

11-05-2021

DC - Circuits ...

current :-

$$i = \frac{dq}{dt}$$

rate of
change of current (or) controlled

→ Units A (ohm) C/s

moment of
charge

voltage :-

V = Work required to move charge.

$$V = \frac{dw}{dq}$$

J/s (ohm) Volts

Power :-

$$P = \frac{dw}{dt}$$

$$= \frac{dw}{dq} \cdot \frac{da}{dt} = Vi \text{ J/s (ohm) Watts}$$

→ resistance :-

At constant T, $V \propto i$:- By Ohm's law

$$V = iR.$$

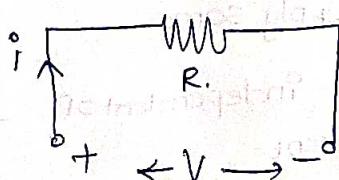
R = Resistance (ohm) Ohm's

constant

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

G = conductance

$$i = GV$$



Short circuit = $R = 0 \Rightarrow$ practically small resistance
 $\downarrow V = 0$

Open circuit = $R = \infty$

$$R \propto \frac{P}{A}$$

$$R = \frac{Pl}{A}$$

P = specific resistance

(O) resistivity.

→ short circuit

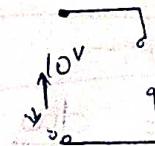
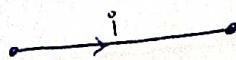
Open circuit

→ voltage is zero

→ voltage exists

→ current is infinite

→ current is zero



Types of sources

depending

Independent source

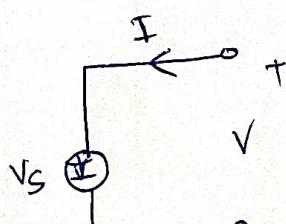
Dependent source.

On quantity

V.S

C.S

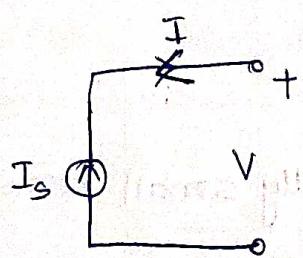
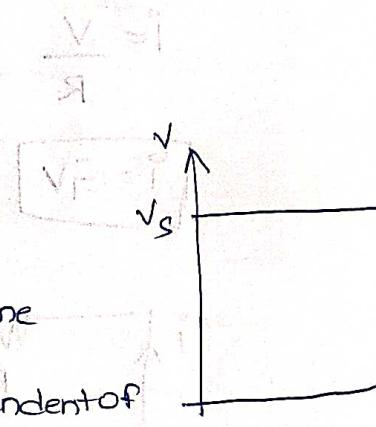
Independent source.



voltage source

Should supply same

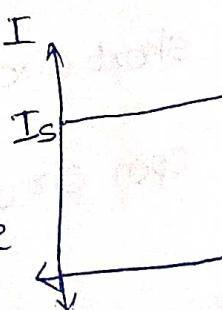
voltage independent of
of current



Current source should
supply same current

independent of voltage

applied



* Opp. Opposition to the flow of current

is called resistance.

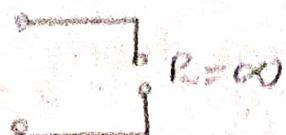
* Open Circuit: $R = \infty$; $I = 0$; $V = \text{constant}$

Short Circuit: $R = 0$; $V = 0$
 $I = \text{max. value}$

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

P = RVI ,
specific
resistance

Open circuits



Short circuit:



⇒ Types of Sources for generating

SOURCES:
Independent Dependent

- Voltage
Source

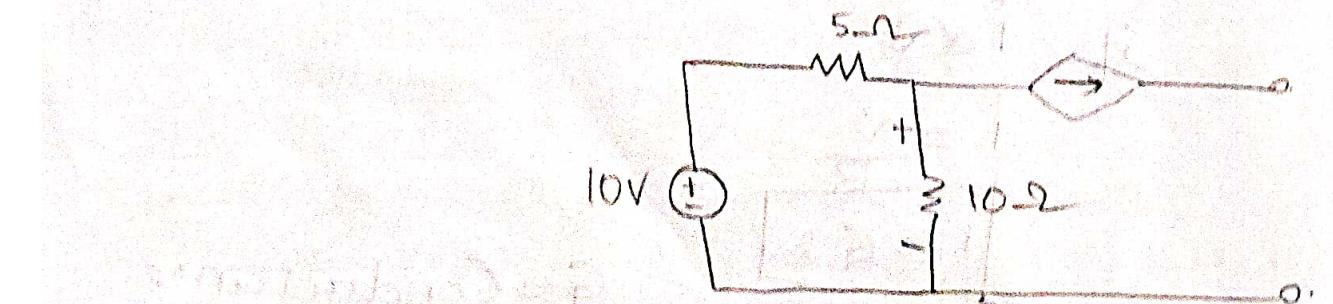
→ Voltage dependent voltage source.

→ Current dependent voltage source.

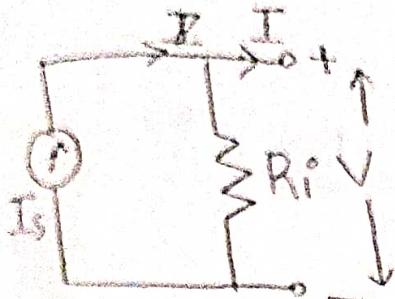
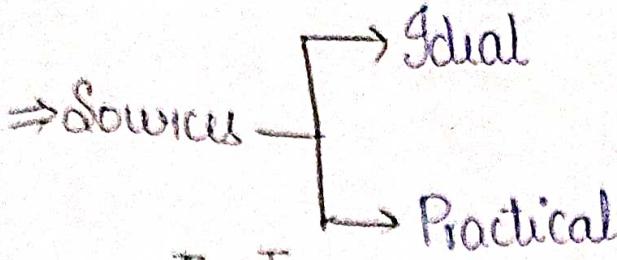
- Current
Source

→ Voltage dependent Current Source.

→ Current dependent Current Source



13/05/2022



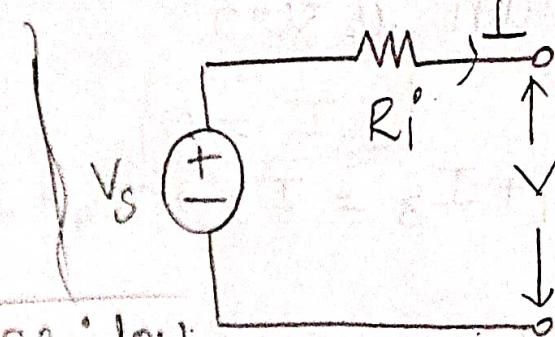
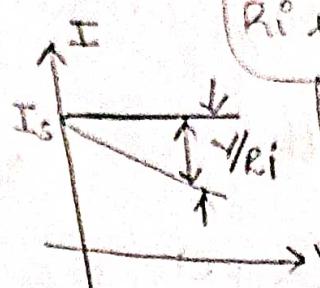
R_i is high

for current source

so as to allow large current through terminal.

$$I = I_s - \frac{V}{R_i}$$

$$V = I_s R_i - I R_i$$



$$V = V_s - I R_i \uparrow$$

ideal
Practical

$I R_i$ drop

drooping

R_i is low for voltage source so as to reduce voltage drop across R_i

* SOURCE TRANSFORMATION:

Condition for conversion of one source to another source i.e. current to voltage (or) vice versa.

TERMINAL CONDITION

$$V_s = I_s R_i$$

* KCL: Kirchhoff's Current Law.

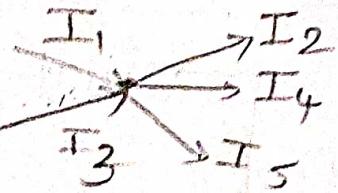
At any junction sum of currents incoming = Sum of currents going out

Algebraic Sum of currents meeting at a

junction is zero.

$$\boxed{\sum I = 0}$$

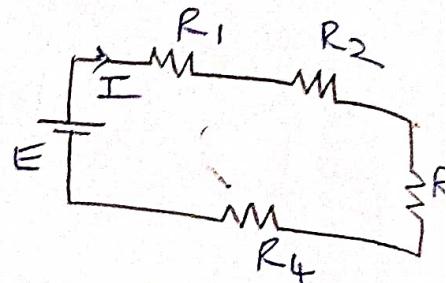
$$I_1 + I_3 = I_2 + I_4 + I_5$$



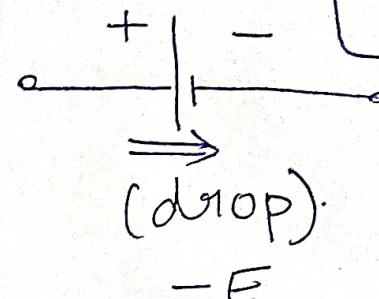
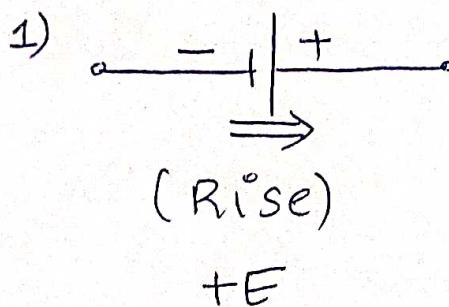
* KVL: Kirchhoff's voltage law.

In any closed path

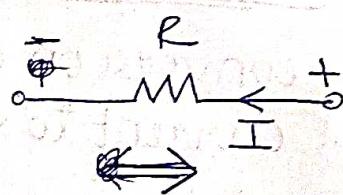
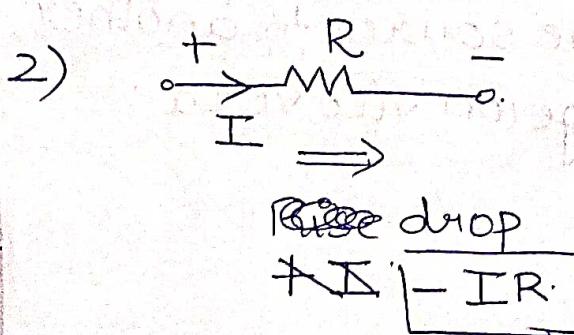
$$\sum emfs + \sum IR = 0$$



Sign Convention:



$$E - IR_1 - IR_2 - IR_3 - IR_4 = 0$$

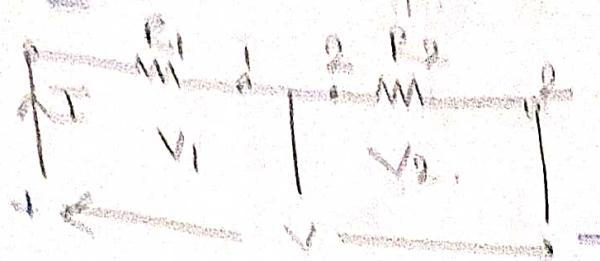


* SERIES CONNECTION: Joining end to end.

Bilateral: Device which acts as same in any direction. ex: Resistor.

Unilateral: Device which acts as ~~so~~ different when connected in different direction.

* Diode



1) i is same

2) V divides

$$V = V_1 + V_2$$

$$I_{\text{Req}} = I_{R1} + I_{R2}$$

$$R_{\text{Req}} = R_1 + R_2$$

* Voltage Division Rule

$$\frac{V_1}{V_2} = \frac{R_1}{R_2}$$

$$\frac{V_1}{V - V_1} = \frac{R_1}{R_2}$$

$$V_1 R_2 = (V - V_1) R_1$$

$$V_1 (R_1 + R_2) = VR_1$$

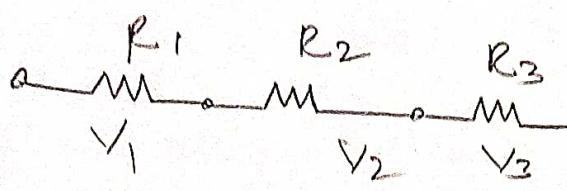
$$V_1 = \frac{VR_1}{R_1 + R_2}$$

$$\frac{V - V_2}{V_2} = \frac{R_1}{R_2}$$

$$VR_2 - V_2 R_2 = V_2 R_1$$

$$V_2 = \frac{V_0 R_2}{R_1 + R_2}$$

$$P = P_1 + P_2$$



$$V_1 = \frac{VR_1}{R_1 + R_2 + R_3}$$

$$V_2 = \frac{VR_2}{R_1 + R_2 + R_3}$$

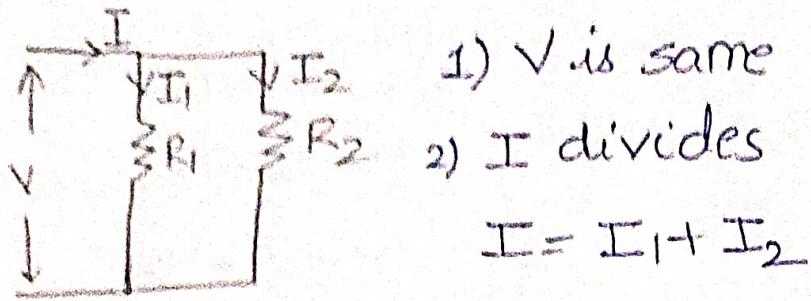
$$V_3 = \frac{VR_3}{R_1 + R_2 + R_3}$$

$$V = V_1 + V_2 + V_3$$

$$R_{\text{Req}} = R_1 + R_2 + R_3$$

* PARALLEL CONNECTION: Joining all similar ends.

$$P = P_1 + P_2$$



$$\frac{V}{R_{\text{eq}}} = \frac{V}{R_1} + \frac{V}{R_2}$$

$$\frac{1}{R_{\text{eq}}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$R_{\text{eq}} = \frac{R_1 R_2}{R_1 + R_2}$$

* Current division Rule:

$$\frac{I_1}{I_2} = \frac{R_2}{R_1}$$

$$R_1(I - I_2) = R_2 I_2$$

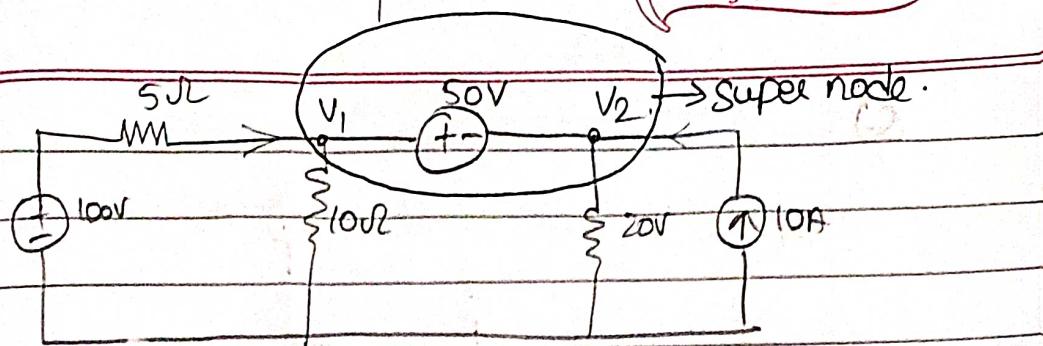
$$I_1 = \frac{IR_2}{R_1 + R_2}$$

$$I_2 = \frac{IR_1}{R_1 + R_2}$$

Assume as single node
classmate

Date _____
Page _____

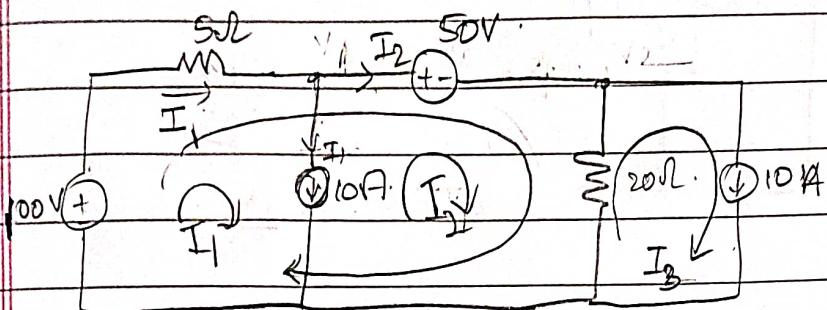
Q:



$$\frac{100 - V_1}{5} + 10 = \frac{V_1}{10} + \frac{V_2}{20} \rightarrow \text{at super node.}$$

$$V_1 - (V_2 + 50) = 0 \rightarrow \text{as it is a single node!}$$

Super mesh:-



$$100 - 5I_1 - 50 - (I_3 - I_2)20 = 0$$

$$I_3 + 10 = 0$$

$$I_1 = I_2 + 10$$

* Super position theorem :- In any linear bilateral active network containing more than one source, response in any element is equal to sum of individual responses.

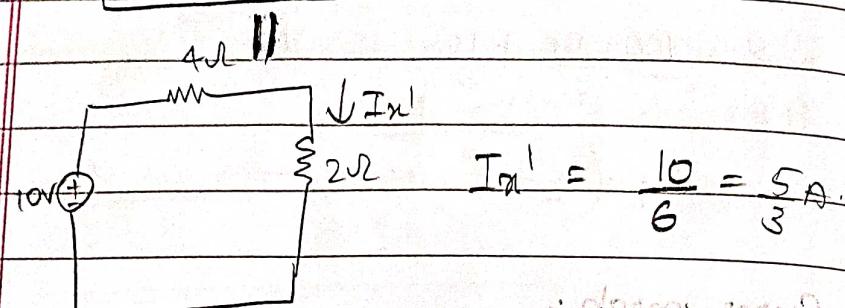
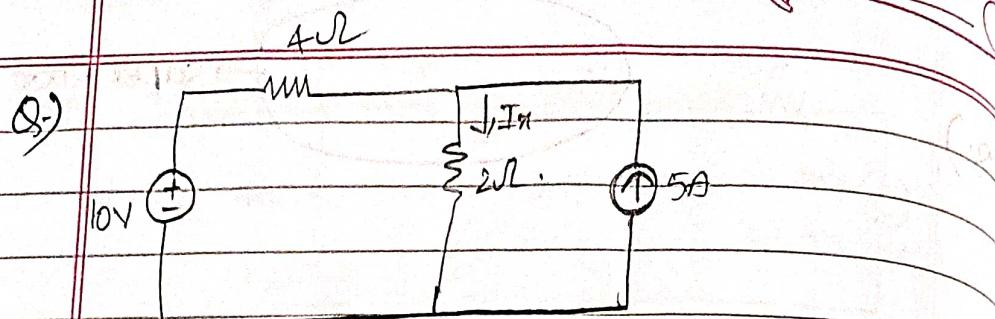
* linear :- output is proportional to input. ($V=IR$)

* bilateral :- element behaves same in both directions.

