Wb/s

induced emf = Rate of change of flux $= N\frac{d\Phi}{dt}$

Avg emf induced per turn $= 4f\Phi_m$

for sinosoidal flux $\rightarrow$ RMS value per turn $= 1.11 \times 4f\Phi_m$
$= 4.44 f\Phi_m$ Volt.

RMS value of induced emf in Primary winding of N_1 turns

$$\boxed{E_1 = 4.44 f N_1 \Phi_m} \quad \text{—— (i)}$$

RMS value of induced emf in secondary winding of N_2 turns

$$\boxed{E_2 = 4.44 f N_2 \Phi_m} \quad \text{—— (ii)}$$

Transformation Ratio (K)

$$\frac{E_1}{E_2} = \frac{N_1}{N_2} = \frac{1}{K} \Rightarrow \frac{E_2}{E_1} = \frac{N_2}{N_1} = K$$

for ideal transformer → 100% η → zero losses
V_1 supplied ~~=~~ E_1 generated $\propto$ E_2 generated $= V_2$ output

$$\frac{E_1}{E_2} = \frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{1}{K}$$

Also by the definition of TFM
$$V_1 I_1 = V_2 I_2$$
$$\frac{V_1}{V_2} = \frac{I_2}{I_1}$$

$$\boxed{\frac{E_1}{E_2} = \frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1} = \frac{1}{K}}$$

$K > 1 \Rightarrow N_2 > N_1 \Rightarrow$ Step Up transformer.

Q1. A 25KVA 1-ϕ TFM has $250 = N_1$ & $40 = N_2$. The primary is connected 1500 V, 50Hz mains supply. Cal I_1 & I_2, E_2, Max ϕ in core.

A1. Power $= V_1 I_1 = V_2 I_2 = 25\text{KVA} = 25000\text{VA}$
$N_1 = 250$, $N_2 = 40$
$E_1 = 1500$, $\nu_1 = 50$

$$\frac{N_1}{N_2} = \frac{I_2}{I_1} = \frac{V_1}{V_2} \Rightarrow \frac{N_1}{N_2} = \frac{V_1}{V_2}\left(\frac{E_1}{E_2}\right)$$

$$\frac{250}{40} = \frac{1500}{E_2}$$

$$E_2 = \frac{1500 \times 4\cancel{0}}{25\cancel{0}} = 15 \times 4 \times 4$$
$$= 240\text{ V}$$

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$25000 = 240 \times I_2 = 1500 \times I_1$

$I_2 = \frac{2500\cancel{0}}{24\cancel{0}} = 104.16\,A$

$I_1 = \frac{25000}{1500} = 16.6\,A$

$E_1 = 4.44\, f N_1 \phi_m$

$\frac{1500}{4.44 \times 50 \times 250} = \phi_m = 0.027\ Wb = 27\,mWb.$

Q. Max flux density in the core of a 250/3000V 50Hz 1φ transformer is 1.2wb/m². If the emf per turn is 8V. Det secondary & Primary turns & Area of core.

$4 f \phi_m \times 1.11 = 8V$

$4.44 \times 50 \times \phi_m = 8$

$\phi_m = \frac{8}{4.44 \times 50} = 36\ mWb.$

$\frac{\phi}{Area} = \frac{36 \times 10^{-3}}{Area} = 1.2$

$Area = 30 \times 10^{-3}\ m^2 \Rightarrow 3 \times 10^{-2} m^2$

$250/8000 \Rightarrow E_1 = 250,\ E_2 = \cancel{8}3000$

~~$\frac{\phi}{Area} = B_m \Rightarrow \phi = B \times Area$~~

$E_1 = 4.44\, f N_1 \phi_m$

$250 = 4.44 \times 50 \times 36 \times 10^{-3} \times N_1$

$N_1 = \frac{25\cancel{0} \times 10^3}{4.44 \times 5\cancel{0} \times 36} = 0.03128 \times 10^3 = 31.28 \cancel{=}$

$N_1 \approx 32$

$E_1 = 250 \quad E_2 = 3000$

$N_1 = 32 \quad N_2 = ?$

$$\frac{E_1}{E_2} = \frac{N_1}{N_2} \Rightarrow N_2 = \frac{N_1 \times E_2}{E_1} = 384 \text{ turns.}$$

$\frac{I_2}{I_1} \Rightarrow$

Q. What will happen if TFM 1° is supplied by DC supply.
flux will be setup but not alternating in nature ⇒ MMF DC in nature ⇒ no E_2.
Eventually primary winding will burn with heat losses.

(a)
(b)
(c)
(d)

(a)
(b)
(c)

$Z_1 = R_1 + jX$
$Z_2 = R_2 + jX_2$

Date :- 28 Jan 2023

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EQUIVALENT CIRCUIT

Ideal transformer 100 η%. Zero losses

assumptions

(a) × core losses (Hysteresis & Eddy)

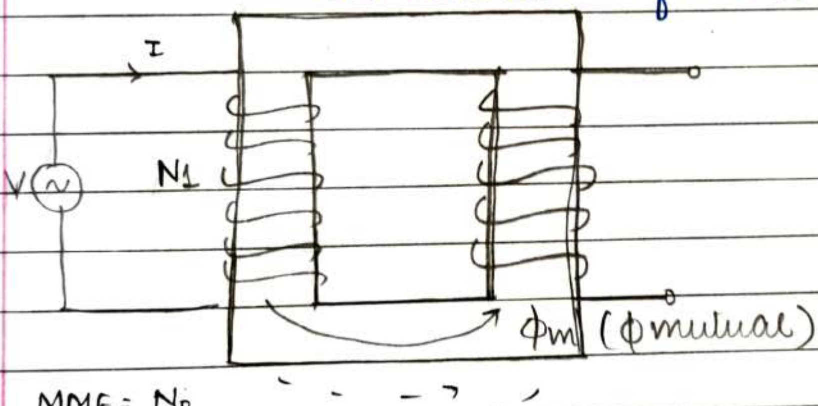
(b) × Ohmic losses (Cu losses, I^2R losses)

(c) No leakage flux

(d) 100% permeability $B = \mu H$

$H = N \times I$ (No. of turns × current)

all current → flux setup (no wastage)

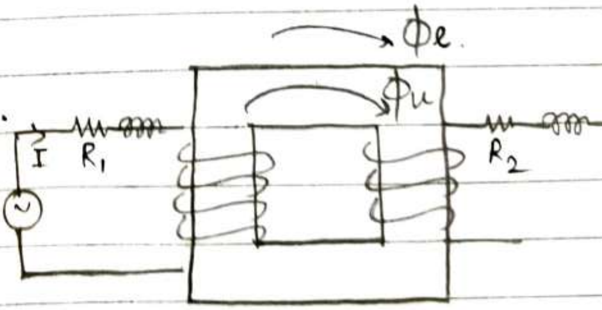


MMF = N_0

$\phi_{leaking}$ ⇒ no contribution in emf

Practical Transformer

η = 95%. time = 50 years.



(a) ✓ core losses

(b) ✓ ohmic losses ($I^2R_1 + I^2R_2$)

(c) Leakage ϕ

$\phi_{Total} = \phi_{useful} + \phi_{leakage}$

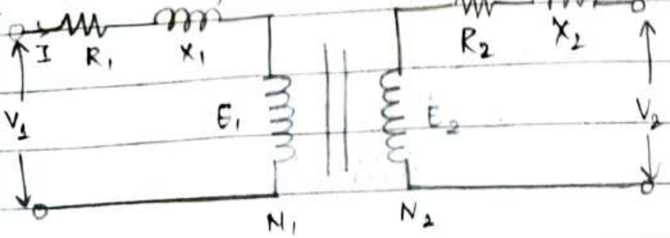
$100\% = 95\% + 5\%$

↳ x reactance

leakage Voltage drop or leakage reactance.

