30/07/24

Linear Network Theory

combinat^n of ckt

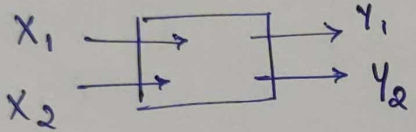
always closed path

Not necessary be closed

. Linear ckt follows additive property. & Homogeneity prop.

$$x, a \longrightarrow y = y_1^{a}$$

I/P



O/P

$$x_1 + x_2 \longrightarrow y = y_1 + y_2$$

→ R.L.C Circuit ⇒ Linear ckt

→ if. $i_1 = e^{V_1}$

$$\left.\begin{array}{l} i_2 = e^{V_2} \\ \\ i = i_1 + i_2 = e^{V_1} + e^{V_2} \end{array}\right\} \text{Non Linear}$$

$\cancel{i = e^{(V_1 + V_2)}}$

$$i = e^{V}$$

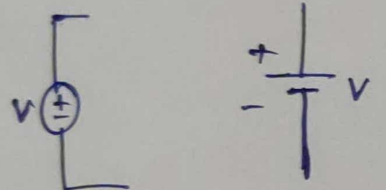
$$i = e^{(V_1 + V_2)}$$

→ **Active Element** → Any thing capable of generating energy.
↳ Generator, Battery

→ **Passive Element** →
↳ R, L, C

Sources

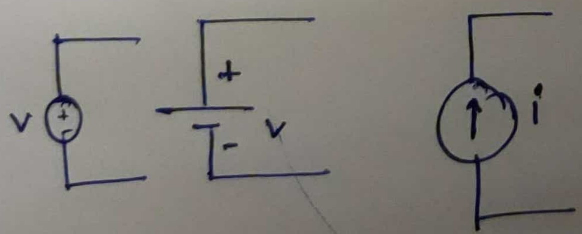
① Ac or Dc



② Independent & dependent

③ Voltage Source or Current-"

• In ideal independent Source is an active element that provides specified voltage, Current that is Completely independent of other Circuit variables.



$$\boxed{b = l + n - 1}$$

(Controlled)

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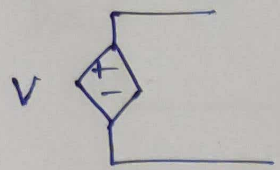
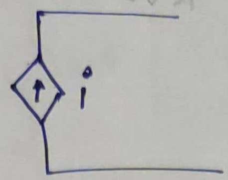
→ **Dependent Source** ⇒ is an active element in which the source quantity is controlled by another voltage or current.

Representatⁿ ⇒





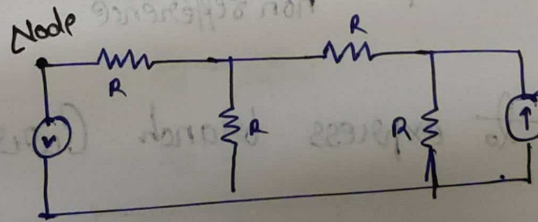
(i) Voltage Controlled current Source

(ii) Current Controlled ____, ____.

(i) Voltage controlled voltage source.

(ii) Current controlled ____, ____.

→ **Branch** ⇒ It represent single element such as voltage source, current or any ~~other~~ passive element.



6 Branches

→ **Node** ⇒ Point of Connection b/w two or more branches.

→ **Loop** ⇒ Closed path in Ckt.

A network with 'b' branches, 'l' independent loop & 'n' nodes will satisfies fundamental theorem.

Nodal Analysis

Nodal → Ohm's Law, KCL

Ohm's Law, KVL → Mesh

① Datum Node — 0V

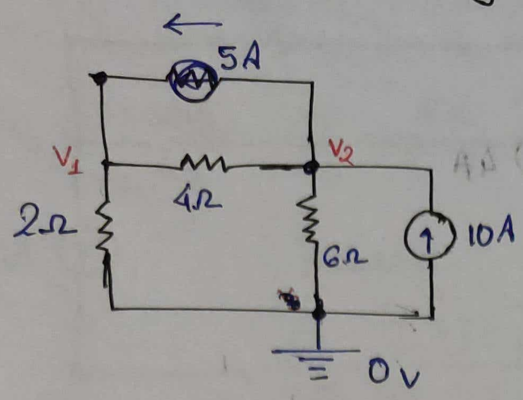
② Earth or ground — 0V

③ Reference Node — 0V

Steps to solve nodal analysis →

1. Select a node as reference node.
2. Assign voltages (V_1, V_2, ... V_{n-1}) to the remaining $n-1$ nodes.
3. Apply KCL to each of ($n-1$) non refference nodes.
4. Use ohm's Law to express branch Currents in terms of node voltages.
5. Solve the resulting simultaneous equations to obtain Unknown node voltages.