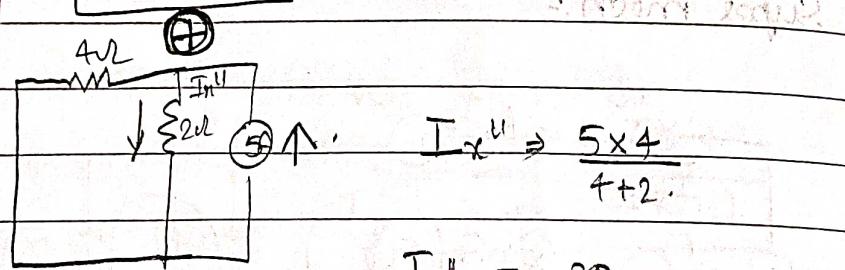
* active :- element which can deliver finite amount of force at infinite times. (powerstat - on)

\Rightarrow diode is a unilateral. ~~ie. open~~

\Rightarrow resistor is bilateral.

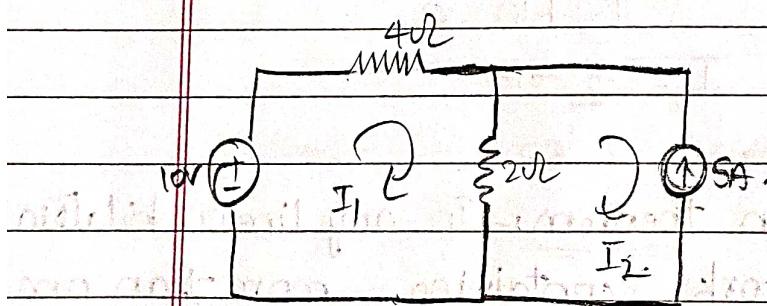


$$I_A' = \frac{10}{6} = \frac{5}{3} A.$$



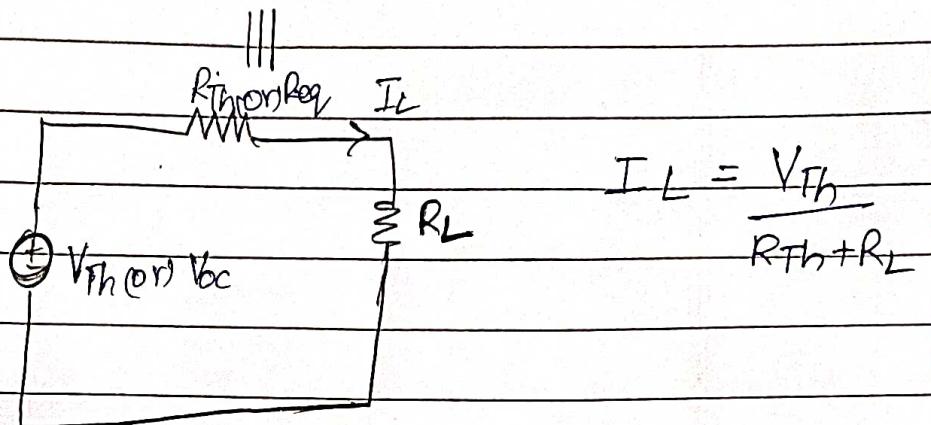
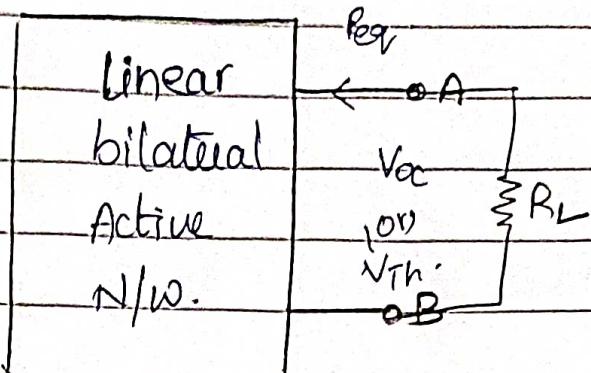
$$I_A'' = \frac{20}{6}.$$

$$I = I_A' + I_A'' = \frac{30}{6} = 5 A.$$



$$-4I_1 - (I_2 - I_1) 2 \neq 10 \Rightarrow \text{No solution}$$

The Thevenin's Theorem:-



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

Any linear bilateral active complex network btw terminals A and B (across which the load resistance is connected, In which load current (or) response is to be found) can be replaced by a single voltage source (V_{Th}) in series with single resistance (R_{Th})

V_{Th} can be found by open circuiting (load ^{terminals} resistance) and measure across it.

R_{Th} is equivalent resistance btw A & B by replacing the sources by their internal resistances (for ideal voltage source make it short circuit & for ideal current source make it open circuit).

$$\begin{aligned} -25I_2 + I_3 + 10I_1 &= 0 \quad (2) \\ -45I_3 + 20I_2 &= 50 \quad (3) \\ 10I_2 - 15I_1 &= 100 \quad (1) \end{aligned}$$

~~Δ~~

$$\Delta = \begin{bmatrix} 10 & -25 & 1 \\ 0 & 20 & -45 \\ -15 & 10 & 0 \end{bmatrix}$$

$$15I_1 - 10I_2 = -100 \quad (1)$$

$$20I_2 - 45I_3 = 50 \quad (3)$$

$$10I_1 + I_3 - 25I_2 = 0 \quad (2)$$

$$\begin{aligned} I_1 &= -15.4 \\ I_2 &= +3.5 \\ I_3 &= +2.7 \\ I_1 &= 9.05A \end{aligned}$$

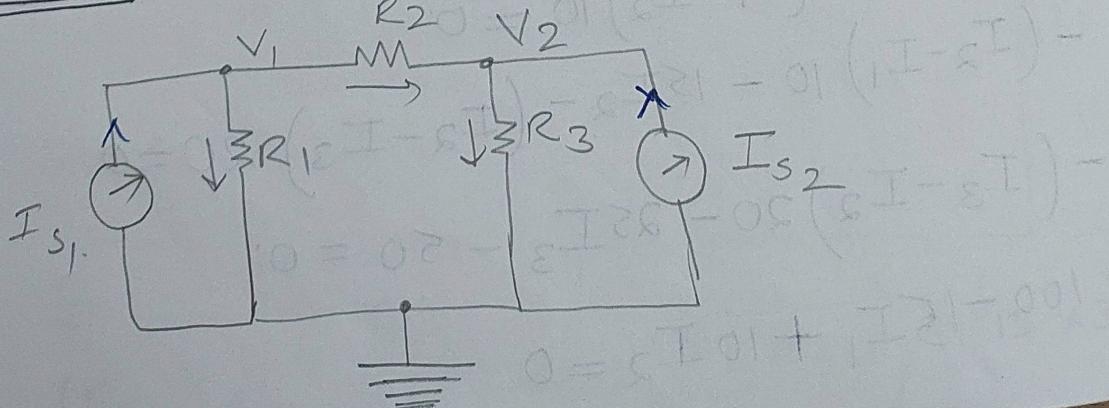
$$I_L = 7.6A$$

$$I_2 = 1.7A$$

$$I_3 = +1.9A$$

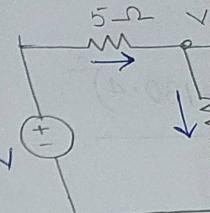
$$I_1 = 7.85A$$

01/06/2022
* Nodal Analysis:



$$I_{S1} = \frac{V_1 - 0}{R_1}$$

$$I_{S2} = \frac{V_1 - V_2}{R_2}$$

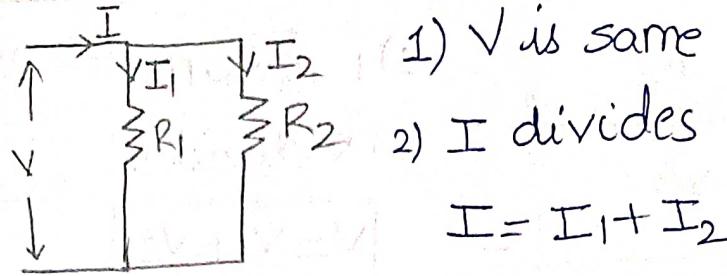


at V_1 : KCL

$$\frac{100 - V}{5}$$

10

at V_1



1) ∇ is same

2) I divides

$$I = I_1 + I_2$$

$$\frac{V}{R_{eq}} = \frac{V}{R_1} + \frac{V}{R_2}$$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$Req = \frac{R_1 R_2}{R_1 + R_2}$$

* Current division Rule:

$$\frac{I_1}{I_2} = \frac{R_2}{R_1}$$

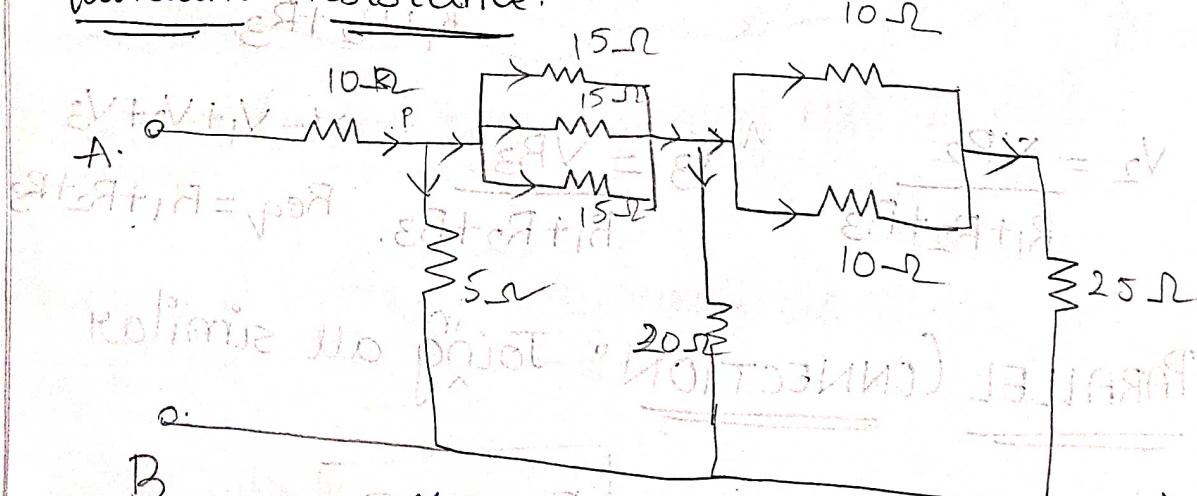
$$I_1 = \frac{IR_2}{R_1 + R_2}$$

$$R_1(I - I_2) = R_2 I_2$$

$$I_2 = \frac{IR_1}{R_1 + R_2}$$

30 | 05 | 2022

Equivalent Resistance



$$(Req)_{AB} = \left(25 + \frac{100}{20} \right) || 20 + \left(15^{-1} \times 3 \right)^{-1} || 15$$

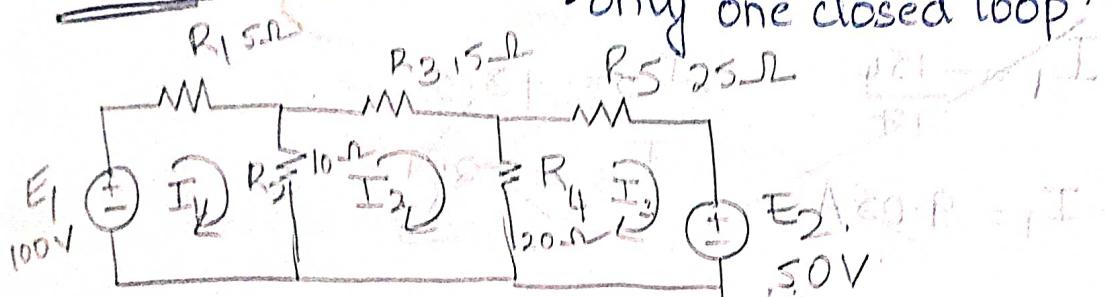
$$= \left(\left(\left(\frac{6}{3.0 \times 2.0} + 0.00 \right) || 5 \right) + 10 \right)$$

$$= \frac{1.9}{10.0} + 10 = 10.19$$

$$\text{Req. } = 13.86 \Omega$$

* MESH ANALYSIS: Mesh is an independent loop

• only one closed loop



KVL:

$$\text{I} \Rightarrow E_1 - I_1 R_1 - (I_1 - I_2) R_2 = 0$$

$$\text{II} \Rightarrow -(I_2 - I_1) R_2 - I_2 R_3 - (I_2 - I_3) R_4 = 0$$

$$\text{III} \Rightarrow -(I_3 - I_2) R_4 - I_3 R_5 - E_2 = 0$$

$$100 - 5I_1 - (I_1 - I_2) 10 = 0$$

$$-(I_2 - I_1) 10 - 15I_2 - (I_2 - I_3) 20 = 0$$

$$-(I_3 - I_2) 20 - 25I_3 - 50 = 0$$

$$100 - 15I_1 + 10I_2 = 0$$

$$-25I_2 + I_3 + 10I_1 = 0 \quad -\textcircled{2}$$

$$-45I_3 + 20I_2 = 50 \quad -\textcircled{3}$$

$$10I_2 - 15I_1 = 100 \quad -\textcircled{1}$$

~~Δ~~

$$\Delta = \begin{bmatrix} 10 & -25 & 0 \\ 0 & 20 & -45 \\ -15 & 10 & 0 \end{bmatrix}$$

$$15I_1 - 10I_2 = -100 \quad -\textcircled{1}$$

$$20I_2 - 45I_3 = 50 \quad -\textcircled{3}$$

$$10I_1 + I_3 - 25I_2 = 0 \quad -\textcircled{2}$$

$$\begin{aligned} I_1 &= -15A \\ I_2 &= +3.5A \\ I_3 &= +2.7A \\ I_1 &= 9.05A \end{aligned}$$

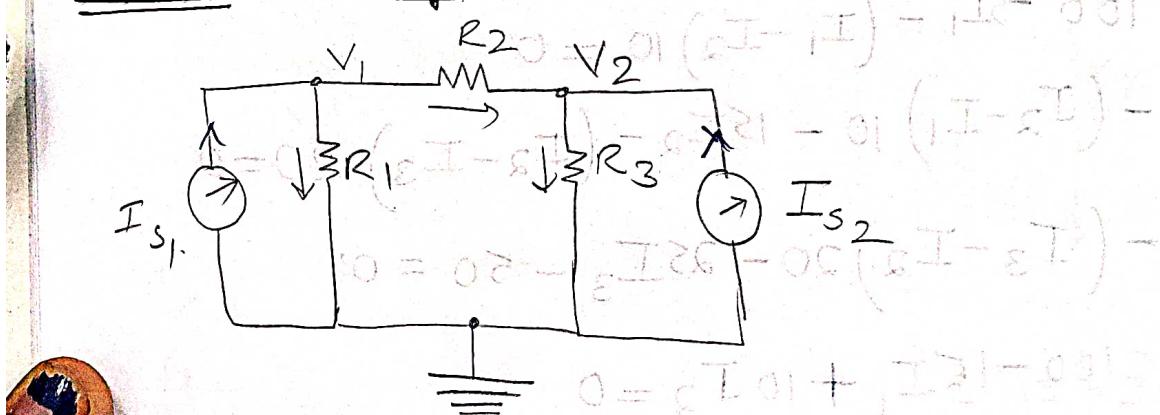
$$I_2 = 1.7A$$

$$I_3 = +1.9A$$

$$I_1 = +7.85A$$

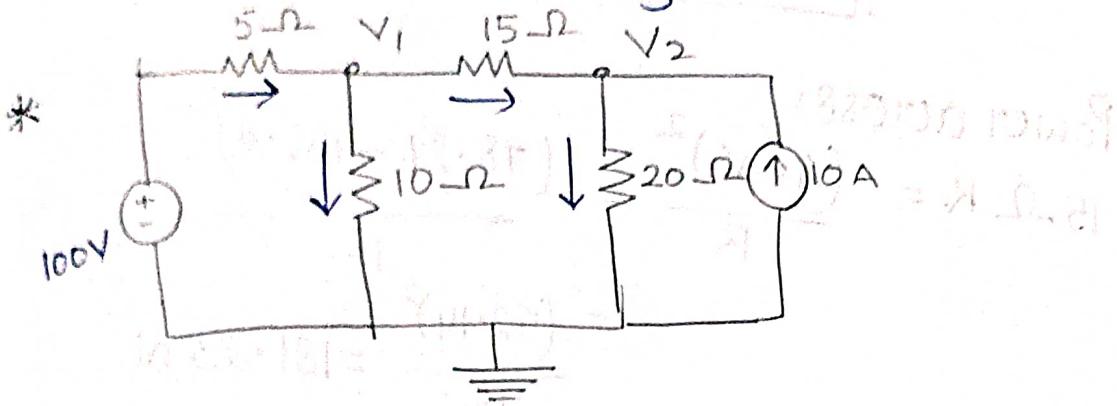
$$01/06/2022$$

* Nodal Analysis:



$$I_{S1} = \frac{V_1 - 0}{R_1} + \frac{V_1 - V_2}{R_2}$$

$$I_{S2} + \frac{V_1 - V_2}{R_2} = \frac{V_2}{R_3}$$



at V_1 : KCL

$$\frac{100 - V_1}{5} = \frac{V_1 - 0}{10} + \frac{V_1 - V_2}{15}$$

$$200 = 3V_1 \quad \leftarrow \text{Adj}$$

$$V_1 = 66.67 \quad \cancel{\text{V1}} =$$

$$\frac{100 - V_1}{5} = \frac{3V_1 + 2V_1 - 2V_2}{30}$$

$$600 - 6V_1 = 5V_1 - 2V_2$$

$$11V_1 - 2V_2 = 600$$

at V_2 : KCL

$$\frac{V_1 - V_2}{15} + 10 = \frac{V_2}{20}$$

$$\frac{V_1 - V_2 + 150}{15} = \frac{V_2}{20}$$

$$4V_1 - 4V_2 + 600 = 3V_2$$

$$7V_2 - 4V_1 = 600 \quad \text{---(2)}$$

$$V_1 = \frac{1800}{23}$$

$$V_1 = 78.26 \text{ V}$$

$$V_2 = 130.4 \text{ V}$$

Power across:

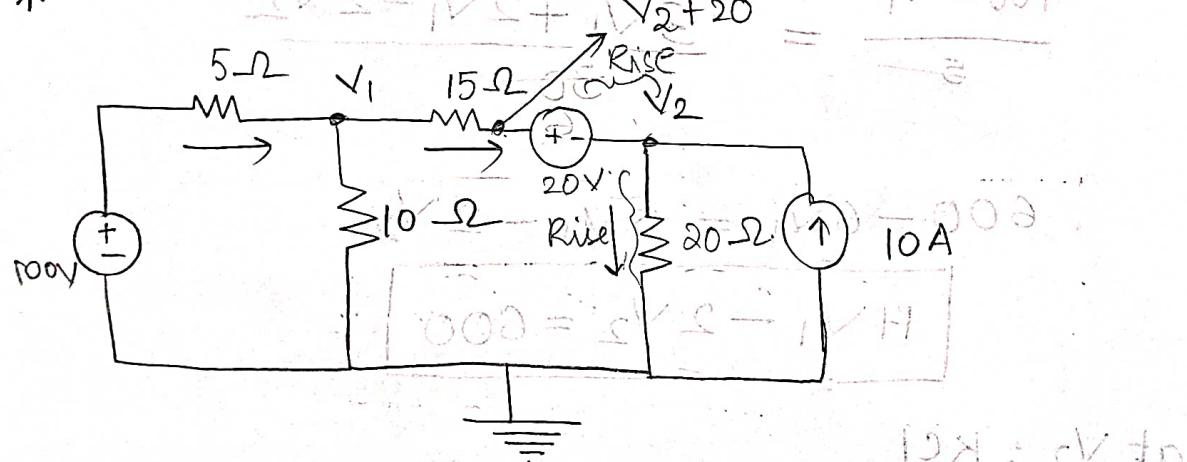
$$15 \Omega R = \frac{(V_1 - V_2)^2}{R} = \frac{(78.26 - 130.4)^2}{15}$$

$$= \frac{(52.14)^2}{15} = 181.23 \text{ W}$$

$$100 \text{ V Supply} \Rightarrow P = \frac{100 - 78.26}{5} \times 100 \\ = 434.8 \text{ W}$$

$$10 \text{ A} \Rightarrow P = V_2 \times 10 \\ = 130.4 \times 10 \\ = \underline{\underline{1304 \text{ W}}}$$

*

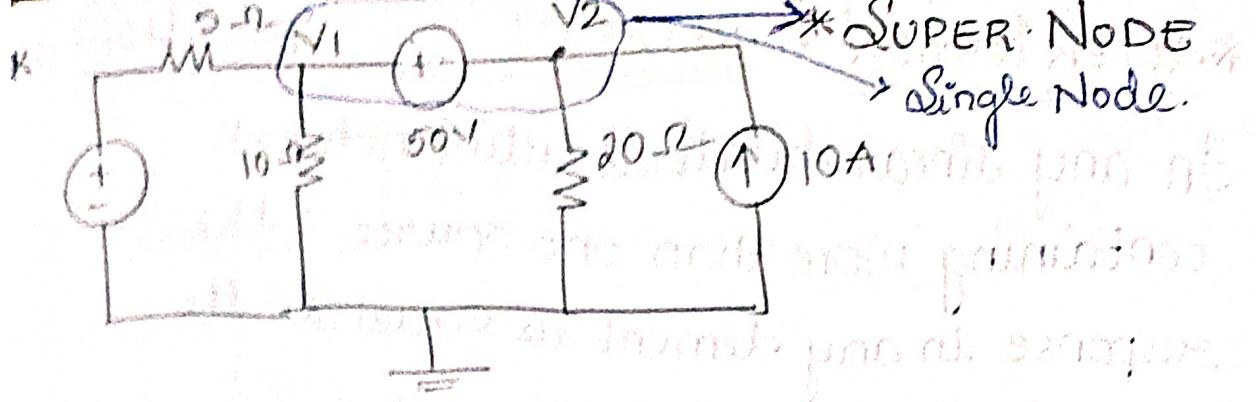


$$V_1 - 15I - 20 = V_2 = 0$$

$$15I = V_1 - V_2 - 20$$

$$I = \frac{V_1 - V_2 - 20}{15}$$

$$\Delta V = 0.6 + 15.8 + 1.4 = 23.8$$



$$\frac{100 - V_1}{5} + 10 = \frac{V_1}{10} + \frac{V_2}{20}$$

$$V_1 - V_2 = 50$$

$$\frac{100 - V_1 + 50}{5} = \frac{2V_1 + V_2}{20}$$

$$400 - 4V_1 + 200 = 2V_1 + V_2$$

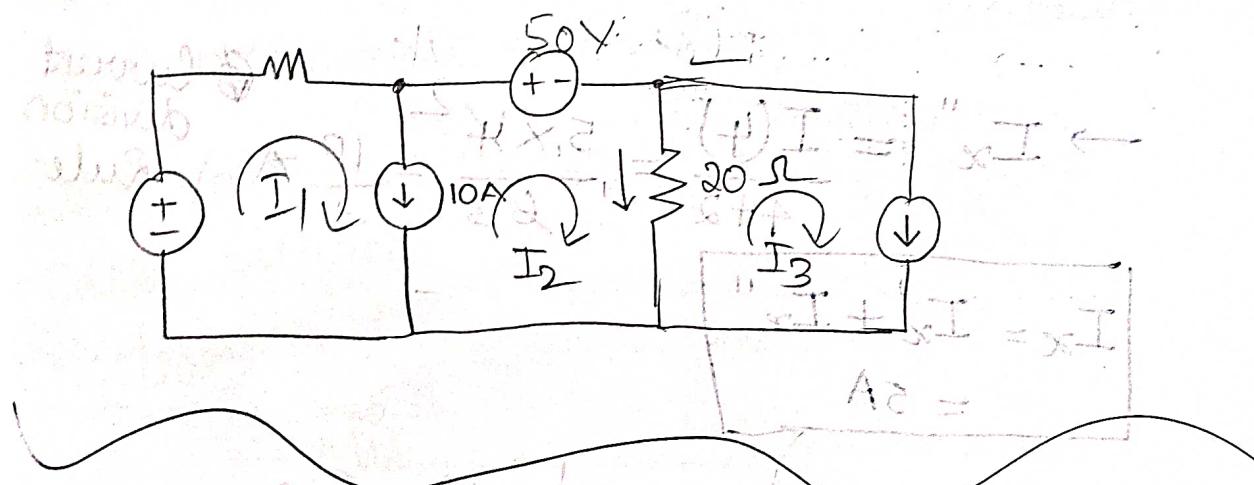
$$V_2 = 42.8 \text{ V}$$

$$6V_1 + V_2 = 600$$

$$7V_1 = 650$$

$$V_1 = 92.8 \text{ V}$$

*SUPER MESH:



$$A_{12} = \frac{V_1}{I_1} = \frac{1}{5}$$

$$A_{23} = \frac{V_2}{I_2} = \frac{1}{2}$$

$$A_{31} = \frac{V_3}{I_3} = \frac{1}{10}$$

*SUPER POSITION & THEOREM:

03/06/2022

In any linear bilateral active network containing more than one source ; the response in any element is equal to the sum of individual responses.

Linear : output proportional to input $V = IR$
 Bilateral : acts ~~as~~ in same way wrt. polarity
 Active : deliver a finite amount of power in infinite time



$$\begin{aligned} 10 - 4I_1 \\ - 2(I_1 - I_2) \\ = 0 \end{aligned}$$

$$I_2 = -5A$$

$$10 - 4I_1 - 2I_2$$

$$I_1 = 0A$$

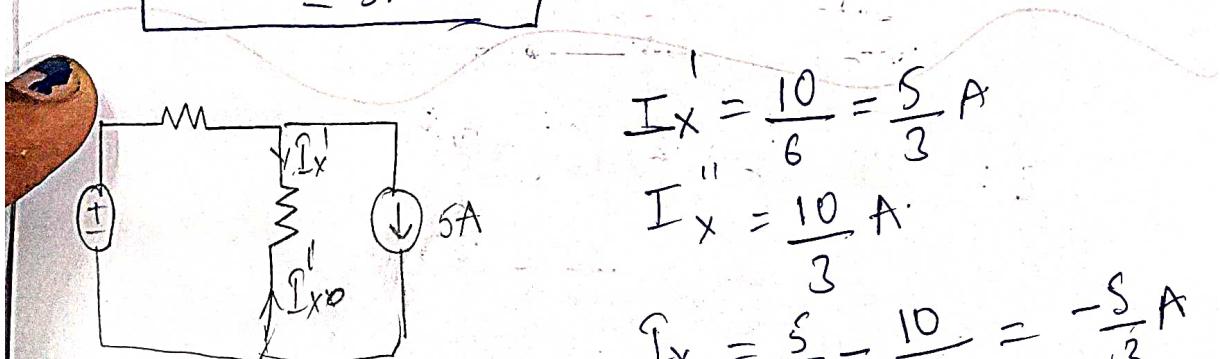
Determine I_x using SPT.

$$\rightarrow I_x' = \frac{10}{6} = \frac{5}{3} A$$

$$\rightarrow I_x'' = \frac{I(4)}{4+2} = \frac{5 \times 4^2}{6 \times 3} = \frac{10}{3} A$$

Current division Rule

$$\boxed{I_x = I_x' + I_x'' = 5A}$$



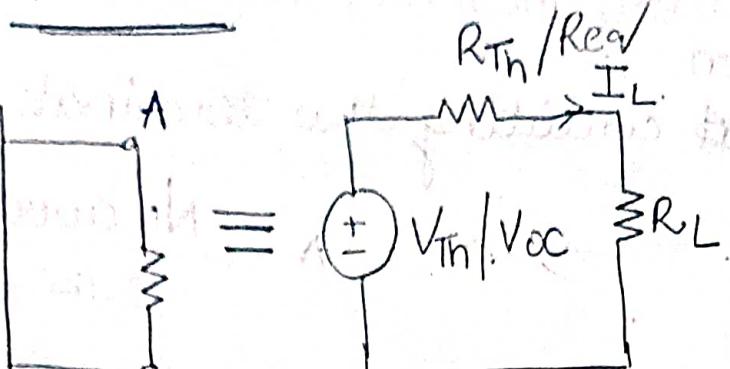
$$I_x' = \frac{10}{6} = \frac{5}{3} A$$

$$I_x'' = \frac{10}{3} A$$

$$I_x = \frac{5}{3} - \frac{10}{3} = -\frac{5}{3} A$$

* THEVENIN'S THEOREM

Linear
Bilateral
Active
network



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

Any linear bilateral active complex network

between terminals A and B (across which the

load resistance is connected; in which load

current/response is to be found) can be

replaced by a single voltage source (V_{Th}) in

series with the single resistance (R_{Th}), V_{Th} can

be found by open circuiting the load ~~resistance~~

and measure voltage across it. R_{Th} is eq.

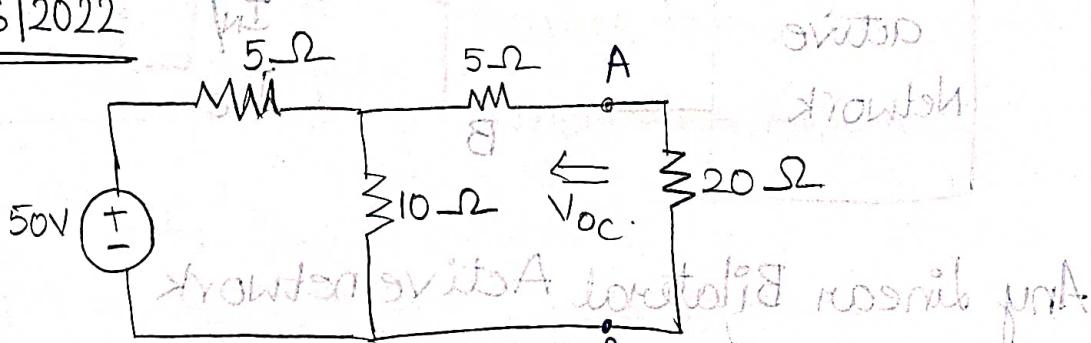
resistance between terminals A & B by replacing

the sources with their internal resistance.

Ideal Voltage Source: Short Circuit

Ideal Current Source: Open Circuit

07/06/2022

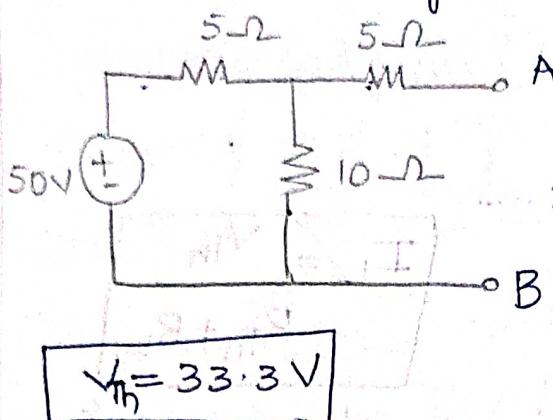


Determine the current through 20Ω load

Using Thevenin's theorem:

Open:

* ~~short~~ circuiting the terminals A & B



No current through
5Ω resistance.

$$R = 15\Omega$$

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

$$V = \frac{V_1}{R} \times 10$$

$$R_{Th} = 10 \times \frac{2}{3} + 5$$

$$R_{Th} = \frac{25}{3}$$

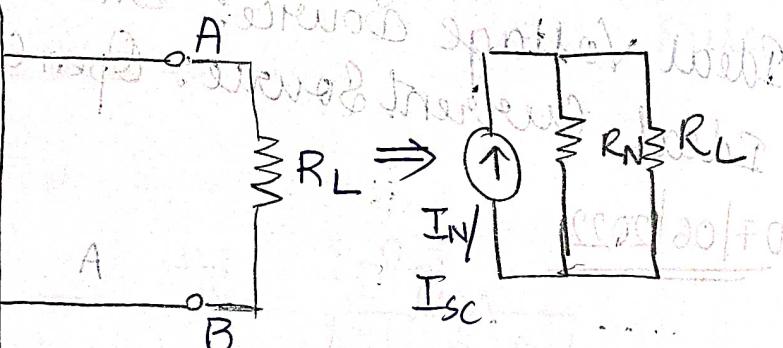
$$V = 50 \times \frac{2}{3}$$

$$I_{Th} = \frac{100/3}{25/3 + 20} = \frac{100}{85} = \frac{20}{17}$$

$$I_{Th} = 1.176A$$

* NORTON'S THEOREM:

linear
Bilateral
active
Network

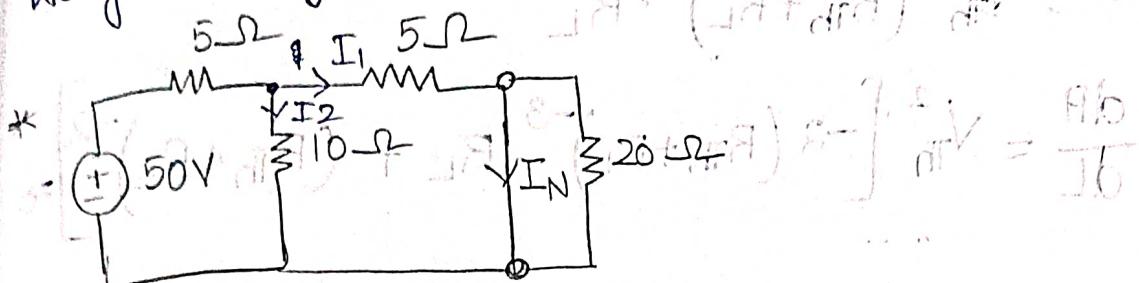


Any Linear Bilateral Active network

between terminals A & B can be replaced

by a single current source (I_N) in parallel to a single resistance (R_N):

We get I_N by short circuiting the load terminals.



$$R_{eq} = \frac{25}{3} \Omega = R_N$$

$$I = \frac{50}{25} = 2A$$

$$\boxed{I = 6A}$$

$$I_N = \frac{6 \times 10}{10 + 5} = \frac{60}{15} = 4A$$

$$\boxed{I_N = 4A}$$

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

$$I_L = \frac{4 \times \frac{25}{3}}{\frac{25}{3} + 20} = \frac{100}{148.33} = \frac{100}{148.33} = 1.176A$$

$$\boxed{I_L = 1.176A}$$

* MAXIMUM POWER TRANSFER THEOREM:



Maximum Power will be

transferred from
source to load

when $R_L = R_s / R_{Th}$

$$P = I_L^2 R_L$$

$$P = \left(\frac{V_{Th}}{R_{Th} + R_L} \right)^2 R_L$$

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

$$P = V_{Th}^2 \left(R_{Th} + R_L \right)^{-2} \cdot R_L$$

$$\frac{dP}{dL} = V_{Th}^2 \left[-2 \left(R_{Th} + R_L \right)^{-3} \cdot R_L + \left(R_{Th} + R_L \right)^{-2} \right] = 0$$

$$\frac{2R_L}{\left(R_{Th} + R_L \right)^3} = \frac{1}{\left(R_{Th} + R_L \right)^2}$$