$Z_1 = R_1 + jX_1$

$Z_2 = R_2 + jX_2$



no load eq. ckt

R_1 = Primary winding resistance

X_1 = 1° Leakage Reactance

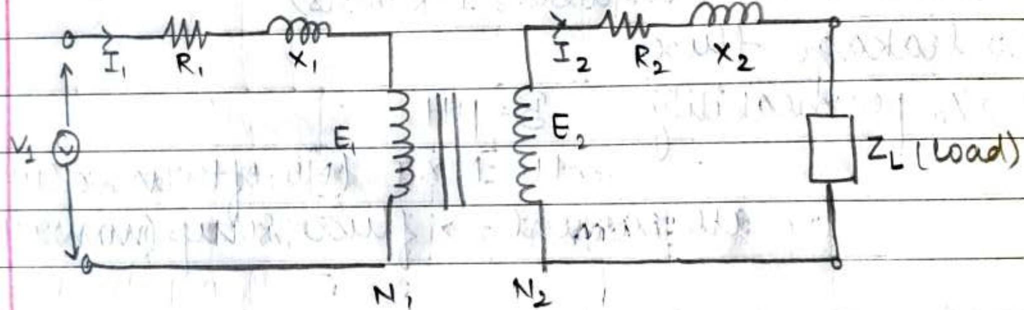
V_2 = 2° Terminal V

E_2 = 2° Induced EMF

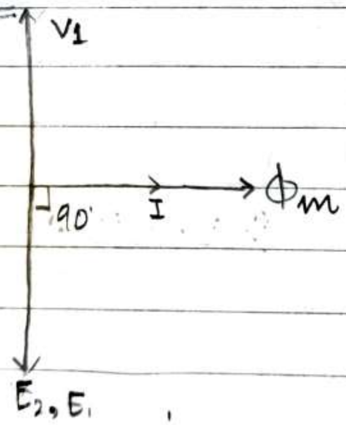
Phasor Diagram

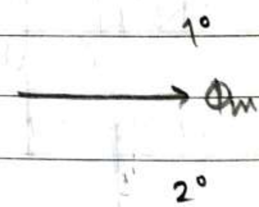
– on NO LOAD CONDITION

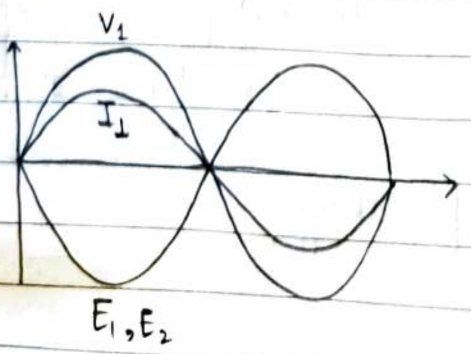
Equivalent ckt at LOAD CONDITION



PHASOR:- No load







For Resistive Load

$V_1 = -E_1$

at no load

$I_0 = 2\text{-}10\%$ of I_{full}

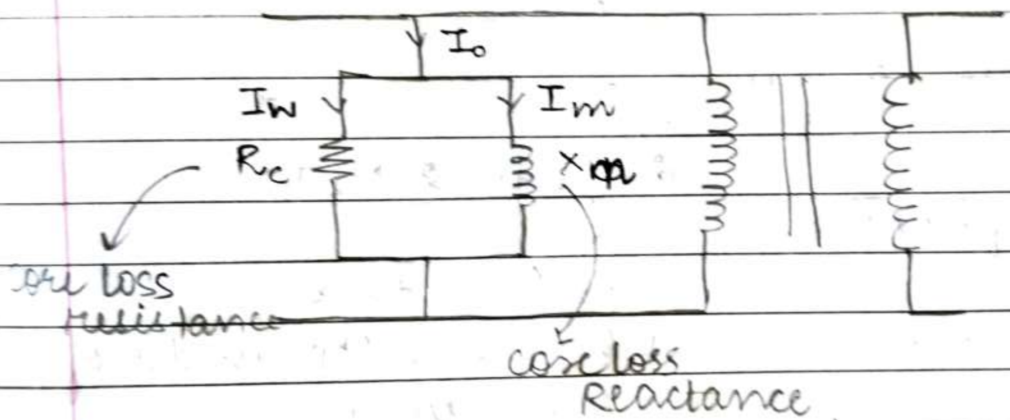
$\Rightarrow$ neglect ohmic losses

$\Rightarrow$ × —WW— R

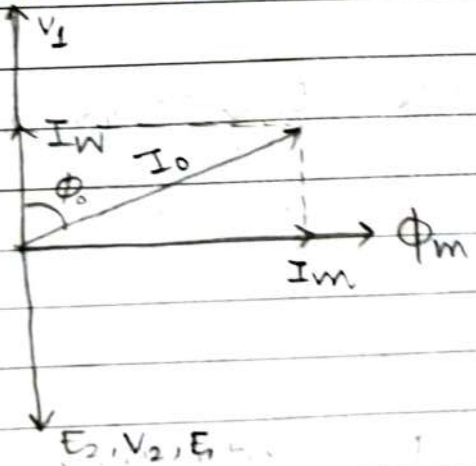
$I_0 \rightarrow \phi_m$ mutual flux maintaunce (I_m) (Magnetising component of no load current)

$\hookrightarrow$ ~~current~~ core losses (I_W) (core loss component)

$$\boxed{\vec{I_0} = \vec{I_m} + \vec{I_W}}$$



TFM with core loss at no load

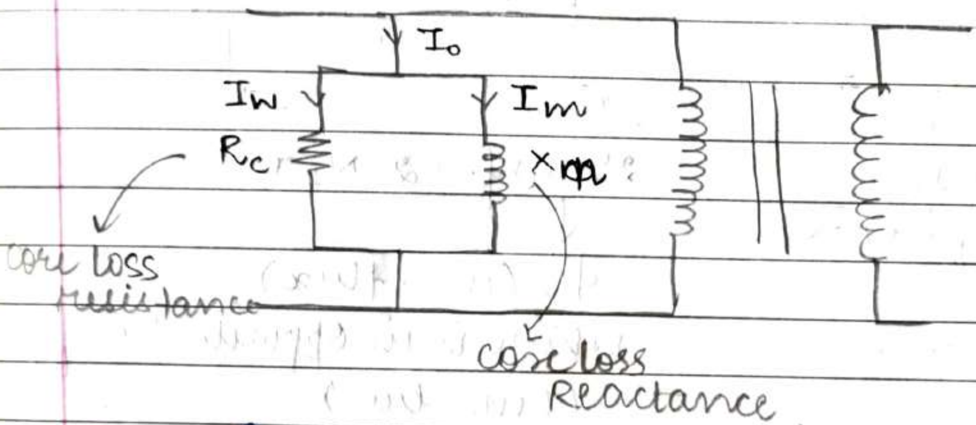


ϕ_0 = no load power factor

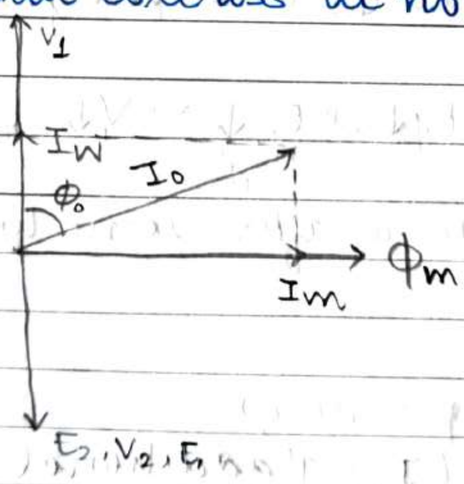
$I_0 \rightarrow \phi_m$ mutual flux maintaince (I_m) (Magnetising component of no load current)

↳ ~~current~~ core losses (I_w) (core loss component)

$$\boxed{\vec{I_0} = \vec{I_m} + \vec{I_w}}$$



TFM with core loss at no load



ϕ_0 = no load power factor.

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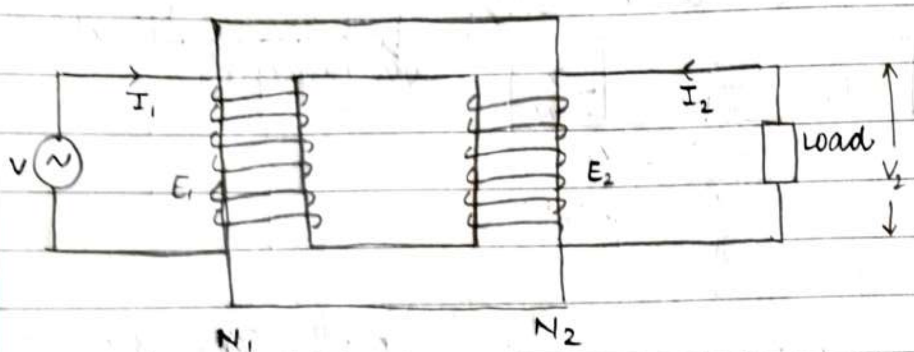
Date : 1 Feb-2023

TRANSFORMER ON LOAD



1° MMf = $N_1 I_1$
(to setup a flux)

2° mmf = $N_2 I_2$
$\downarrow$
ϕ_2 (own flux)
which is in opposite dir of ϕ_m
(Lenz law)

Net → less flux hence ϕ_2 is demagnetising flux.

$$\downarrow\phi \Rightarrow \downarrow\frac{d\phi}{dt} \Rightarrow E_1\downarrow \;\&\; E_2\downarrow \Rightarrow V_1\downarrow = E_1\downarrow$$

which is not possible as after some time $E_1 = 0$

* Loop Hole *

$\boxed{I_2 = I_1'}$ (load compensator)

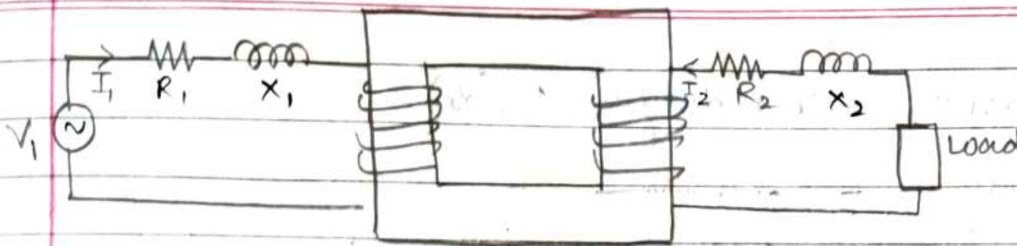
$\boxed{\vec{I_0} + \vec{I_1'} = \vec{I_1}}$ (I_1' = 1° additional current)

$\downarrow$
no load current

$I_0 \rightarrow \phi_m$ & $I_1' \rightarrow \phi_2'$

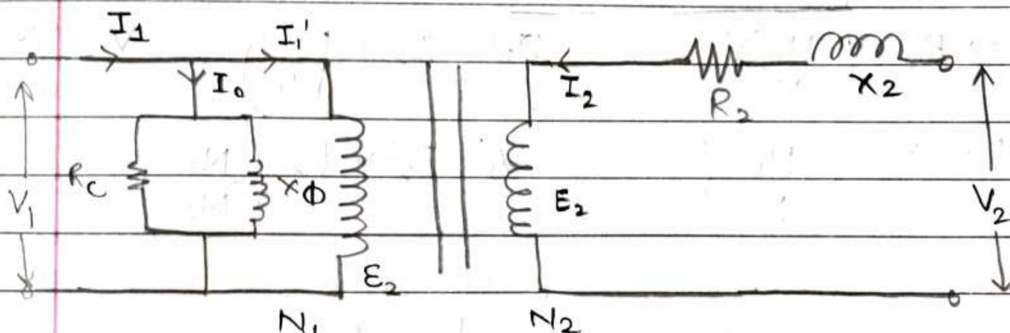
$I_2 \rightarrow \phi_2$

$I_1' = I_2 \Rightarrow \phi_2' = \phi_2$



const.
working
EMF eqn
Numerical
Phasor

$X_C \rightarrow$ core reactance
$R_C \rightarrow$ core loss Resistant



Equivalent ckt for on load condition

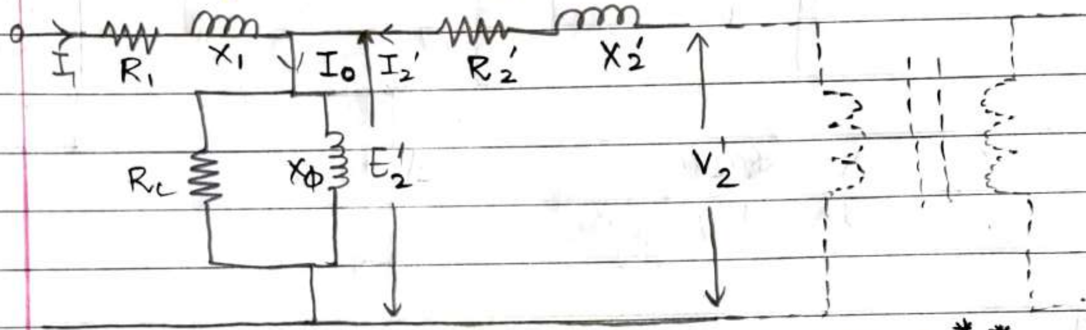
secondary terminal voltage

$$\boxed{\vec{E_2} = \vec{V_2} + \vec{I_2}(R_2 + jX_2)}$$ secondary voltage eqn

$$\boxed{\vec{V_1}\ \cancel{\vec{E}} = \vec{I_1}\underbrace{(R_1 + jX_1)}_{1^\circ \text{ ohmic loss}} + \vec{E_1}}$$

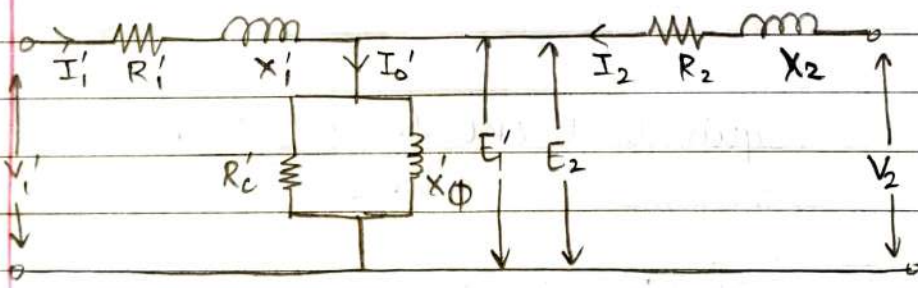
stray losses:- extra losses
cu losses :- I_2 dependent
flux leakage losses:- X_2, X_1 to compensate.
core losses:- V, ν ~~losses~~ dependent.