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

$$R_L = R_{Th}$$

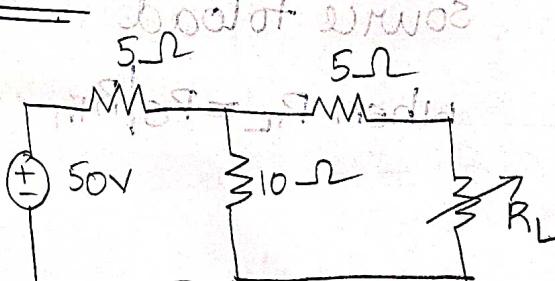
$$P_{out} = P_{max}$$

$$P_{in} = V_{Th} \cdot I_L = \frac{V_{Th}}{2R_{Th}} \cdot I_L = \frac{P_{out}}{P_{in}}$$

$$= V_{Th} \cdot \frac{V_{Th}}{2R_{Th}} = \frac{1}{2} = 50\%$$

$$R_S = \frac{V_{Th}^2}{2R_{Th}} = P_{in}$$

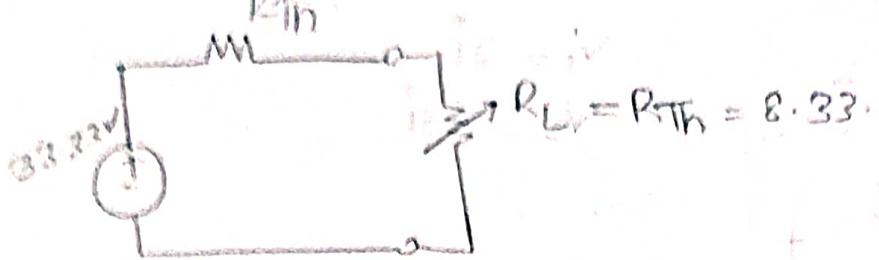
08/06/2022



Determine ~~for~~ R_L for MPT.

and MPT

$$\frac{1}{R_{in}} = \frac{1}{5\Omega} + \frac{1}{10\Omega}$$



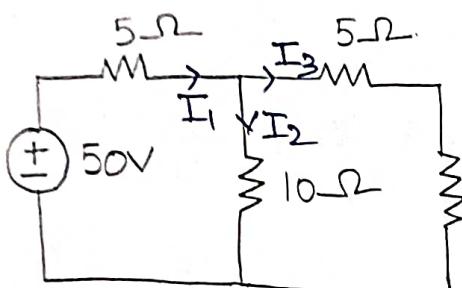
$$P_{in} = \frac{V_{Th}^2}{2R_{Th}} = 66.68 \text{ V}$$

$$0 = i_1 + i_2 - 8A$$

$$0 = i_2 - (8 - i_1) + i_3 = 8A$$

* TELEGEN'S THEOREM:

$$\sum \text{Power (P)} = 0$$



$$V_8 - I_1 = \frac{50}{5 + \left(\frac{10 \times 20}{30}\right)} = \frac{50}{5 + 50/7} = 4.11A$$

$$I_2 = \frac{4.11 \times 20}{30} = 2.93A$$

$$I_1 = \frac{50}{5 + 7.14} = 4.11A$$

$$\begin{aligned} I_2 &= 0.58A \\ I_3 &= 4.11 \times 1 \\ I_2 &= 2.93A \end{aligned}$$

$$\begin{aligned} I_3 &= I_1 - I_2 \\ &= 4.11 - 2.93 \end{aligned}$$

$$I_3 = 1.18A$$

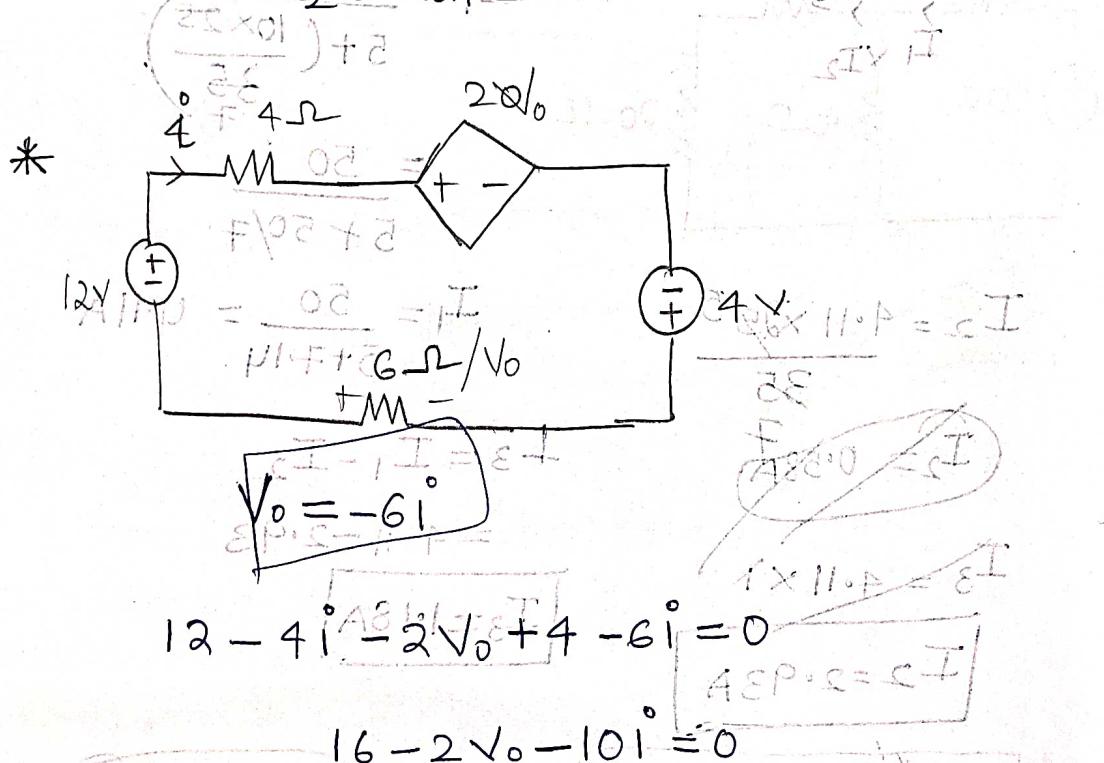
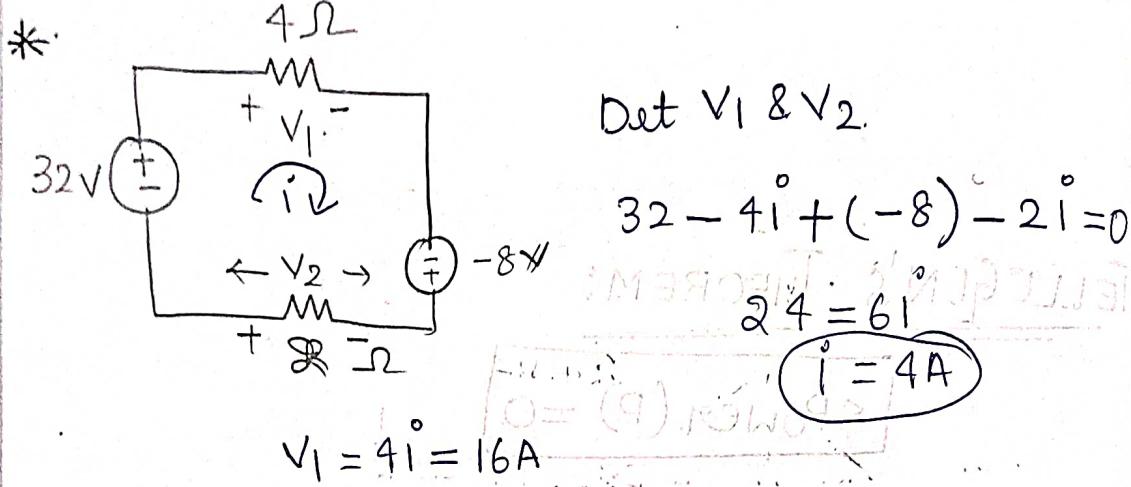
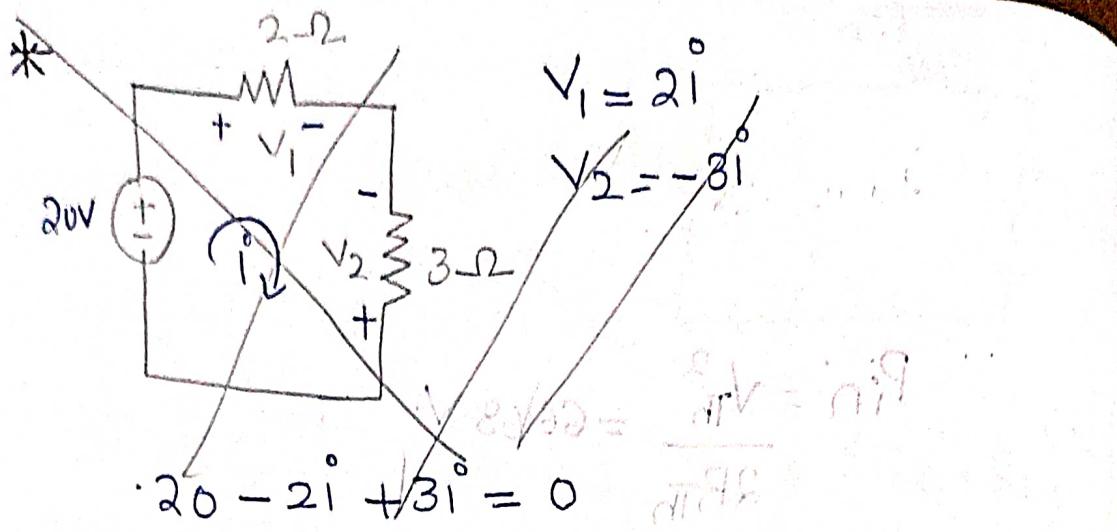
$$P = 50I_1 = 205.5W$$

$$P_1 = I_1^2 R_1 = 84.4W$$

$$P_2 = I_2^2 R_2 = 85.84W$$

$$P_3 = I_3^2 R_3 = 34.81W$$

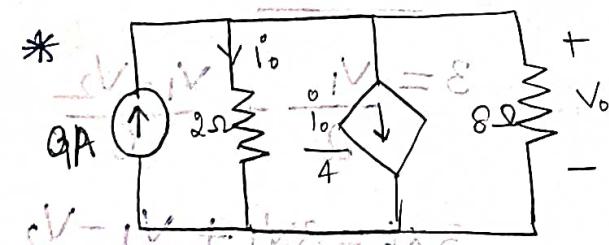
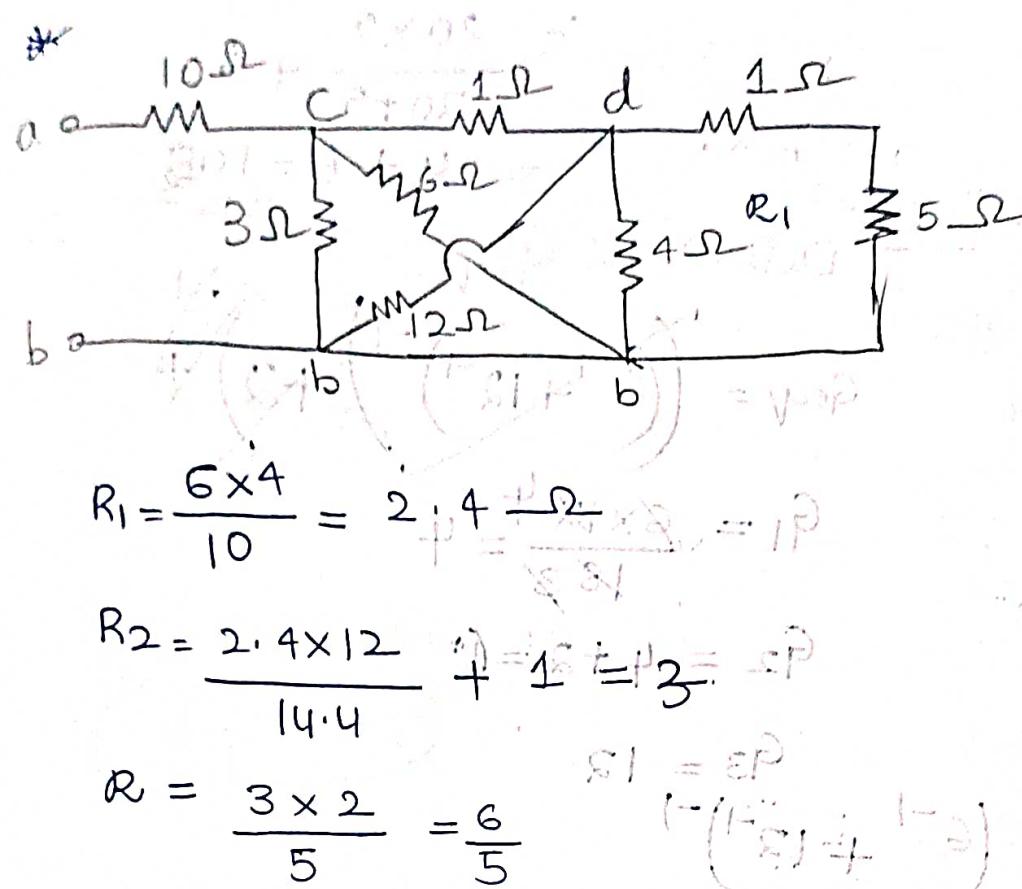
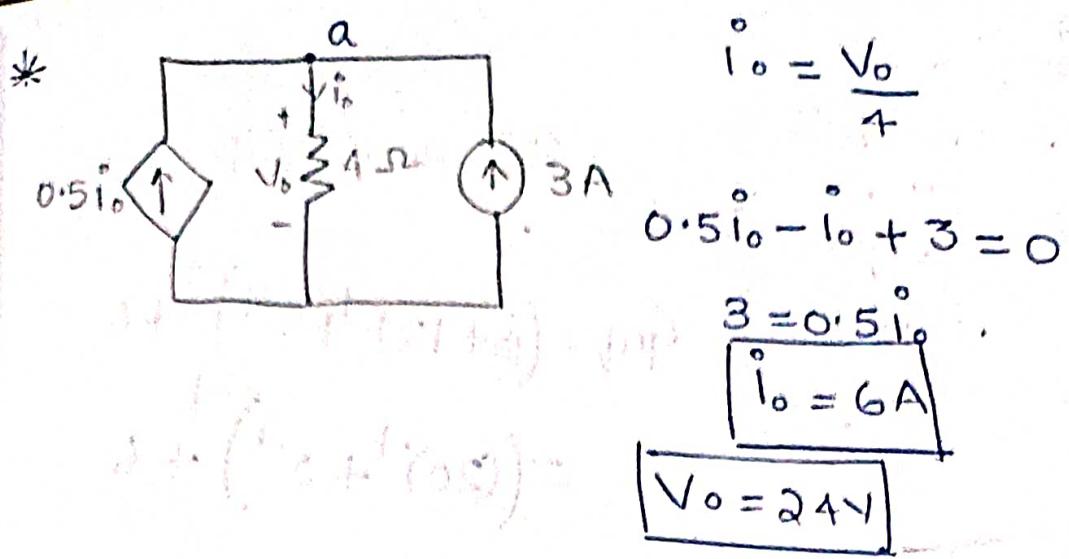
$$P = P_1 + P_2 + P_3$$



$$16 + 2i = 0$$

$$i = -8A$$

$$V_0 = 14.8V$$



$$2V = 2V - i_o/2$$

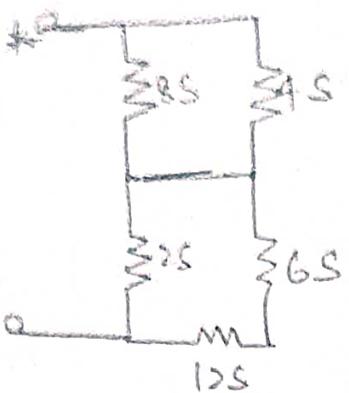


10/06/2022



Determine G_{eq}

$$\begin{aligned}
 G_{eq} &= ((8+12)^{-1} + 5^{-1})^{-1} + 6 \\
 &= (20^{-1} + 5^{-1})^{-1} + 6 \\
 &= \frac{20 \times 5}{20+5} + 6 \\
 &= 4 + 6 = 10 \text{ S}
 \end{aligned}$$