Referred to 1°
(Primary & secondary in 1° side)



$R_2' \Rightarrow R_2 \cdot \left(\frac{N_1}{N_2}\right)^2$ → jiski side, → jaha se $I_2' = I_2\left(\frac{N_2}{N_1}\right)$ ** $V_2' = V_2\left(\frac{N_1}{N_2}\right)$

$X_2' = X_2 \cdot \left(\frac{N_1}{N_2}\right)^2$ ∀ $E_2' = E_2\left(\frac{N_1}{N_2}\right)$



∀

Referred to 2°

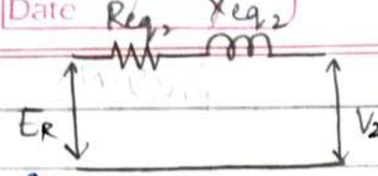
$V_1' = V_1 \cdot \left(\frac{N_2}{N_1}\right)$; $R_1' = R_1\left(\frac{N_2}{N_1}\right)^2$

$I_1' = I_1\left(\frac{N_1}{N_2}\right)$; $X_1' = X_1\left(\frac{N_2}{N_1}\right)^2$

R_{eq_1} :- R equivalent 1° = $R_1 + R_2'$
X_{eq_1} :- X equivalent 1° = $X_1 + X_2'$

voltage Regulation :- (Ideal VR = 0)

$\vec{E_2} - \vec{V_2} = 0$
no load on load



V no load = V on load $\Rightarrow \vec{V_2} = \vec{E_2}$

$$\vec{E_2} = \vec{V_2} + \underbrace{(I_2(R_2 + jX_2))}_{=0 \text{ but not possible}}$$

Defⁿ :- At constant supply voltage, the change in 2° terminal voltage from no load to full load wrt no load voltage is called voltage Regulation of transformer.

$$\boxed{\frac{E_2 - V_2}{E_2} = \text{voltage Reg}}$$

$$\% VR = \frac{E_2 - V_2}{E_2} \times 100 \qquad \{\text{Large } VR = \text{Poor } VR$$

Date :- 3 Feb 2023

PHASOR DIAGRAM

Actual Transformer on load :-
(with magnetic load and winding resistance)

$\vec{I_0} = \vec{I_C} + \vec{I_W}$

$I_1' = I_2$

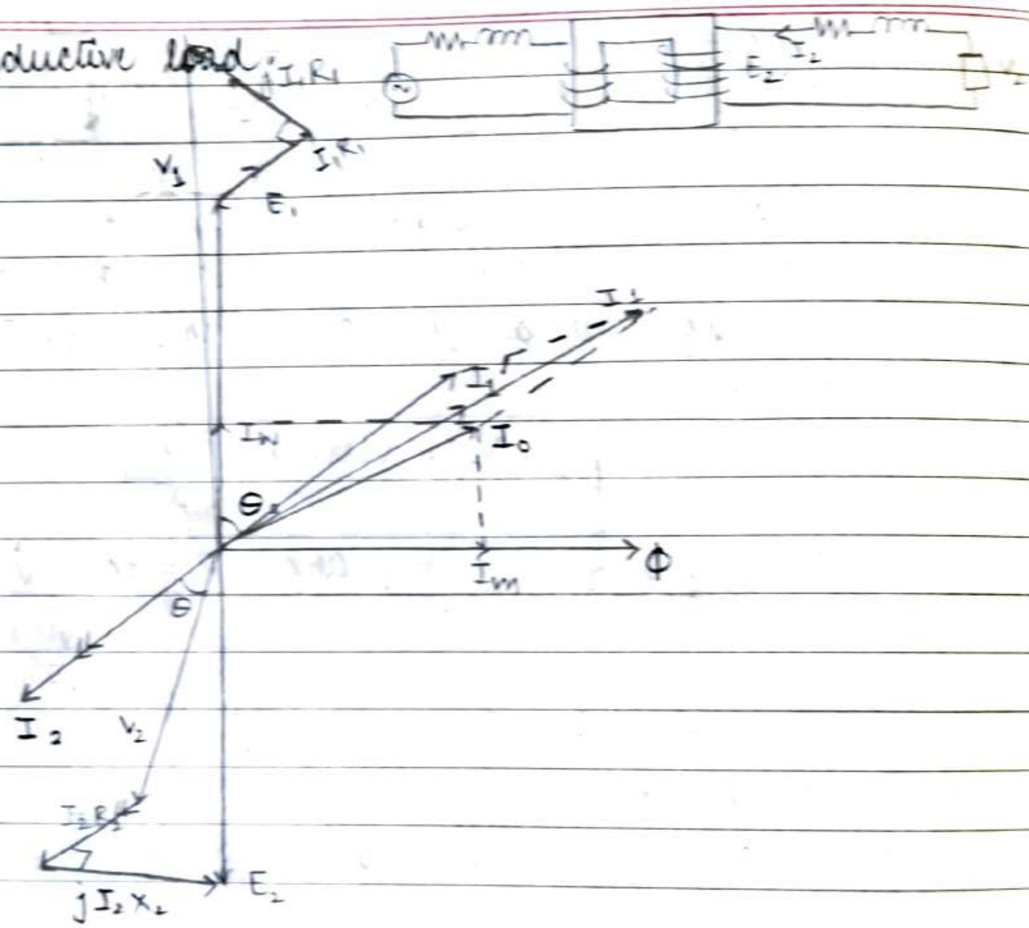
$\vec{I_1} = I_0 + I_1'$

$E_2 = V_2 + I_2 Z_2 \qquad (Z_2 = R_2 + jX_2)$

$V_1 = E_1 + I_1(R_1 + jX_1)$

:-

Inductive load

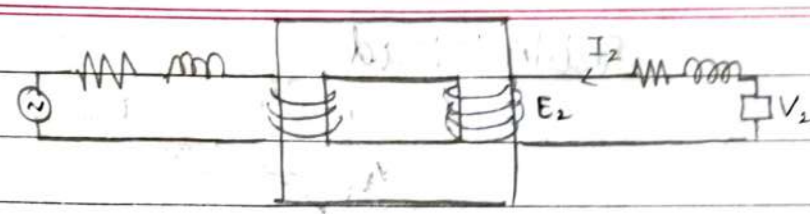


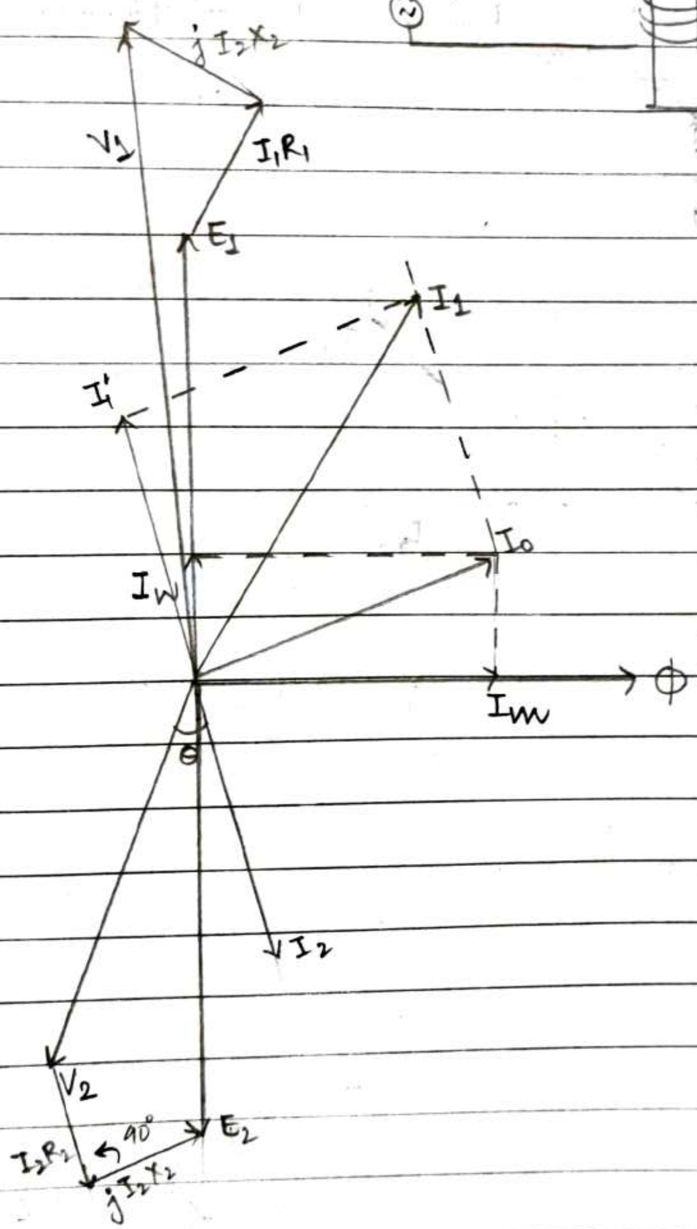
→ I_2 lags V_2 for Inductive load

→ $E_2 = V_2 + I_2 Z_2$

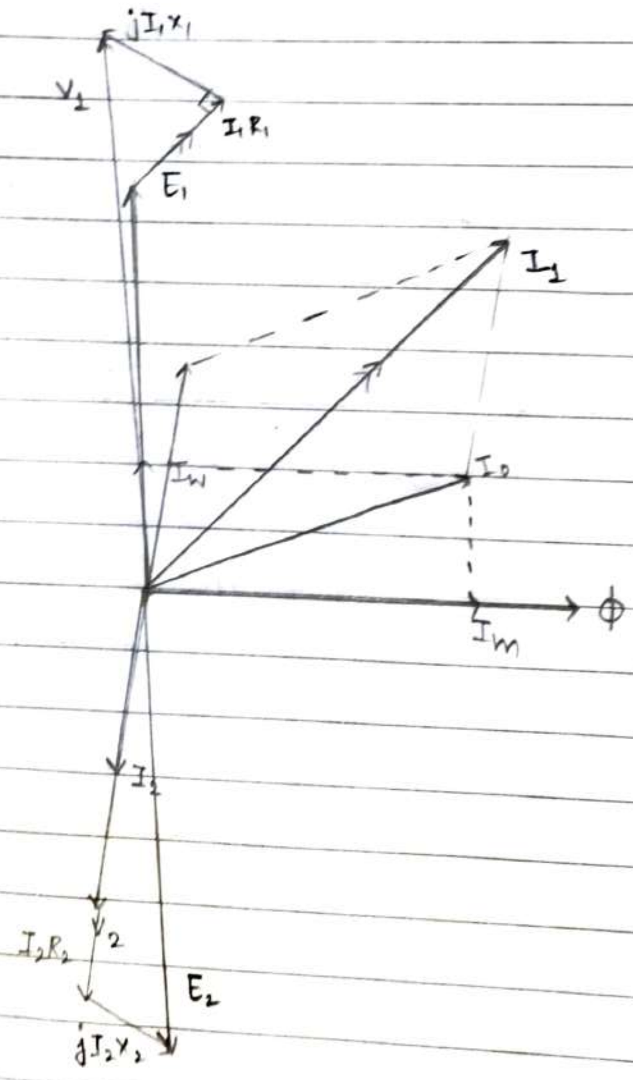
Neglect leakage losses:- neglect X_1 & X_2

Capacitive Load





Resistive Load.



Efficiency

$$\eta = \frac{\text{Output power}}{\text{Input power}} = \frac{\text{Output Power}}{\text{Output Power + losses}}$$

If x is fraction of full load ; $\eta = \dfrac{\text{Output Power}}{\text{Output Power} + \text{Power loss}}$ (full load)

Power loss → Cu, core

$P_{cu} = I_2^2 R_{eq_2}$ Output Power $= V_2 I_2 \cos\phi_2$

P_{core} / P_{Iron}

$R_{eq_2} = r_2 + r_1'$

$$\boxed{\eta_{(x)} = \frac{x V_2 I_2 \cos\phi_2}{x V_2 I_2 \cos\phi_2 + P_i + x^2 P_{cu}}}$$

For η to be max

$$\frac{d\eta}{dI_2} = 0$$

at full load $P_I = P_{cu}$

at x load $P_i = x^2 P_{cu}$

Iron loss $= x^2$ Cu losses

$$x = \sqrt{\frac{P_i}{P_{cu}}}$$

Output KVA for max η = $x \times$ ~~too~~ full load KVA

$= \sqrt{\dfrac{P_i}{P_{cu}}} \times$ full load KVA

OC & SC test :-

→ All day efficiency

It is the ratio of $\frac{\text{output power in KWh}}{\text{Input power}}$ → Energy unit

* Voltage Regulation

$$E_2 - V_2 = I_2 r_{eq_2} \cos\theta_2 + I_2 x_{eq_2} \sin\theta_2$$

$\cos\theta$ → Load power factor

Per unit voltage R. $= \frac{I_2 r_{eq_2} \cos\theta_2}{E_2} + \frac{I_2 x_{eq_2} \sin\theta_2}{E_2}$

$= \varepsilon_r \cos\theta_2 \pm \varepsilon_x \sin\theta_2$ Inductive + capacitive −

$\varepsilon_r \cos\theta_2$ ↓ per unit resistive drop

$\varepsilon_x \sin\theta_2$ ↓ per unit ~~inductive~~ reactance drop

$$\varepsilon_r = \frac{I_2 r_{eq}}{E_2} \qquad \varepsilon_x = \frac{I_2 x_{eq_2}}{E_2}$$

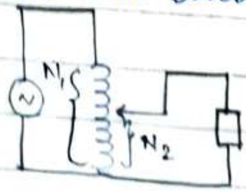
$$\% VR = (\varepsilon_r \cos\theta_2 \pm \varepsilon_x \sin\theta_2) \times 100$$

condition for zero voltage Regulation

(i) load power factor is leading (capacitive load)

Auto-transformer (variac)

A transformer in which a part of the winding is common to both the primary & secondary circuit. In autotransformer two windings are not electrically isolated



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Date / /

On load, a part of the load current is obtained directly from the supply & remaining part is obtained by transformer action.

Autotransformer is stepdown transformer.

Date : 8 Feb 2023

3 unit Measuring Instruments

* which measures. Power, wattage, voltage, current. energy, etc.

→ Wattmeter
→ Voltmeter
→ Ammeter
} Analogue only.

Q. Essential Req of Electrical Instruments

Measuring Instruments

Absolute M.I

Measuring qty $\propto$ constt

Eg:- Tangent Galvanometer

$V \propto \tan\theta$

syllabus

Secondary MI

Measured qty $\propto$ Deflection (moving part)

Indicating

deflection of needle points measured qty

→ Ammeter
→ Voltmeter.

syllabus

Integrating

Integrating diff characteristics of ckt.

→ Energy meter (Induction type)

Recording

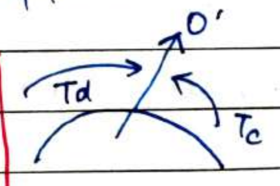
Recording the readings of Indicating & Integrating type devices

→ All indicating type can be converted into recording type.

Q. Essentials of Measuring Instrument (3-5 marks)

A1.

(a) Deflecting Torque (T_d)	(b) Controlling Torque (T_c)	(c) Damping Torque
→ moving needle from stationary to measured value → Torque can be due to magnetic, chemical force, etc. → Magneto-type Ammeter → using magnetic force → Induction type Energy meter → using faraday law of induction.	when measured force is removed, pointer should come back to zero & to stabilise the pointer at reading controlling Torque (Equal to Deflection Torque but in opposite dir)	vibration/ oscillations at measuring value which is due to inertia hence Damping Torque minimises this oscillation

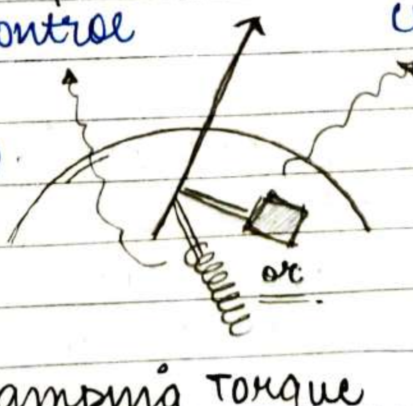


Methods to produce controlling torque

(a) Spring control ($T_c \propto \theta$)

(b) Weight Control ($T_c \propto mg$)

($T_c \propto \sin\theta$)



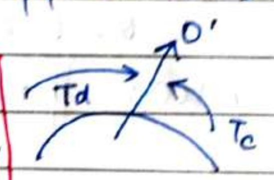
Types of Damping Torque

(a) Eddy current	(b) Fluid friction	(c) Oil damping
opposite eddy current to absorb vibrations/ oscillations. Placed ...	Instrument kept in air in chamber	chamber placed in oil

Q. Essentials of Measuring Instrument (3-5 marks)

A1.