Determine G_{eq}

$$G_{eq} = \left((6^{-1} + 12^{-1})^{-1} + 2 \right)^{-1}$$

$$G_1 = \frac{6 \times 12}{18} = 4 \text{ S}$$

$$G_2 = 4 + 2 = 6 \text{ S}$$

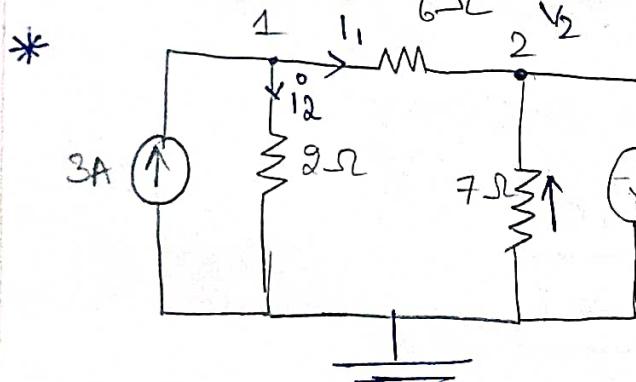
$$G_3 = 12 \text{ S}$$

$$G_{eq} = (6^{-1} + 12^{-1})^{-1}$$

$$\frac{\partial}{\partial} = \frac{2 \times 6}{6} = 2 \text{ S}$$

$$= \frac{6 \times 12}{18} = 4 \text{ S}$$

$$01 + \frac{\partial}{\partial} = 4 \text{ S}$$



at node 1:

$$3I = \frac{V_1}{2} + \frac{V_1 - V_2}{6}$$

$$3 \times 6 = 3V_1 + V_1 - V_2$$

$$4V_1 - V_2 = 18$$

at node 2: $+12 = \frac{V_2}{7}$

$$\boxed{V_2 = 84A}$$

$$V = \frac{4V}{3} + \frac{V - A}{4}$$

~~$$\frac{-V_2}{7} = 12 +$$~~

~~$$-V_2 = 84A$$~~

~~$$V_2 = -84A$$~~

~~$$4V_1 = 18 + \frac{V_2}{2}$$~~

~~$$4V_1 = 18 - 84$$~~

~~$$4V_1 = 66$$~~

~~$$\frac{-V_2}{7} + \frac{V_2 - V_1}{6} = 12 + 18$$~~

~~$$-6V_2 + 7V_2 - 7V_1 = 12 \times 42$$~~

$$12 + \frac{V_2 - V_1}{6}$$

~~$$V_2 - 7V_1 = 504$$~~

~~$$= -\frac{V_2}{7}$$~~

~~$$-V_2 + 4V_1 = 18$$~~

$$\Rightarrow \frac{7V_2 + V_2 - V_1}{6} = -\frac{V_2}{7}$$

$$504 + 7V_2 - 7V_1 = -6V_2$$

~~$$\begin{array}{r} 142 \\ \times 12 \\ \hline 184 \\ 142 \\ \hline 504 \end{array}$$~~

$$V_2 = -24 - 18$$

$$V_2 = -42V$$

$$7V_1 - 13V_2 = 504$$

$$4V_1 - V_2 = 18$$

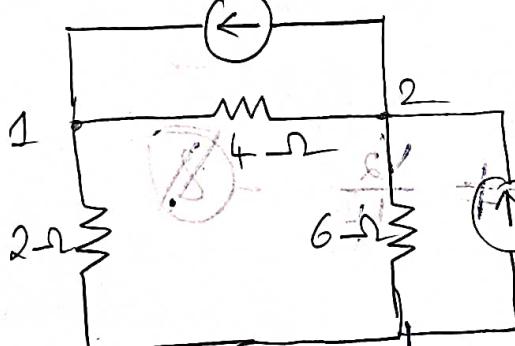
~~$$7V_1 - 13V_2 = 504$$~~

$$E = \frac{7V_1 - 5.2V_1 + 13V_2}{4} = 234$$

$$-4.5V_1 = 270$$

$$V_1 = 6V$$

*



at node 1:

$$\frac{E - V_1}{1} + \frac{V_1 - V_2}{4} + \frac{V_1}{2} = 0$$

$$5 \times 4V = V_1 - V_2 + 2V$$

at node 2:

$$5 + \frac{V_2 - V_1}{4} + \frac{V_2}{6} = 10 + 2V + 1V + 1V$$

$$3V_1 - V_2 = 20$$

$$\frac{V_2 - V_1}{4} + \frac{V_2}{6} = 5$$

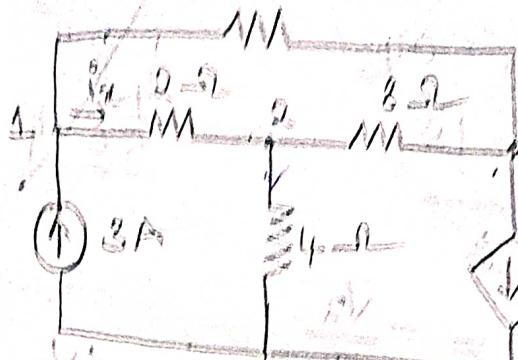
$$6V_2 - 6V_1 + 4V_2 = 120$$

$$10V_2 - 6V_1 = 120$$

$$(-V_2 + 3V_1 = 20) \times 10$$

$$24V_1 = 320$$

$$V_1 = \frac{14.0}{3} = 13.33V$$



$$I_x = V_1 - V_2 / 2V$$

$$I_x = \frac{V_1 - V_2}{2} / 2V$$

at node 1:

$$(V_1 - V_2) / 2 + (V_1 - V_3) / 4 = 3$$

$$\frac{V_1 - V_2}{2} + \frac{V_1 - V_3}{4} = 3$$

$$3V_1 - 2V_2 - V_3 = 12 \quad \textcircled{1}$$

at node 1/2:

~~$$V_1 - V_2$$~~

$$\frac{V_1 - V_2}{2} = \frac{V_2 - V_3}{8} + \frac{V_2}{4}$$

or

$$\frac{V_1 - V_2}{2} = 3V_2 - V_3$$

$$\left[\frac{4V_1 - 7V_2 + V_3}{8} = 0 \right] \quad \textcircled{2}$$

at node 3

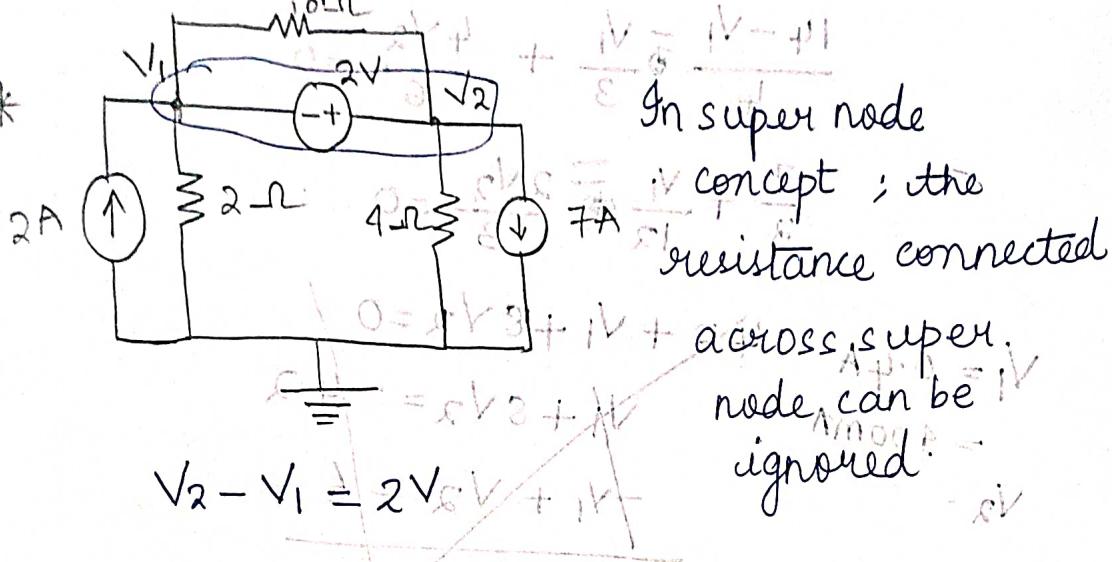
$$\frac{V_1 - V_3}{4} + \frac{V_2 - V_3}{8} = 2\left(\frac{V_1 - V_2}{2}\right)$$

$$2V_1 + V_2 - 3V_3 = 8V_1 - 8V_2$$

$$6V_1 - 9V_2 + 3V_3 = 0$$

$$V_1 = 4.8V \quad V_2 = 2.4V \quad V_3 = -9.6V$$

$$V_1 = 4.8V$$



$$2 = \frac{V_1}{2} + \frac{V_2}{4} + 7$$

$$8 = 2V_1 + V_2 + 28$$

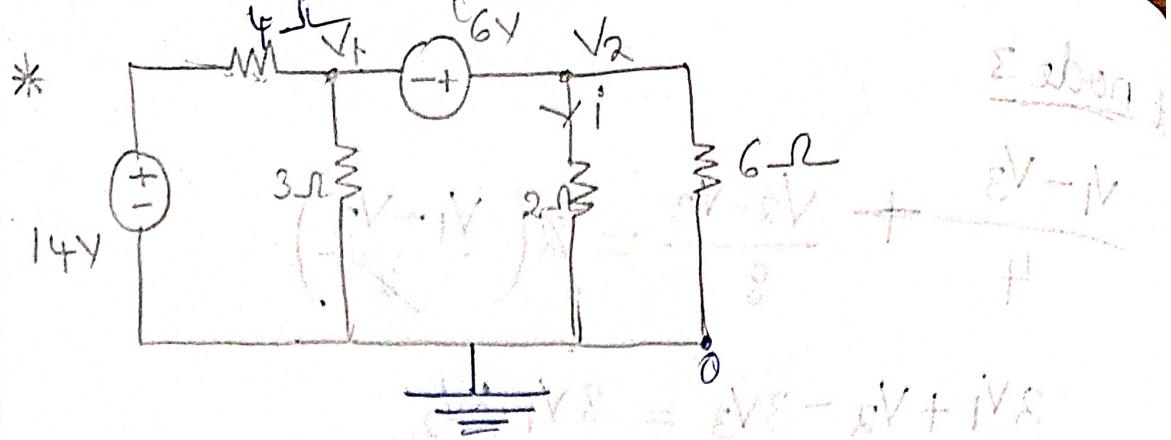
$$2V_1 + V_2 = -20$$

$$\begin{array}{r} -V_1 + V_2 = 2 \\ +V_1 + V_2 = -2 \end{array}$$

$$3V_1 = -22$$

$$V_2 = -5.33V$$

$$V_1 = -7.33V$$



$$V_2 - V_1 = 6V$$

$$0 = 8V_2 + 6V_1 - 14V_0$$

$$\frac{14 - V_1}{4} = \frac{V_1}{3} + \frac{V_2}{2} + \frac{V_3}{6}$$

$$\frac{14 - V_1}{4} = \frac{V_1}{3} + \frac{4V_2}{6} = 0$$

~~shear negat. m.~~

$$\text{so: } \frac{7}{2} + \frac{V_1}{12} - \frac{2V_2}{3} = 0$$

~~$$V_1 = 0.4A$$~~

~~500mA aber~~

~~verwirrt~~

~~$$V_1 + 8V_2 = -4$$~~

~~$$-V_1 + V_2 = 6V - 8V$$~~

~~$$+ 9V_2 - 36V = 8$$~~

~~$$V_2 = -4V$$~~

~~$$8V + 6V + 1V = 8$$~~

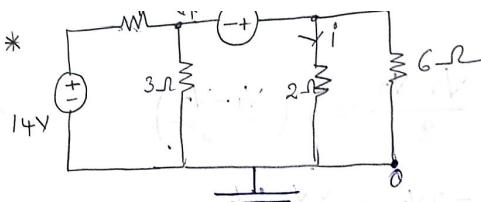
~~$$V_1 = -10V$$~~

~~$$0.8 = 6V + 1V$$~~

~~$$0.8 = 8V + 1V$$~~

~~$$8V = 1V$$~~

$$\boxed{V_{EF} = 1V}$$



$$V_2 - V_1 = 6 \text{ V}$$

$$\frac{14 - V_1}{4} = \frac{V_1}{3} + \frac{V_2}{2} + \frac{V_2}{6}$$

$$\frac{14 - V_1}{4} = \frac{V_1}{3} + \frac{4V_2}{6} = 0$$

$$\frac{7}{2} + \frac{V_1}{12} = \frac{2V_2}{3} = 0$$

$$V_1 = 0.4 \text{ A}$$

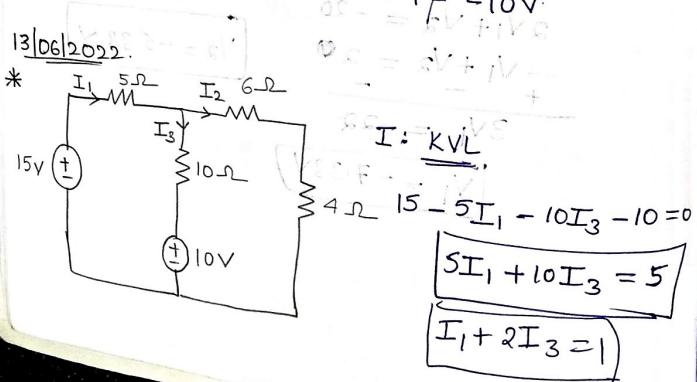
$$= 400 \text{ mV}$$

$$I = 2.8 \text{ A}$$

~~$$9V_2 = -36 \text{ V}$$~~

~~$$V_2 = -4 \text{ V}$$~~

~~$$V_1 = -10 \text{ V}$$~~



I: KVL

$$15 - 5I_1 - 10I_3 - 10 = 0$$

$$5I_1 + 10I_3 = 5$$

$$I_1 + 2I_3 = 1$$

II:

$$10 - 10I_3 - 6I_2 - 4I_2 = 0$$

$$10 = 10I_3 + 10I_2$$

$$I_3 + I_2 = 1$$

$$I_1 + 2I_1 - 2I_2 = 1$$

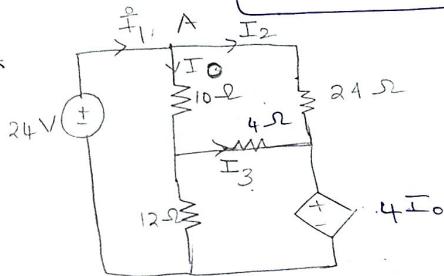
$$3I_1 - 2I_2 = 1$$

$$I_2 = 1 \text{ A}$$

$$I_3 = I_1 - I_2$$

$$I_1 = 1 \text{ A}$$

$$3I_1 - 1 = 2I_2$$



III:

$$-24 + 10(I_1 - I_2) + 12(I_1 - I_3) = 0$$

$$-24 + 22I_1 - 12I_2 - 12I_3 = 0 \quad \text{--- (1)}$$

$$24I_2 + 10(I_1 - I_2) = 0$$

$$-10I_1 + 14I_2 = 0 \quad \text{--- (2)}$$

$$-18I_2 + 10I_1 + 4I_3 = 0 \quad \text{--- (2)}$$

III:

$$-4(I_3 - I_2) - 4(I_1 - I_2) + 12(I_3 - I_1) = 0$$

$$-16I_3 + 8I_2 + 8I_1 = 0$$

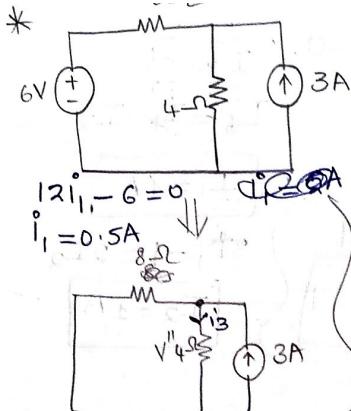
$$8I_1 + 8I_2 - 16I_3 = 0$$

$$I_1 + I_2 - 2I_3 = 0 \quad \text{--- (3)}$$

$$I_1 = 6 \text{ A}$$

~~$$I_2 = 4.5 \text{ A}$$~~

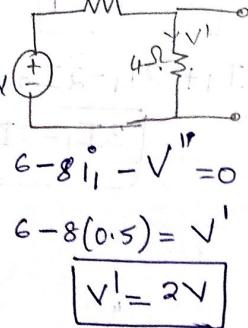
$$I_3 = 5.25 \text{ A}$$



Determine V_o using

SPT

$$8\Omega$$



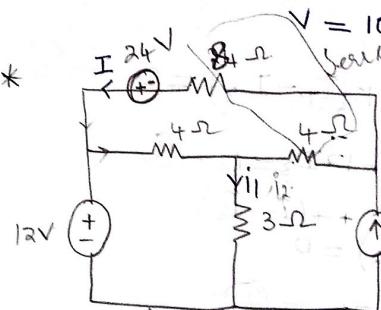
$$6 - 8i_1 - V' = 0$$

$$6 - 8(0.5) = V'$$

$$V' = 2V$$

$$i_3 = \frac{3 \times 8}{12}$$

$$i_3 = 2A \quad V'' = 4 \times 2 = 8V$$



Determine I^o using
SPT

24V removed.

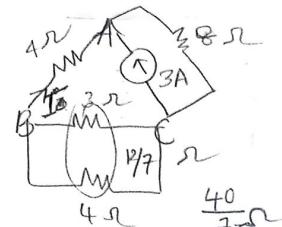
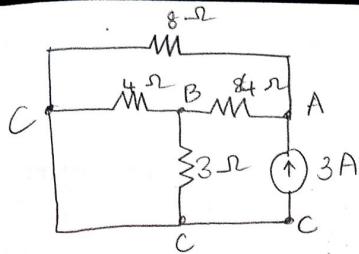
$$i_1 = \frac{12}{4+12} = \frac{12}{16} = \frac{3}{4}A = 0.75A$$

s.c.

$$i_2 = \frac{7}{7+4} = 1A$$

$$I = \frac{24}{(4+12)+4} = \frac{24}{16} = 1.5A$$

$$= \frac{24 \times 7}{12 + 12 \times 7} = \frac{2 \times 7}{8} = \frac{7}{4}A$$

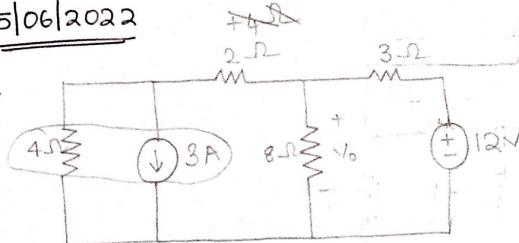


$$i_3 = \frac{4 \times 7}{4+7} = \frac{28}{11} = 1A$$

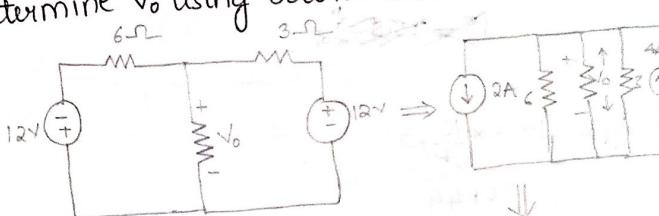
$$I = \frac{3 \times 8}{8+40} = \frac{24}{48} = \frac{1}{2}A$$

$$I = \frac{7}{4}A$$

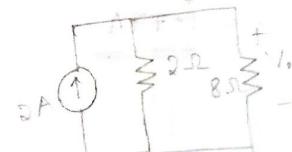
15/06/2022

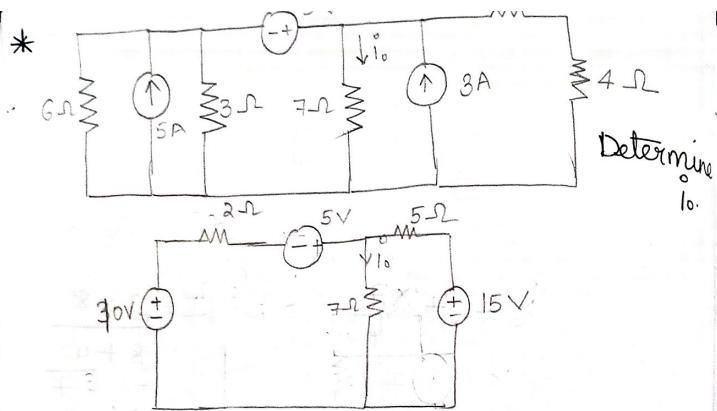


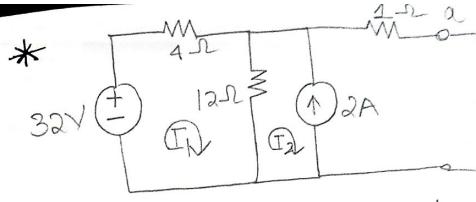
Determine V_o using source transformation.



$$V_o = (2)(\frac{16}{5}) = 3.2V$$





* 

$R_L = 6\Omega$

$I_2 = -2A$

$32 - 4I_1 - 12(I_1 + 2) = 0$

$32 - 16I_1 - 24 = 0$

$16I_1 = 8$

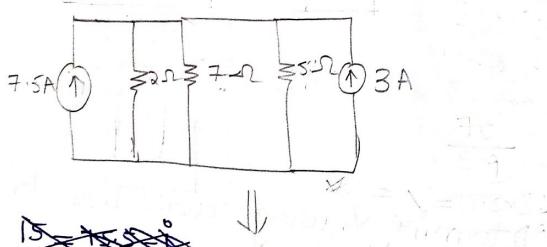
$I_1 = 0.5A$

$\text{Voc} = (I_1 - I_2)12$

Ques
 $(4 \parallel (12+1))$
 $R_{Th} = \frac{4 \times 12}{16}$
 $= 4\Omega$

Voltage across 12Ω is same as Voc .