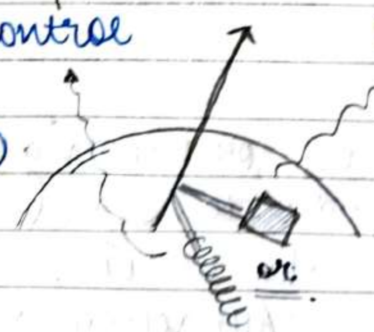
(a) Deflecting Torque (T_d)	(b) Controlling Torque (T_c)	(c) Damping Torque
→ moving needle from stationary to measured value → Torque can be due to magnetic, chemical force, etc. → Magneto-type Ammeter → using magnetic force → Induction type Energy meter → using faraday law of induction.	when measured force is removed, pointer should come back to zero & to stabilise the pointer at reading controlling Torque (Equal to Deflection Torque but in opposite dir)	vibration/oscillations at measuring value which is due to inertia hence Damping Torque minimises this oscillation



Methods to produce Controlling torque

(a) Spring control
($T_c \propto \theta$)
($T_c \propto \sin\theta$).

(b) Weight Control
($T_c \propto mg$)



Types of Damping Torque

(a) Eddy current	(b) Fluid friction	(c) Oil damping
opposite eddy current to absorb vibrations/oscillations. Placed on spirals.	Instrument kept in air in chamber	chamber placed in oil

$\perp$ vertical position $\sqcap$ Horizontal position

Date :- 10 Feb 2023

CLASSTIME Pg. No.
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MEASURING INSTRUMENTS

- Moving iron type
  - Attraction type
  - Repulsion type
- Moving coil Type
  - PMMC (V & A)
  - Dynamometer type (wattmeter)

Q Difference b/w voltmeter & Ammeter.

→ coil 50 mA & 50 mV → extend the range.

Voltage → connect ~~Shunt~~ multiplier in ~~||el~~ Series

Ammeter ↔ connected ~~multiplier~~ Shunt in ~~Series~~ ||el

LOGIC :-

More current we need to measure → R↓ → connect in parallel (FORMULA) or thick wire

Shunt ~~is~~ means parallel.

More voltage → More R → In series or thin wire.

Deflecting Torque is due to Current

~~Current~~

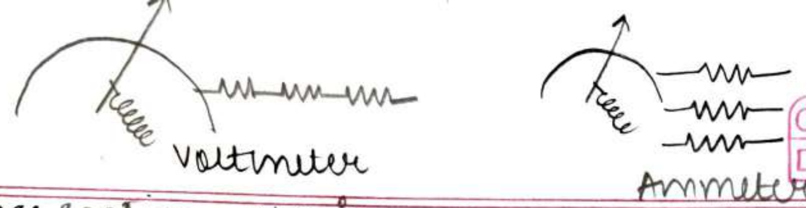
Q. Diff b/w Moving Iron or moving coil ⊛

A. Needle movement ⇒ due to Iron → Moving Iron
  → due to coil → Moving coil

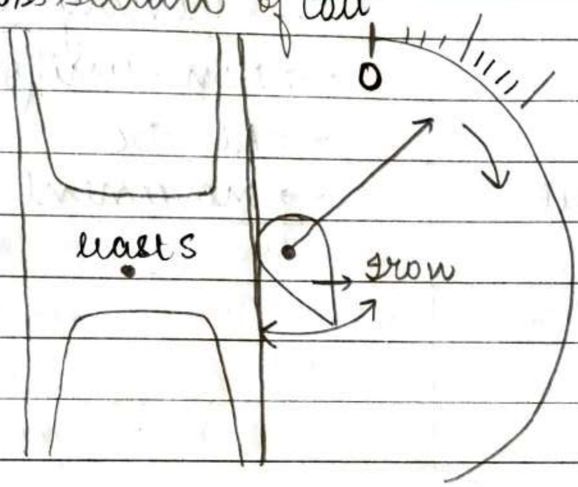
Iron → Magnetism → Attractive & Repulsive force.

MOVING COIL TYPE :-

Attraction type :-



cross section of coil



current carrying coil produces magnetism

Moving iron attracts towards the center of coil.

deflection → Iron → attraction → Magnetism → current
($B \propto I$)

Reluctance ~ Resistance
(S) ↳ Opposition the flow of Magnetism

Principle: when a soft iron piece is placed in the M.F of a current carrying coil it is attracted towards center of the coil because center of coil is the point of Min Reluctance.

Advantage :-
(a) Cheap
(b) Simple
(c) Both AC & DC. $\sim$

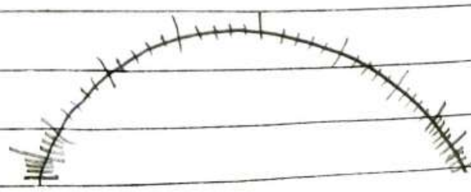
$$\boxed{\begin{gathered}\theta \propto I^2 \\ T_d \propto I^2\end{gathered}}$$

$T_c = T_d$

$T_c \propto \theta$

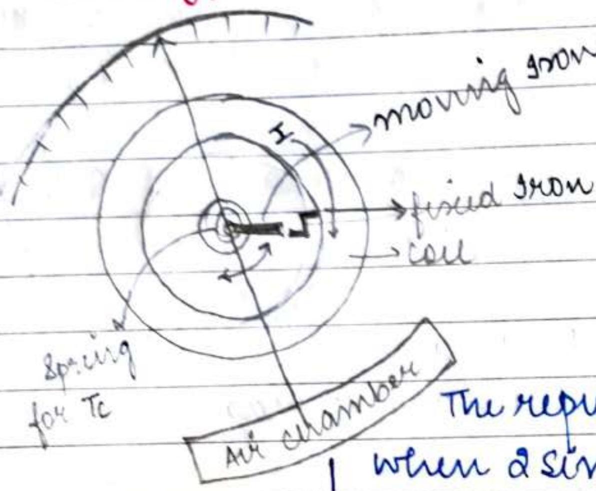
$\theta \rightarrow$ deflection

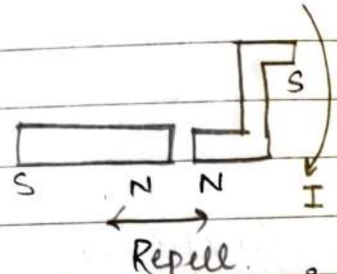
→ non-uniform scale.



Moving Coil	Moving Iron
→ Uniform scale	→ Non-uniform Scale.
→ Only DC	→ AC - DC
→ Movement due to Coil	→ Movement due to Iron

Repulsion type :-





The repulsive forces will act when 2 similarly magnetised Iron pieces are placed near to each other.

PMMC Type :-

Permanent Magnet Moving Coil Type :-

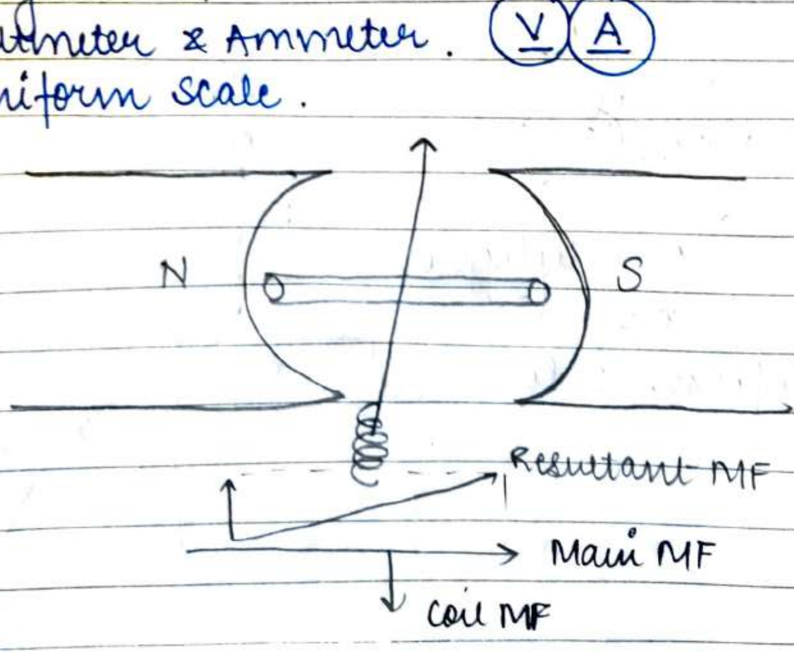
Characteristics

(a) Sensitive & accurate

(b) Only on DC.

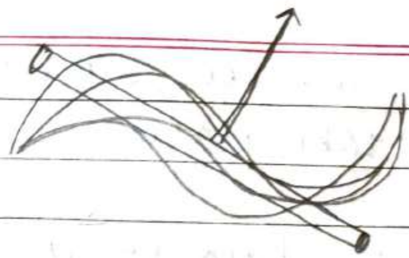
(c) Voltmeter & Ammeter. V A

(d) Uniform Scale.



Permanent Magnetic field
V
MF due to I
↓
Net MF

Speed $\propto$ poles.



Pointer → coil → Resultant MF → 2MF → Field due to coil → I

**

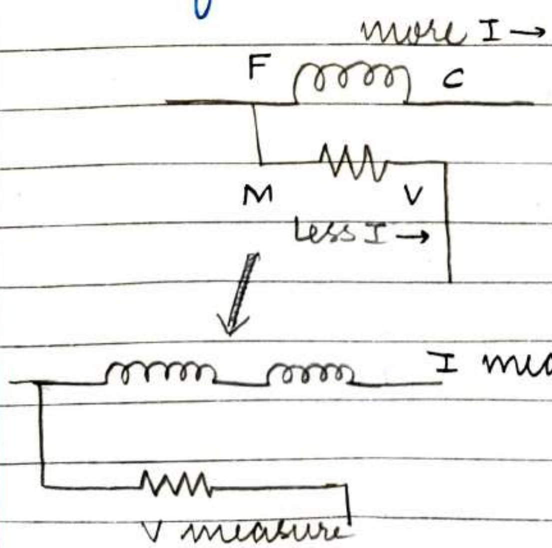
When a current carrying coil is placed in a uniform MF, it experiences a MForce → τ

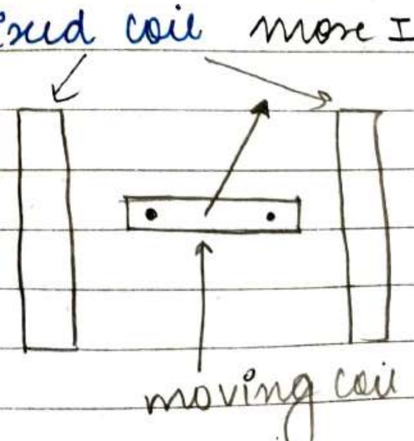
Main field N → S
(~) S → N & N → S } ⟹

If current in the coil is reversed, the dir of deflecting Torque will be reversed bcz field produced by Permanent Magnet does not change. This will give wrong dir of rotation.

$$\boxed{\theta \propto I}$$

DYNAMOMETER TYPE :-
(moving coil type)
(used for wattmeter only).





When a current carrying ~~MF~~ M.coil is placed in MF produced by the current carrying fixed coil, A force is exerted on the coil sides of the moving coil & deflection takes place.

In other words, when the field produced by the current carrying moving coil tries to come in line with the field produced by the current carrying fixed coil. A deflecting torque is exerted on the moving sys & deflection takes place.

The fixed coil is connected in series with the load & carries ckt current. Therefore it is called current coil.

The moving coil is placed b/w the 2 parts of fixed coil & is mounted on spindle. The moving coil is connected in IIᵉˡ with load & carries the current proportional to voltage. Therefore it is called potential coil.

an added battery w load
E_c, incoming I_a

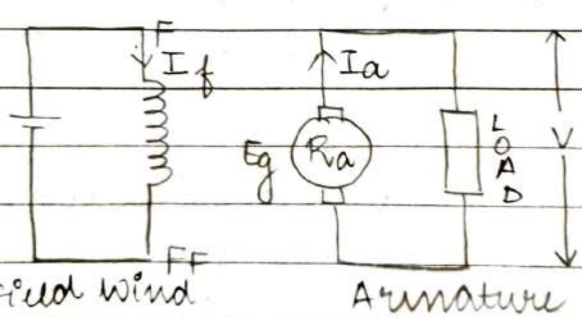
DC MACHINES

→ Motor (Elec → Mech)
→ Generator E_g (Mech → Elec) outcoming I_g

Construction
Principle
Working
Speed control of Shunt / Service Motor.

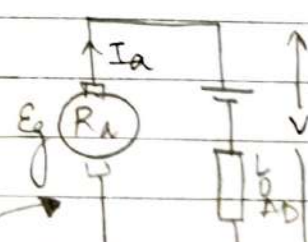
DC Machines

- Separately Excited DC machines
  - Field winding (generate flux)
  - Armature part (rotating part)
- Self Excited DC machines (current from machine)
  - ~~Simple~~ ~~Source~~ Series
  - Shunt
  - Compound
    - → Long Shunt
    - → Short Shunt
    - → differentially comp.
    - → cummulative compound



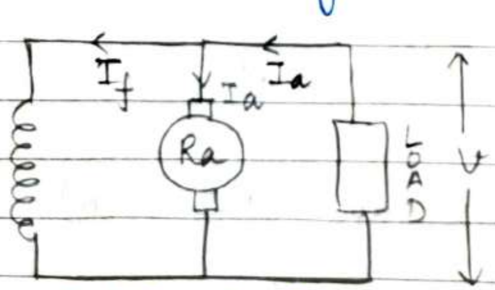
Field wind Armature

Current carrying coil ⇒ M Flux



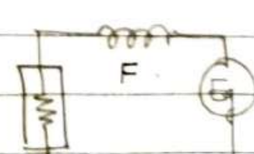
for Motor

V terminal voltage (Motor → Input, Generator → Output)

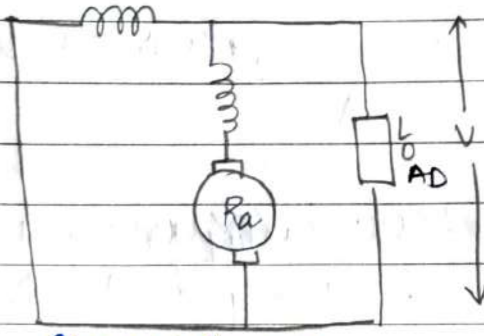


Self Excited (Shunt)