$\text{Voc} = 2.5 \times 12$
 $\boxed{\text{Voc} = 30V} = V_{Th}$ $I_{Th} = \frac{\text{Voc}}{R_{Th} + R_L} = \frac{V_{Th}}{R_{Th} + R_L}$



$R_L = 16\Omega$

$I_{Th} = \frac{30}{2\Omega} = 1.5A$

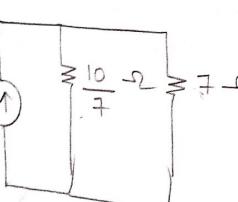
$R_L = 36\Omega$

$I_{Th} = \frac{30}{4+6} = 3A$

$I_{Th} = \frac{30}{40} = 0.75A$

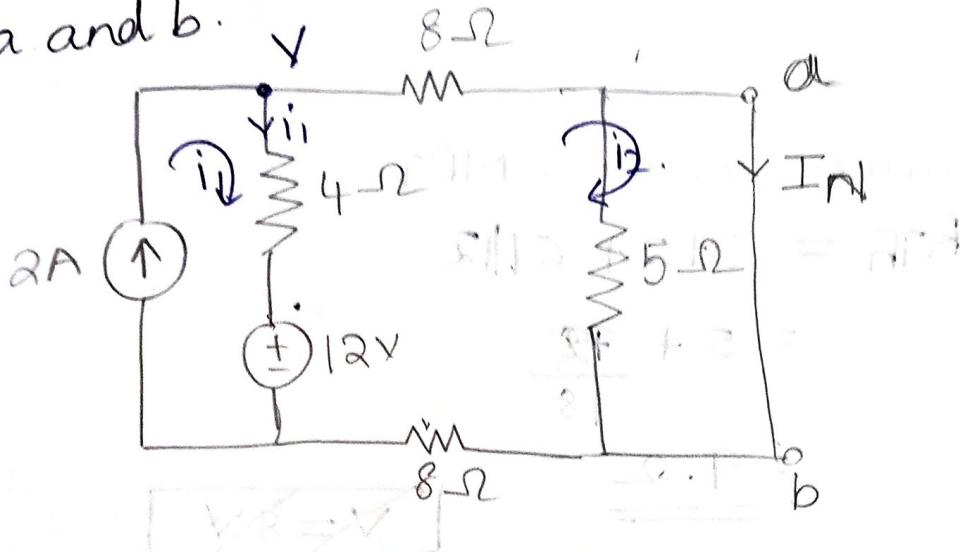
$I_1 = \frac{10.5 \times 10 \times 7}{10+49} = 0.5A$

$I_1 = 1.77A$



17/06/2022

* Determine Norton's equivalent circuit b/w
a and b.



$$2 = \frac{V - 12}{4} + \frac{V}{16}$$

$$2 \times 16 = 4V - 48 + V$$

$$5V = 80$$

$$V = 16V$$

$$R_N = 5 \parallel (8 + 4 + 8)$$

~~$$= \frac{4}{25}$$~~

~~$$R_N = 4\Omega$$~~

~~$$I = \frac{12}{4} = 3A$$~~

$\therefore 5\Omega$ resistor is

ignored

~~$$\therefore 2A = i_1$$~~

$$20i_2 - 4i_1 - 12 = 0$$

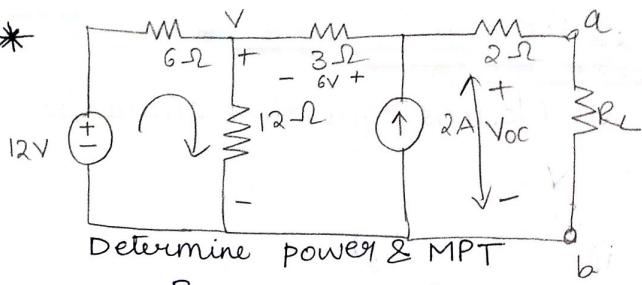
~~$$I_N = \frac{3}{2} A$$~~

$$20i_2 - 8 - 12 = 0$$

$$\boxed{I_N = 1A}$$

$$\boxed{i_2 = 1A}$$

$$\frac{V - 12}{4} = I_N = \frac{16 - 12}{4} = 1A$$

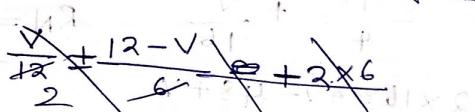


$$R_{Th} = 3 + 2 + 6 \parallel 2$$

$$= 5 + \frac{12}{18}$$

$$= 9 \Omega$$

$$\boxed{V = 8V}$$



$$V = 24 - 2V$$

$$\frac{V}{12} = \frac{12-V}{6} + 2$$

$$\frac{V}{12} = \frac{12-V+12}{6}$$

$$V = 48 - 2V$$

$$3V = 48$$

$$\boxed{V = 16V}$$

$$V + 6 \neq -V_{oc} = 0$$

$$V_{oc} = V_{Th} = 22V$$

$$P_{max} = \frac{V^2}{4R_{Th}}$$

$$= \frac{(22)^2}{4 \times 9}$$

$$= \frac{(22)^2}{36}$$

$$\boxed{P_{max} = 13.44W}$$

* Capacitor:

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- 2 metallic plates separated by dielectric material.

- Stores energy in the form of charge / electric field.

$$\boxed{C = \frac{\epsilon A}{d} F}$$

$q \propto V$
charge \propto voltage.

$$\boxed{q = CV}$$

$$\frac{dq}{dt} = C \frac{dv}{dt}$$

$$\boxed{i = C \frac{dv}{dt}}$$

$$\boxed{W = \int pdt}$$

$$W = \int P dt$$

P = power

$$W = \int VI dt$$

$$W = \int V \cdot C \frac{dv}{dt} dt \Rightarrow W = \int Cv dv$$

$$\boxed{W = \frac{Cv^2}{2}}$$

$$v = \frac{1}{C} \int_{-\infty}^t idt$$

$$v = \frac{1}{C} \left[\int_{-\infty}^0 idt + \int_0^t idt + \int_t^\infty idt \right]$$

$$v = V_0 + 0 + \int_0^t idt$$

$$\boxed{v = V_0 + \int_{0+}^t idt}$$

* When we apply DC; the capacitor acts as open circuit

* Response oscillates over the final condition until the steady state where it attains a steady state value.

Capacitor delivers energy only for short time.

∴ It is a passive element

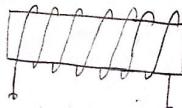
* Capacitor do not allow sudden changes in voltage.

* Capacitor acts as voltage source under initial conditions and acts as open circuit under final conditions

* Inductance : (L)

- Stores energy in the form of magnetic field.

- Rate of change of flux generates an emf.



$$V \propto \frac{di}{dt}$$

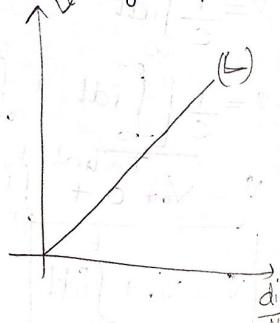
$$V = L \frac{di}{dt} \quad \boxed{= N \frac{d\phi}{dt}}$$

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

N = No. of turns

A = area of the bar

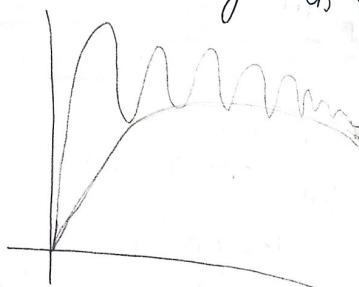
l = length of bar.



* Inductor is a passive element.

* Active elements provide energy for infinite time.

* Passive elements provide energy for a short interval of time.



$$L = \frac{\text{Flux Linkage}}{\text{Amperes}}$$

$$V = L \frac{di}{dt}$$

$$i = \frac{1}{L} \int v dt$$

$$I = \frac{1}{L} \left[\int_{-\infty}^{0-} v dt + \int_{0-}^{0+} v dt + \int_{0+}^{t} v dt \right]$$

$$I = I_0 + \int v dt$$

* Inductor acts as current source under initial conditions.

⇒ Inductor do not allow sudden changes in current.

* Inductor acts as short circuit under final conditions.

$$* \boxed{L_1 + L_2 = L} \rightarrow \text{Series}$$

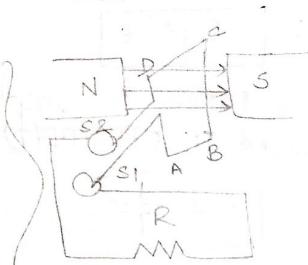
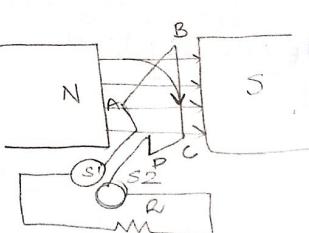
$$\boxed{L = \frac{L_1 L_2}{L_1 + L_2}} \rightarrow \text{Parallel}$$

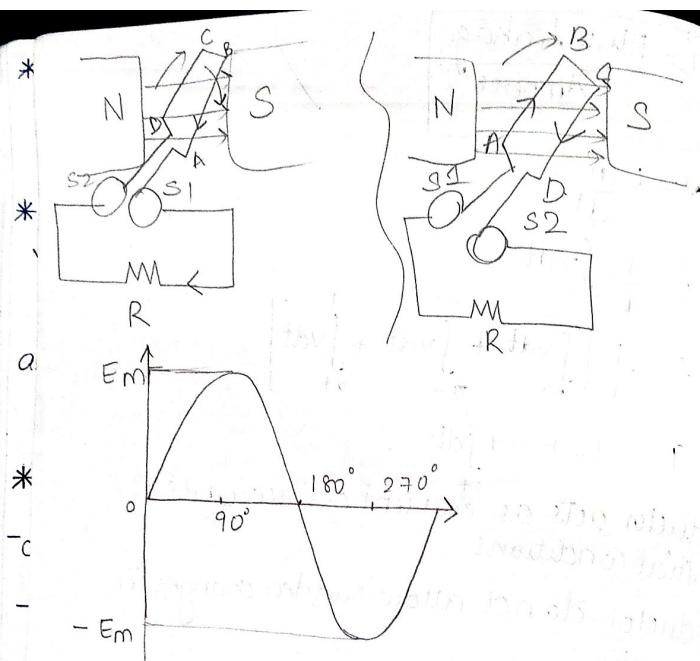
$$* \boxed{C_1 + C_2 = C} \rightarrow \text{Parallel}$$

$$\boxed{C = \frac{C_1 C_2}{C_1 + C_2}} \rightarrow \text{Series}$$

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* AC GENERATOR :





→ AC can be transmitted to a higher voltage frequencies due to which it is very economical:

Ex: Transformer

$$e = E_m \sin \omega t$$

ω = Angular frequency / velocity

$$\omega = \theta / t$$

θ = Angular displacement

$$\theta = \omega t$$

$$\Rightarrow e = E_m \sin \theta$$

* Time taken to complete one cycle is called TIME PERIOD (T)

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

* No. of cycles per second is called FREQUENCY.

$$f = 50 \text{ Hz} \quad T = 20 \text{ msec} \Rightarrow \text{Complete cycle.}$$

$$T = 10 \text{ msec} \Rightarrow \text{Half cycle.}$$

$$\boxed{\omega = 2\pi/T}$$

$$\omega = \frac{2\pi}{T}$$

$$f = \frac{2\pi}{\omega}$$

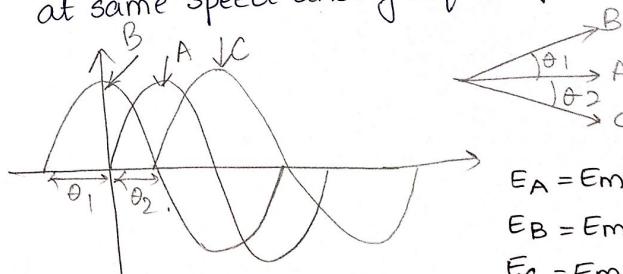
$$\boxed{\omega = 2\pi f}$$

$$\boxed{\omega = 2\pi f} \quad \boxed{f = \frac{\omega}{2\pi}}$$

* Grid has the capability to take the excess power as well as to provide it if it is in deficiency for a customer.

* A rotating vector is called PHASOR.

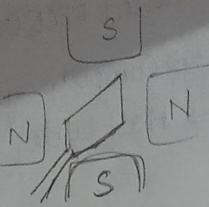
To compare 2 waves; both waves should be at same speed and frequency.



$$E_A = E_m \sin \theta$$

$$E_B = E_m \sin(\theta + \theta_1)$$

$$E_C = E_m \sin(\theta - \theta_2)$$



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$$f = \frac{\text{no. of cycles}}{\text{sec}} = \frac{\text{no. of cycles}}{\text{no. of revolutions}} \times \frac{\text{no. of revolutions}}{\text{sec}}$$

$$= \frac{P}{2} \times \frac{N}{60}$$

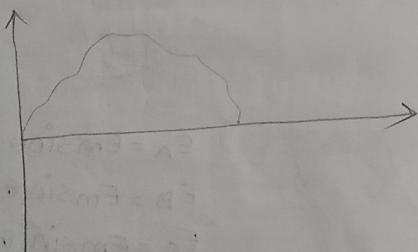
$$50 = \frac{PN}{60}$$

$$f = \frac{NP}{120}$$

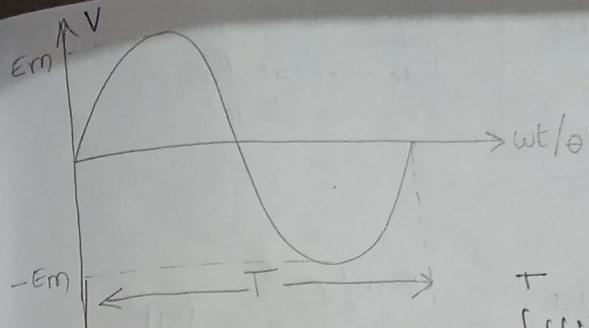
$$N = \frac{50 \times 60}{1}$$

Mechanically it completes half cycle and electrically it completes complete cycle.