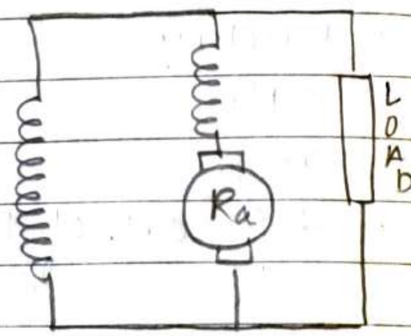
Series :-



Compound



Short Shunt

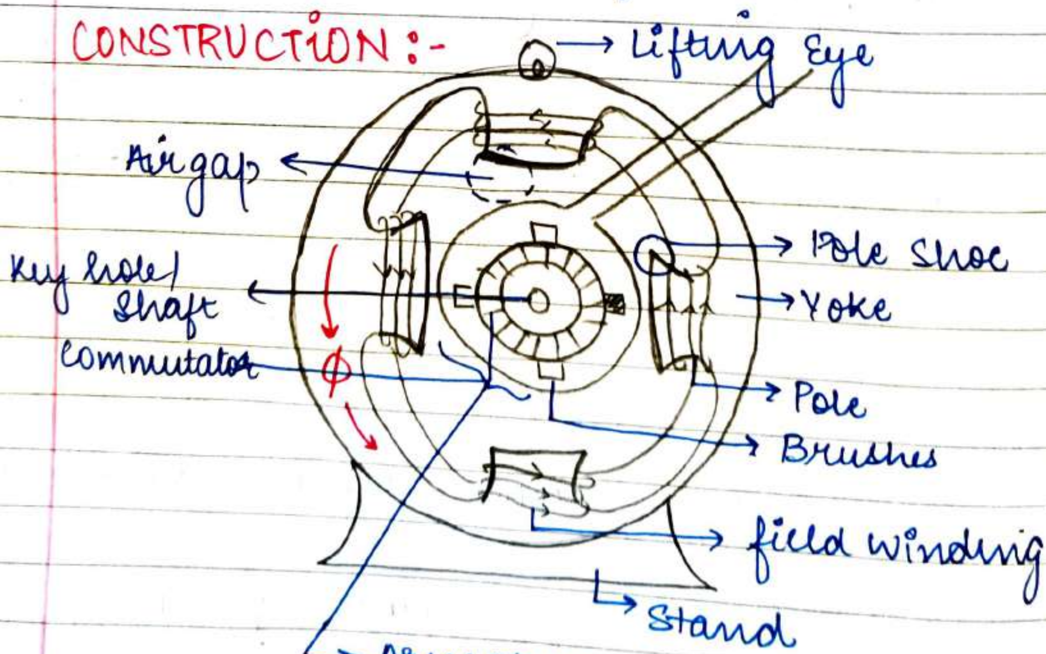


Long Shunt

⟹ Differentially compound :- Net flux of both coils is subtraction of each flux (joined in opposite direction)

⟹ Cummulative :- both coil has supporting field so net field is addition of both.

CONSTRUCTION :-



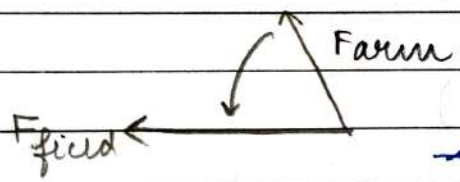
4 pole :- 4 pole DC machine (even no)

Yoke :- carry flux(magnetic material

made up of soft Iron, frame of DC machine,

Field winding (in series) is connected on pole & supply ϕ in Air gap.

Current carrying coil ~~produces~~ in MF → experience a force.
(Armature :- own MF, field winding :- own MF
FW > A ⇒ Substract)

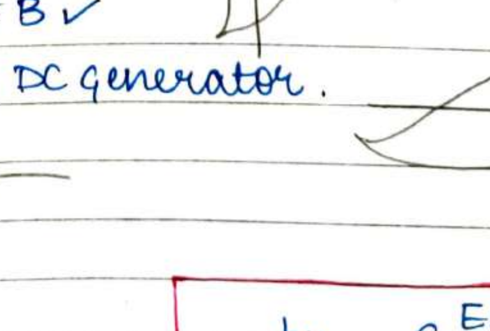


Armature will try to allign with MF → Armature Rotate → cut flux → $\frac{d\phi}{dt}$ → emf → produces current → own MF, interact with field winding MF → try to allign & so on.

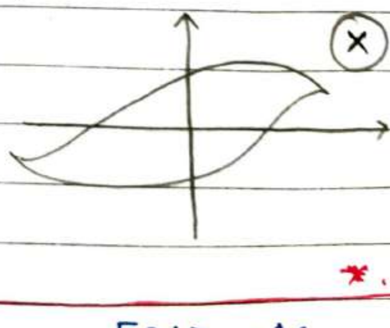
Commutator :- ~~SSP~~ split/slip rings + brushes (Rectifier for DC machine)

→ Residual magnetism
Retentivity

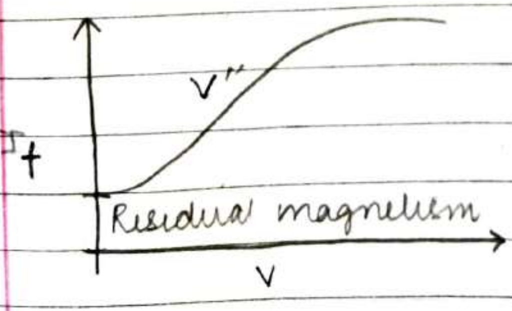
H = NI = 0
But B ✓



for core of DC Generator



Used to start DC generator.

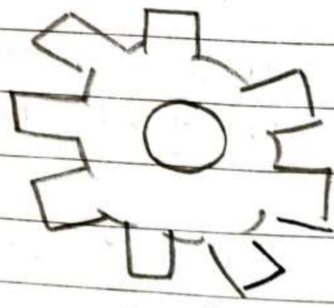


by commutator { EMF → AC
Current → DC

EMF equation for DC Generator.

$$\boxed{= \frac{\phi Z N}{60} \frac{P}{A} \text{ volts}}$$

P = No. of poles
ϕ = flux produced by each pole. (Wb/Pole)
N = Speed of Armature in RPM
Z = Total no. of Armature conductors
A = No. of parallel paths.
A = P (Lap winding)
A = 2 (Wave winding)



Inside Armature.

Date :- 15 Feb 2023

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AC Machines

AC Machines → Generator
→ Motor

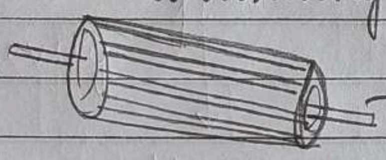
Inductive Machine $(N < N_{syn})$
→ singly excited machine (Input to stator only)

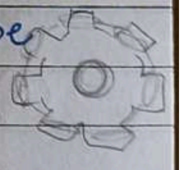
- 1-Φ Inductive Motor (domestic supply)
  (upto 3HP)
  not self starting
  → capacitor :- to start & to enhance cos Φ.
- 3-Φ IM
  (upto > 3HP)
  "self starting"

Synchronous Machines $(N = N_s)$
→ Synchronous Generator / alternator
50Hz, 11KV
→ Doubly excited Mach (alag input to stator & Rotor)

$N_s = \frac{120 f}{P}$ in RPM P → Poles
f → power frequency

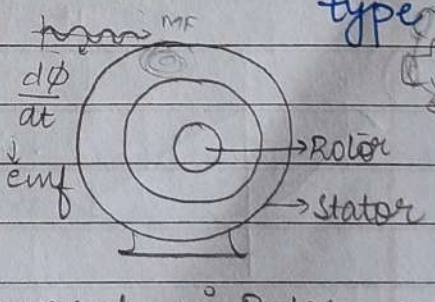
$\boxed{1\text{-}\Phi\ \text{I.M}}$ → construction Rotor → Squirrel cage type (slant - reduce humming)
→ Round wound type
no winding ⇒ Al / Cu bars





$\boxed{3\text{-}\Phi\ \text{I.M}}$ → Rotor
→ Stator

Induction 3Φ



MF in stator → $\frac{d\phi}{dt}$ → emf → current in Rotor →
own MF → resultant (main field > Rotor field) →
Try to align w main field.
Stator is running at N_s (f is 50Hz)
Rotor (w capacitor) $N < N_s$

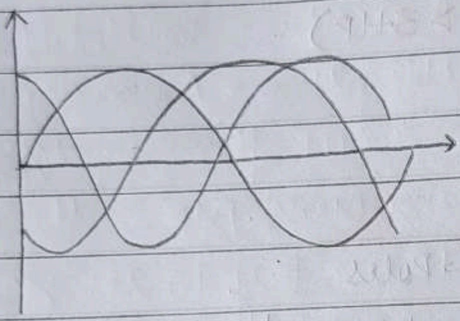
CLASSTIME Date / / Pg.No.

If $N = N_s \Rightarrow$ relatively stationary $\rightarrow$ rotor w.r.t stator

Slip :- $N_s - N$ (kitna piche rotor)

$$\%S = \frac{N_s - N}{N_s} \times 100$$

3-ϕ field $\rightarrow$ Revolving field



120° ϕ diff $\Leftrightarrow$ no neutral