* Average Value of a sinusoid:



$$F_{av} = \frac{\text{area under curve}}{\text{length of the time base}}$$



$$\text{Average Value} = F_{av} = \frac{1}{T} \int_0^T f(t) dt$$

$$\begin{aligned} * \text{Take only half cycle. } F_{av} &= \frac{1}{\pi} \int_0^{\pi} E_m \sin \theta d\theta \\ &= \frac{E_m}{\pi} (-1) (-1) \end{aligned}$$

$$F_{av} = \frac{2E_m}{\pi}$$

$$* \underline{\text{RMS Value}}: \quad \sqrt{\frac{F_1^2 + F_2^2 + \dots + F_n^2}{n^2}}$$

$$F_{rms} = \sqrt{\frac{1}{T} \int_0^T f^2(t) dt}$$

$$F_{rms} = \sqrt{\frac{1}{\pi} \int_0^{\pi} E_m^2 \sin^2 \theta d\theta}$$

$$= \sqrt{\frac{E_m^2}{\pi} \int_0^{\pi} \frac{1 - \cos 2\theta}{2} d\theta}$$

$$= \sqrt{\frac{E_m^2}{2\pi} (\pi - 0)} = \frac{E_m}{\sqrt{2\pi}} = \frac{E_m}{\sqrt{2}}$$

* Average Value

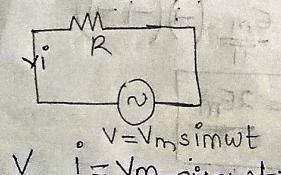
$$I_{dc} \rightarrow Q, t \\ I_{ac} \rightarrow "$$

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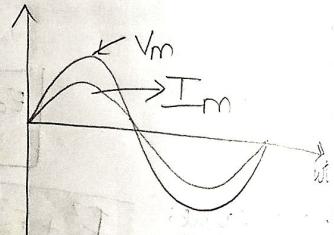
* Form Factor:

$$= \frac{\text{Rms Value}}{\text{Avg Value}} = \frac{E_m / \sqrt{2}}{2E_m / \pi} = 1.11$$

* AC through pure resistance:



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



$$\phi = \frac{1}{2} \pi$$

$$P_{av} = \frac{1}{T} \int_0^T V_m I_m \sin^2 \omega t dt = 0 \\ = \frac{V_m I_m}{2\pi} \int_0^{\pi} (1 - \cos 2\omega t) dt.$$

$$= \frac{V_m I_m}{2\pi} \left[\omega t - \frac{1}{2} \sin 2\omega t \right]_0^{\pi}$$

$$= \frac{V_m I_m}{2} \Rightarrow P = \frac{\sqrt{2} V_m}{2} \times \frac{I_m}{\sqrt{2}}$$

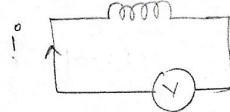
$$P = \sqrt{V_{rms} \times I_{rms}}$$

$$P = \sqrt{V_{rms} \times I_{rms}}$$

\Rightarrow In half cycle, 2ω completes full cycle. \Rightarrow avg $= 0$

\Rightarrow In half cycle, 2ω completes full cycle. \Rightarrow avg $= 0$

* AC through pure inductance

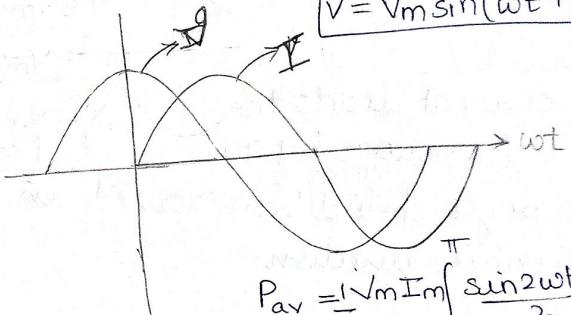


$$V = L \frac{di}{dt}$$

$$\omega L = 2\pi f L \\ = X_L$$

$$V = V_m \cos \omega t \\ V_m = X_L I_m$$

$$V = V_m \sin(\omega t + 90^\circ)$$



$$P_{av} = i \frac{V_m I_m}{\pi} \int_0^{\pi} \sin^2 \omega t d\omega t$$

$$= \frac{V_m I_m}{\pi} \frac{1}{2} (0)$$

$$P_{av} = 0$$

$$j = \sqrt{-1} \\ j^2 = -1$$

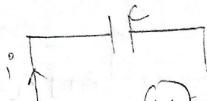
current lagging voltage by 90°

Inductor will not consume any power.

$$i = I_m e^{j\omega t} \\ \vartheta = I_m j \omega L e^{j\omega t}$$

$$V = j X_L I_m e^{j\omega t}$$

* AC through pure capacitance:



$$V = V_m \sin \omega t$$

$$i = c \frac{dy}{dt}$$

$$i = c V_m \omega \cos \omega t$$

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

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

$$X_C = \frac{1}{2\pi f C}$$

$$I = -j X_C V_m e^{j\omega t}$$

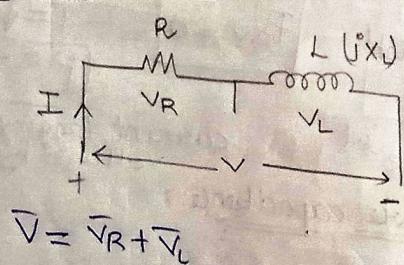
$$\begin{aligned} V &= V_m e^{j\omega t} \\ i &= I_m e^{j\omega t} \\ I &= I_m e^{j\omega t} / j X_C \end{aligned}$$

current leads the voltage by 90° .

→ Leading angle should be measured in anti-clockwise direction.

01/07/2022

* SERIES R-L circuit:



$$V = V_R + V_L$$

$$= IR + I(jX_L)$$

$$V = I(R + jX_L)$$

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

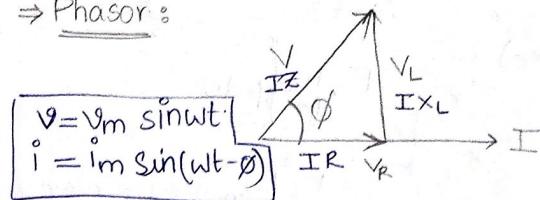
$$R + jX_L = Z \text{ (impedance)}$$

$$\text{Admittance } Y = \frac{1}{Z}$$

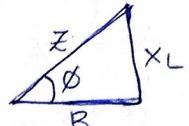
$$j = 1 \angle 90^\circ$$

→ For pure resistance; V & I are at 0° ; i.e. V & I are in phase.

⇒ Phasor:



$$\phi = 0 \text{ to } 90^\circ$$



Impedance Δ

clockwise → \rightarrow lagging angle

cosine

$$P = \frac{1}{\pi} \int_0^{\pi} P d\theta$$

$$= \frac{1}{\pi} \int_0^{\pi} V_m I_m \sin \theta \sin(\theta - \phi) d\theta$$

$$= \frac{V_m I_m}{\pi} \int_0^{\pi} \left[\cos\left(\frac{\phi}{2}\right) - \cos\left(\frac{2\theta - \phi}{2}\right) \right] d\theta$$

$$= \frac{V_m I_m}{\pi} \int_0^{\pi} \left[\cos\phi - \cos(2\theta - \phi) \right] d\theta$$

$$= \frac{V_m I_m}{2\pi} \cdot \cos\phi \cdot \pi$$

$\cos\phi = \text{Power factor}$

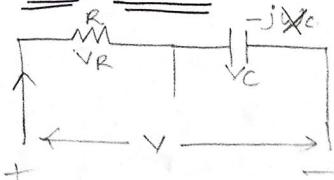
$$P = \frac{V_m I_m \cos\phi}{2}$$

$$P = V_{rms} I_{rms} \cos\phi$$

$$P = VI \cos\phi$$

* ϕ should be close to 0° so as to get max. power

* SERIES RC CIRCUIT:



$$V = V_R + V_C$$

$$= IR + I(-jX_C)$$

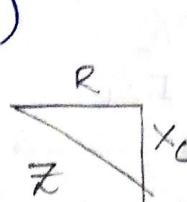
$$Z = R - jX_C$$

$$= I(R - jX_C)$$

$$V = IZ$$

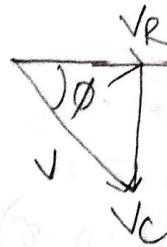
$$Z = \frac{V}{I}$$

$$P = VI$$



$$P = \frac{1}{\pi} \int_0^{\pi} P d\theta$$

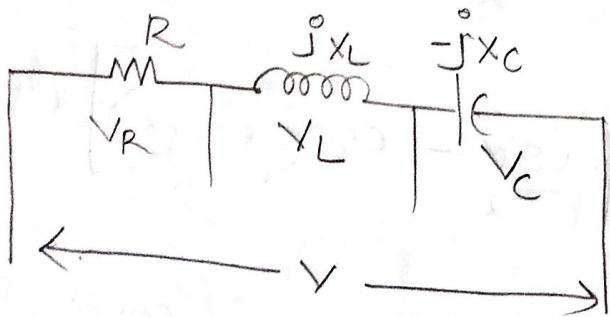
$$= \frac{1}{\pi} \int_0^{\pi} V_m \sin\theta \cdot I_m \sin(\theta) d\theta$$



$$I = \frac{V_m I_m}{\pi} \int_0^{\pi} \sin\theta \cdot \sin(\theta - \phi) d\theta$$

$$P = \frac{V_m I_m}{2} \cos\phi$$

* SERIES LCR CIRCUIT:

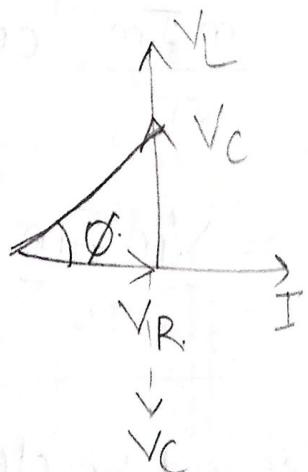


$$V = V_R + V_L + V_C$$

$$= IR + IjX_L - IjX_C$$

$$= IR + Ij(X_L - X_C)$$

$$V = I(R + j(X_L - X_C))$$

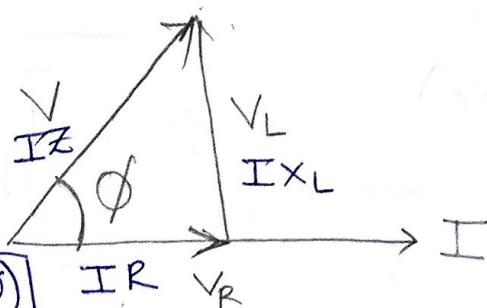


→ For pure resistance; V & I are at 0°
i.e. V & I are in phase.

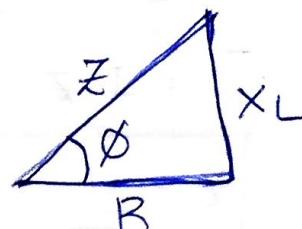
→ Phasor:

$$V = V_m \sin \omega t$$

$$i = i_m \sin(\omega t - \phi)$$



$$\phi = 0 \text{ to } 90^\circ$$



Impedance Δ

Clockwise → ve → lagging angle

$$P = \frac{1}{\pi} \int_0^{\pi} P d\theta$$

$$= \frac{1}{\pi} \int_0^{\pi} V_m I_m \sin \theta \sin(\theta - \phi) d\theta$$

$$= \frac{V_m I_m}{\pi} \int_0^{\pi} \left[\frac{\cos(\phi)}{2} - \frac{\cos(2\theta - \phi)}{2} \right] d\theta$$

$$= \frac{V_m I_m}{\pi} \int_0^{\pi} \left[\frac{\cos \phi - \cos(2\theta - \phi)}{2} \right] d\theta$$

$$= \frac{V_m I_m}{2\pi} \cdot \cos \phi \cdot \pi$$

$\cos \phi$ = Power factor

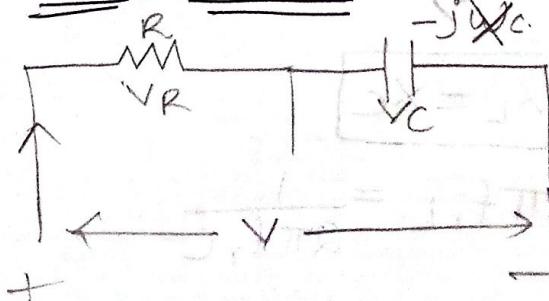
$$P = \frac{V_m I_m}{2} \cos \phi$$

$$P = V_{rms} I_{rms} \cos \phi$$

$$P = VI \cos \phi$$

* ϕ should be close to 0° so as to get max power

* SERIES RC CIRCUIT:



$$(R + jX)I + R = V$$

$$jE_{RC} = jX$$

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

$$= IR + I(-jx_C)$$

$$= I(R - jx_C)$$

$$\bar{V} = IZ$$

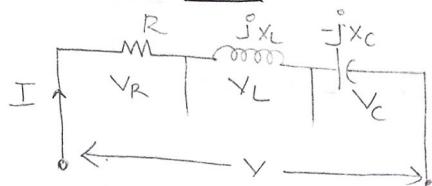
$$Z = \frac{\bar{V}}{I}$$

$$P = VI$$

$$Z = R - jx_C$$

$$\begin{aligned} P &= \frac{1}{\pi} \int_0^\pi P d\theta \\ &= \frac{1}{\pi} \int_0^\pi V_m \sin\theta \cdot I_m \sin(\theta) d\theta \\ &= \frac{V_m I_m}{\pi} \int_0^\pi \sin\theta \cdot \sin(\theta - \phi) d\theta \\ &= \frac{V_m I_m}{2} \cos\phi \end{aligned}$$

* SERIES LCR CIRCUIT:



$$V = V_R + V_L + V_C$$

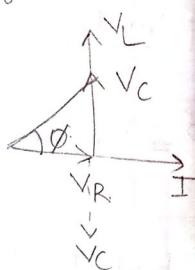
$$= IR + Ijx_L - Ijx_C$$

$$= IR + Ij(x_L - x_C)$$

$$V = I(R + j(x_L - x_C))$$

$$Z = R + j(x_L - x_C)$$

$$\begin{aligned} x_L &= 2\pi f L \\ x_C &= \frac{1}{2\pi f C} \end{aligned} \quad \left. \begin{aligned} x_L &= x_C \\ 2\pi f_r L &= \frac{1}{2\pi f_r C} \end{aligned} \right.$$

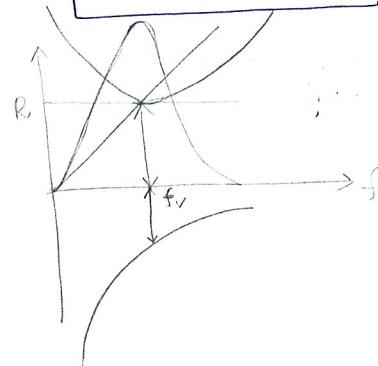


05/07/2022

$$f_r^2 = \frac{1}{4\pi^2 LC} \Rightarrow f_r = \frac{1}{2\pi\sqrt{LC}}$$

at $Z = R$ i.e. $x_L = x_C = 0$

$$I_{max} = \frac{V}{Z} = \frac{V}{R}$$



$$* f = 50 \text{ Hz} \quad R = 10 \Omega \quad L = 10 \text{ mH} ; C = 10 \mu\text{F} \quad V = 250 \text{ V}$$

$$x_L = \frac{2\pi f L}{= 314 \times 10 \times 10^{-3}}$$

$$\boxed{x_L = 3.14 \Omega}$$

$$x_C = \frac{1}{2\pi f C} = \frac{1}{314 \times 10^{-5}} = \frac{10^5}{314}$$

$$\omega = \frac{1}{2\pi\sqrt{LC}}$$

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

$$= 80.18 \text{ Hz} \quad 503.54 \text{ Hz}$$

$$I = \frac{250}{10} = 25 \text{ A}$$

$$(x_L)_r = 31.622 \Omega \quad (x_C)_r = \frac{1}{2\pi f_r C}$$

$$V_L = 25 \times 31.622 \quad V_C = 31.623 \Omega \\ = 790.57 \text{ V} \quad = 790.57 \text{ V}$$

$$* R = 7 \Omega; L = 31.8 \text{ mH}; V = 230V; f = 50 \text{ Hz}$$

$$X_L = 2 \times 3.14 \times 50 \times 31.8 \times 10^{-3} = 12.2 \Omega$$

$$= 9.98 \Omega$$

$$jX_L = 9.98 j$$

$$= 10j$$

$$I = \frac{230}{7+10j} = \frac{230}{7+10j} = 18.85 A$$

$$\tan \phi = \frac{X_L}{R} = \frac{12.2}{7} = \frac{10}{7} =$$

$$\phi = 55^\circ$$

$$\cos \phi = 0.57$$

$$P = VI \cos \phi = 247.23 W$$

$$\text{Voltage across } R = IR = 18.85 \times 7 = 131.95 V$$

$$\text{across } L = I \times L = 188.5 V$$

$$* V = 250V; f = 50 \text{ Hz}; I = 5A; P = 750W$$

$$\cos \phi = \frac{P}{VI} = \frac{750}{250 \times 5} = \frac{3}{5}, \text{ lag}$$

$$Z = \frac{V}{I} = 50 \Omega$$

$$I^2 R = 750 \quad \text{no power through}$$

$$R = \frac{750}{25} = 30 \Omega$$

$$Z^2 = R^2 + X_L^2$$

$$(R^2 + X_L^2) = 2500 - 900 = 1600$$

$$X_L^2 = 1600$$

$$X_L = 40 \Omega$$

$$2\pi f L = 40$$

$$L = \frac{40}{2 \times 3.14 \times 50} =$$

$$L = 0.127 H$$

$$* i(t) = 5 \sin(314t + 2\pi/3)$$

$$v(t) = 15 \sin(314t + 5\pi/6)$$

- (i) Impedance (ii) Inductance (iii) average Power
 (iv) Power factor ($\cos \phi$). (v) Resistance

$$\phi = \frac{5\pi}{6} - \frac{2\pi}{3} = \frac{\pi}{6} = 30^\circ$$

current lags the voltage applied by 30° .

$$Z = \frac{V_m}{I_m} = \frac{15}{5} = 3 \Omega$$

$$Z^2 = X_L^2 + R^2$$

$$X_L^2 = 9 - \frac{9 \times 3}{4}$$

$$X_L^2 = \frac{36 - 27}{4}$$

$$X_L = \frac{3}{2}$$

$$L = \frac{3}{2} \times \frac{1}{2\pi \times 314}$$

$$= 4.7 \times 10^{-3}$$

$$= 4.7 \text{ mH}$$

$$\omega = 314 = 2\pi f$$

$$P = I^2 R = VI \cos \phi = \frac{15}{\sqrt{2}} \cdot \frac{5}{\sqrt{2}} \cos 30^\circ = \frac{75 \times \sqrt{3}}{2}$$

$$P = 75 \sqrt{3}/4$$

$$* C = 79.5 \mu F \quad R = 30 \Omega \quad V = 100 V$$

$$f = 50 \text{ Hz} \quad Z = \sqrt{R^2 + X_C^2} = \sqrt{30^2 + X_C^2}$$

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C} = 40 \Omega$$

$$Z = \sqrt{900 + 1600} = 50 \Omega$$

$$I = \frac{V}{Z} = 2 A$$

$$\cos \phi = \frac{R}{Z} \Rightarrow \phi = \cos^{-1}\left(\frac{R}{Z}\right) = \cos^{-1}\left(\frac{30}{50}\right) = 53^\circ \text{ lead.}$$

$$I_m = 2\sqrt{2} A$$

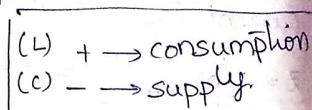
$$\omega = 2\pi f = 314 \text{ rad/sec}$$

$$I = 2.428 \sin(314t + 53)$$

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* COMPLEX POWER(S): \Rightarrow Apparent Power:

$$S = VI^* \rightarrow \text{conjugate.}$$



$$V = VL^*$$

$$I = IL - \phi$$

$$S = VI L - \phi$$

$$S = VI^* = VI L \phi = VI \cos \phi + j VI \sin \phi$$

$VI \cos \phi$ = Active Power (P)

$VI \sin \phi$ = Reactive Power (Q)

VI = Apparent Power (S)

$$* V = 100 \sin 500t$$

$$I = 25 \sin(500t - 30^\circ)$$

Determine circuit elements & their values.

Determine P, Q, S.

$$Z = \frac{V}{I} = 40 \angle 30^\circ = 3.46 + 2j$$

$$I_{rms} = \frac{25}{\sqrt{2}} \angle -30^\circ$$

$$2\pi f L = 2 \Omega$$

$$L = \frac{2\Omega}{500} = [4 \times 10^{-3} \text{ H}]$$

$$P = VI \cos \phi = \frac{2500}{2} \angle -30^\circ \cos \phi \cdot \frac{\sqrt{3}}{2}$$

$$= 1082.53 + 625j$$

$$S = VI^* = \frac{2500}{2} \angle 30^\circ = 1082.53 + 625j$$

$$VI \cos \phi = P = 1082.53 \text{ W}$$

$$VI \sin \phi = Q = 625$$

$$VI = S = 1250$$

* $V(t) = 100 \sin 314t$, $R = 10 \Omega$; $L = 0.0318 + j$,
 $C = 63.6 \mu F$,
 $i(t)$, ϕ , power factor, active power, peak value
of pulsating power.

$$X_L = \omega L = 314 \times 0.0318 = 9.98 \approx 10$$

$$X_C = \frac{1}{\omega C} = \frac{1}{314 \times 63.6} = 5 \times 10^{-5} \times 10^6 = 50$$

$$X = X_L - X_C = -40$$

$$Z = \sqrt{R^2 + Z^2} = \sqrt{(10)^2 + (-40)^2} = \sqrt{100 + 1600}$$

$$Z = \underline{\underline{41.2\Omega}}$$

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

$$= \frac{100/\sqrt{2}}{41.2} = \underline{\underline{1.716A}}$$

$$I_m = \sqrt{2} I = 1.414 \times 1.716 = \underline{\underline{2.426A}}$$

$$\phi = \tan^{-1}(-40/10) = \tan^{-1}(-4) = 76^\circ \text{ lead}$$

$$i = I_m \sin(314t + \phi)$$

$$= 2.43 \sin(314t + 76^\circ)$$

~~$$\cos \phi = \cos 76^\circ = \underline{\underline{0.24}}$$~~

$$VI = 100 \sin 314t \cdot 2.43 \sin(314t + 76^\circ)$$

$$= 243 [\cos(76^\circ) - \cos(628t + 76^\circ)]$$

$$= [58.78 - 243 \cos(628t + 76^\circ)]$$

$$= 58.78 - 243 \sin(90^\circ - 628t - 76^\circ)$$

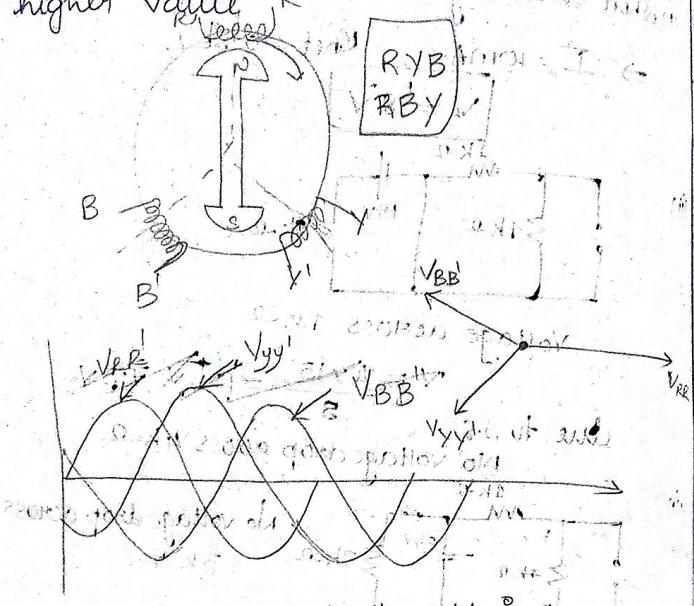
$$= \frac{58.78}{2} + \frac{243}{2} \sin(628t - 14^\circ)$$

$$= \underline{\underline{29.39 + 121.5 \sin(628t - 14^\circ)}}$$

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* THREE PHASE CIRCUITS:

→ Transformer rises the voltage to a higher value.



$$V_{RR'} = V_m \sin \omega t = V L^0$$

$$V_{yy} = V_m \sin(\omega t - 120^\circ) \equiv V_m \sin(\omega t + 240^\circ)$$

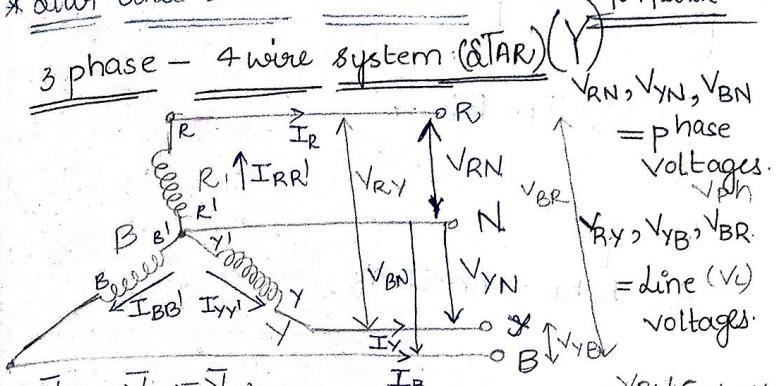
$$V_{BB} = V_m \sin(\omega t - 240^\circ) = V_m \sin(\omega t + 150^\circ)$$

*The order in which the phases attain the reference value is called phase sequence

* We can reverse the phase sequence by rotating the field in clockwise or anticlockwise direction

* Star and Delta connections:

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$$\bar{V}_{R,Y} = \sqrt{R_N} - \sqrt{Y_N}$$

$$I_L = I_{ph} \quad A \quad Y_{BB}$$

30°

$$OB = OA \cos 30^\circ$$

$$OC = 2(OB)$$

$$= 2OA \cos \theta$$

$$L_1 = 2 \cdot \sqrt{p_h} \sqrt{3}$$

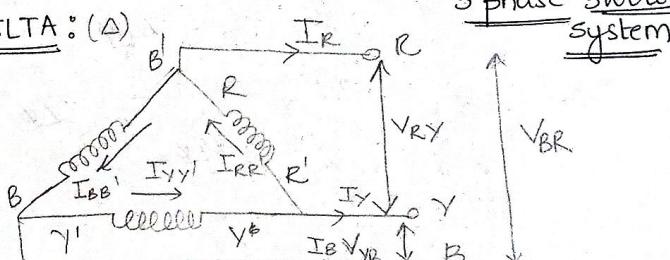
— 1 —

$$\boxed{V_L = \sqrt{3} V_{ph}}$$

Line and phase currents are equal in 3ϕ circuit (star).

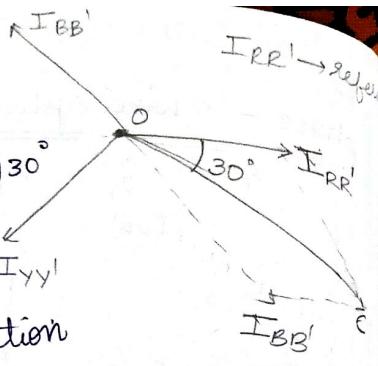
$\therefore \text{phase}(\phi) = 120^\circ \Rightarrow \text{Balanced Supply.}$

* DELTA : (Δ)



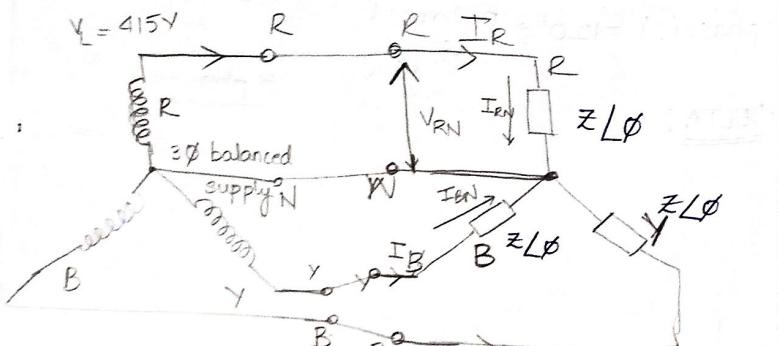
$$I_L = \sqrt{3} I_{ph}$$

I_L lags I_{ph} by 30°
 \star
 $V_L = V_{ph}$ for delta connection



* 3-PHASE STAR CONNECTION: (Y) 27/07/22

$$\begin{aligned} I_R &= \frac{V_{RN}}{Z \angle \phi} & I_Y &= \frac{415}{\sqrt{3} Z} \angle -150^\circ & \text{ph seq. RYB} \\ &= \frac{415}{\sqrt{3} Z} \angle -30^\circ & I_B &= \frac{415}{\sqrt{3} Z} \angle -240^\circ & \text{Ref } V_{RN} \end{aligned}$$



If the impedance of the 3 loads is equal then the load is said to be balanced load.

$$V_{RN} = \frac{415}{\sqrt{3}} \angle 0^\circ \quad V_{YN} = \frac{415}{\sqrt{3}} \angle -120^\circ$$

$$V_{BN} = \frac{415}{\sqrt{3}} \angle -240^\circ$$

⇒ Power in 3 φ circuit:

$$P_{3\phi} = 3(P_{1\phi})$$

$$\begin{aligned} P_{3\phi} &= 3(V_{ph} I_{ph} \cos \phi) \\ &= 3\left(\frac{V_L}{\sqrt{3}} \cdot I_L \cos \phi\right) \rightarrow \text{Star \& Delta} \end{aligned}$$

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

$$Q_{3\phi} = \sqrt{3} V_L I_L \sin \phi$$

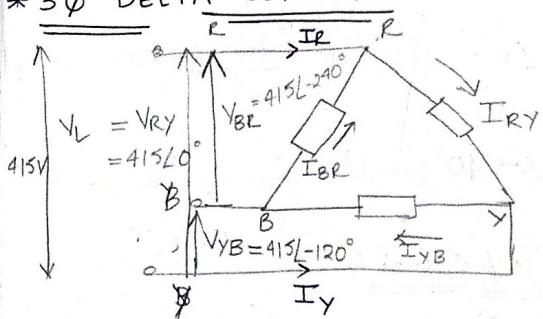
$$S_{3\phi} = \sqrt{3} V_L I_L$$

↓ delta

↓ delta

* All phases will have equal voltages i.e.
balanced circuit

* 3φ DELTA CONNECTION:



at R

$$I_R + I_{BR} \neq I_Y$$

$$I_R = 415 I_Y - I_{BR}$$

$$= \frac{415}{\sqrt{3}} \angle 0^\circ - \frac{415}{\sqrt{3}} \angle -240^\circ$$

$$= \sqrt{3} \times 83 \angle -30^\circ$$

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* DC GENERATOR:

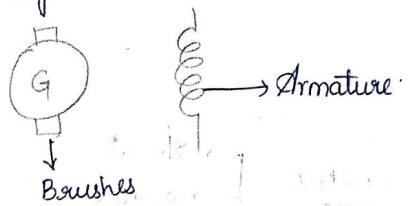
→ Generator: Mechanical Energy to Electrical energy.

* Faraday's Law of electromagnetic induction:
Whenever flux linkage is present emf is generated.

Conductor System: Armature

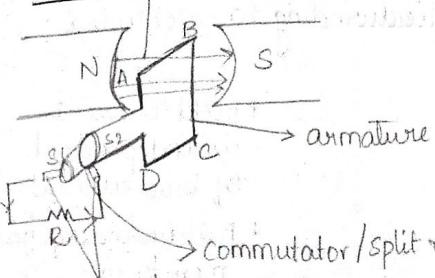
Field System: Flux system (field)

Electromagnets:



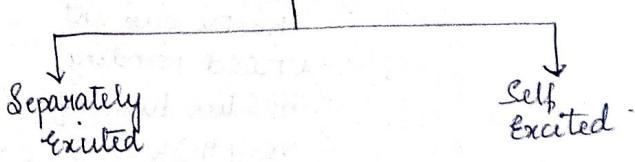
* DC Generator:

flux/field lines



commutator/split rings
Brushes (allows current to flow in 1 direction)

→ TYPES OF GENERATOR:

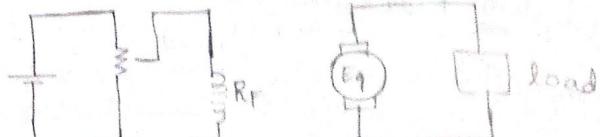


Giving energy to field winding: exciting

→ Separately excited: Giving energy from separate source.

→ Self excited: Giving energy through self.

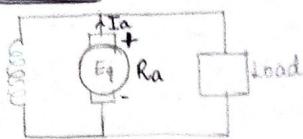
→ Separately Excited:



Self Excited:
→ Shunt
→ Series
→ Compound.

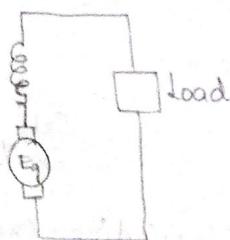
SHUNT: Armature & field winding are coupled.

→ Shunt Generator:



- * Field current is independent of load current.
- * Field winding has more turns.

→ Series Generator:



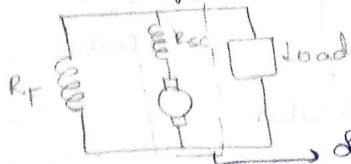
- * Load will decide the DC current.
- * Field winding has less turns of very thick wire.

→ Compound Generator:

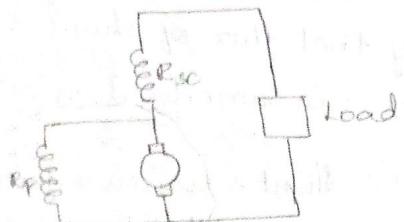
→ Long Shunt
→ Short Shunt.

Combination of Series + shunt = compound.

→ LONG SHUNT: Connecting series to shunt.



→ SHORT SHUNT: Connecting shunt to series.



✓ Shunt

GENERATORS

Separately Excited

Self-Excited.

Series

Shunt

Compound

long
shunt

short
shunt

Cumulatively
Differentially

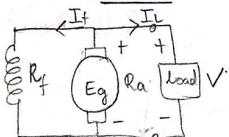
* Compound: → Cumulatively
→ Differentially
based on dim. of winding flux direction changes.

→ CUMULATIVELY: Shunt & series are joined in such a way that flux of shunt & flux of series are in same direction.

→ DIFFERENTIALLY: Shunt & series are joined connected in such a way that flux of shunt and flux of series are in opposite direction.

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* SHUNT GENERATOR:



$$I_a = I_f + I_L$$

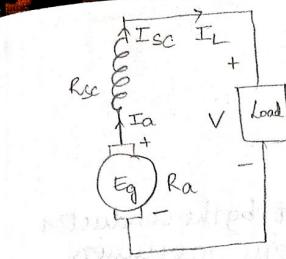
$$I_f = \frac{V}{R_f}$$

$$E_g - I_a R_a - V = 0$$

$$E_g - I_a R_a = V$$

↓ Brush drop.

* SERIES GENERATOR:



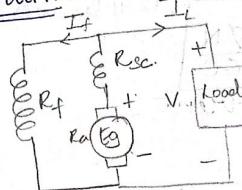
$$I_a = I_{sc} = I_L$$

$$E_g - I_a R_a - I_a R_{sc} - V = 0$$

$$V = E_g - I_a R_a - I_a R_{sc}$$

↓ Brush drop.

* Long Shunt:



$$I_f = \frac{V}{R_f}$$

$$I_a = I_{sc}$$

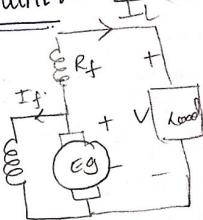
$$I_a = I_f + I_L$$

$$E_g - I_a R_a - I_a R_{sc} - V = 0$$

$$V = E_g - I_a R_a - I_a R_{sc}$$

↓ Brush drop.

* Short Shunt:



$$I_L = I_{sc}$$

$$E_g - I_a R_a - I_L R_{sc} - V = 0$$

$$V = E_g - I_a R_a - I_L R_{sc}$$

↓ Brush drop.

* EMF equation of a DC generator:

ϕ = Flux/Pole in wb.

p = No. of poles

Z = total no. of conductors in armature

N = Speed of armature in rpm.

$A = \text{No. of parallel paths}$

$$\text{Emf of conductor} / = \frac{d\phi}{dt}$$

$$\text{Emf induced} = \frac{d\phi}{dt}$$

= Flux cut by the conductor
in one revolution

Time taken for one revolution.

$$e = \frac{d\phi}{dt} = \frac{P\phi N}{60}$$

No. of parallel paths \propto Current

Lap windings: $A = P \Rightarrow$ i.e. parallel paths depends on poles.

Wave windings: $A = 2 \Rightarrow$ constant.

* Ex:

100 conductors

Lap: $P = A = 4$

$\frac{100}{4} = 25$ conductors sets are connected in series to source

$V = 25V$ and all 4 paths are parallel.

* Wave: $A = 2$

$\frac{100}{2} = 50$ conductors

$$V = 50V$$

$$E_g = \frac{P\phi N}{60} \times \frac{Z}{A} = \frac{\phi Z N}{60} \times \frac{P}{A}$$

for Lap winding: ~~A=2~~

$$E_g = \frac{\phi Z N P}{60 A}$$

for wave winding: $A=2$

$$E_g = \frac{\phi Z N P}{120}$$

* $P = 4$ $A = 2$, $Z = 720$ $N = 1000 \text{ rev/min}$ $\phi = 20 \text{ mWb}$

$$n = \frac{100\phi}{60} = \frac{50}{3}$$

$$\phi = 20 \times 10^{-3} \text{ Wb}$$

$$E_g = \frac{\phi Z N P}{120}$$

$$= \frac{20 \times 10^{-3} \times 720 \times 1000 \times 4}{120}$$

$$= 480 \text{ V}$$

* $P = 8$ $Z = 12$ $\phi = 50 \times 10^{-3}$ per slot 40 slots $E_g = 500V$

total no. of conductors = 12×40
= 480

$$E_g = \frac{\phi Z N P}{60 A}$$