Que. 1) Calc. the node - voltages in the ckt. 02/Aug/24



At Node - 1

$$\frac{V_1 - V_2}{4} + \frac{V_1 - 0}{2} + (-5) = 0$$

$$V_1 - V_2 + 2V_1 - 20 = 0$$

$$3V_1 - V_2 = 20 \quad -①$$

At Node - 2

$$\frac{V_2 - V_1}{4} + \frac{V_2 - 0}{6} - 10 = 0$$
$$+5$$

$$3V_2 - 3V_1 + 2V_2 - \cancel{120}\ 60 = 0$$

$$5V_2 - 3V_1 = \cancel{120}\ 60 \quad -②$$

$$15V_1 - 5V_2 \cancel{= 100}$$
$$\cancel{-3V_1}$$

$$4V_2 = \cancel{140}\ 80$$

$$\cancel{V_2 = 35}\,v$$

$$\cancel{V_1} =$$

$$\boxed{V_2 = 20\ v}$$

$$V_1 = \frac{20 + V_2}{3} = \cancel{\frac{55}{3}}$$

$$\boxed{V_1 = \frac{40}{3}\ v}$$

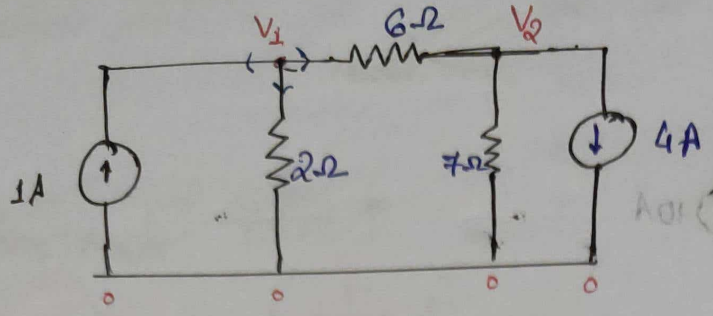
Cramer's Rule

$$\begin{bmatrix} 3 & -1 \\ -3 & 5 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 20 \\ 60 \end{bmatrix} \quad , \quad \Delta = 12$$

$$V_1 = \frac{\Delta_1}{\Delta} = \frac{\begin{bmatrix} 20 & -1 \\ 60 & 5 \end{bmatrix}}{12} = \frac{40}{3}\ v$$

$$V_2 = \frac{\Delta_2}{\Delta} = \frac{\begin{bmatrix} 3 & 20 \\ -3 & 60 \end{bmatrix}}{12} = 20\ v$$

Que.) Obtain the node volt. in ckt



At Node-1

By Applying KCL

$$-1 + \frac{V_1 - 0}{2} + \frac{V_1 - V_2}{6} = 0$$

$$\cancel{-3+}$$

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

$$4V_1 - V_2 = 6 \quad — (1)$$

At Node-2

$$\frac{V_2 - V_1}{6} + \frac{V_2 - 0}{7} + 4 = 0$$

$$7V_2 - 7V_1 + 6V_2 + 168 = 0$$

$$-7V_1 + 13V_2 = -168 \quad — (2)$$

$$\boxed{V_1 = -2\ V}$$

$$\boxed{V_2 = -14\ V}$$

Que.) Determine volt. at Node

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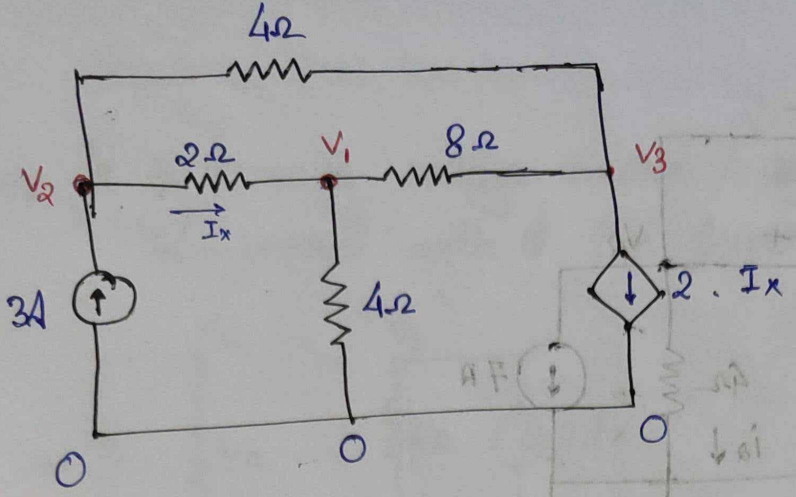


$$\frac{V_1 - V_2}{2} + \frac{V_1 - 0}{4} + \frac{V_1 - V_3}{8} = 0$$

$$4V_1 - 4V_2 + 2V_1 + V_1 - V_3 = 0$$

$$7V_1 - 4V_2 - V_3 = 0 \quad —(1)$$

$$\frac{V_2 - V_3}{4} + \frac{V_2 - V_1}{2} + 3 = 0$$

$$V_2 - V_3 + 2V_2 - 2V_1 + 12 = 0$$

$$-2V_1 + 3V_2 - V_3 = -12 \quad —(2)$$

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

$$\frac{V_3 - V_2}{4} + \frac{V_3 - V_1}{8} + 2I_x = 0$$

$$\cancel{2V_3 - 2V_2 + V_3 - V_1 + 16} = 0$$

$$\cancel{-V_1 - 2V_2 + 3V_3 = -16 = 0} \quad —(3)$$

$$\frac{V_3 - V_2}{4} + \frac{V_3 - V_1}{8} + \frac{V_2 - V_1}{1} = 0$$

$$2V_3 - 2V_2 + V_3 - V_1 + 8V_2 - 8V_1 = 0$$

$$\cancel{7V_1 - 10V_2 + 3V_3 = 0}$$

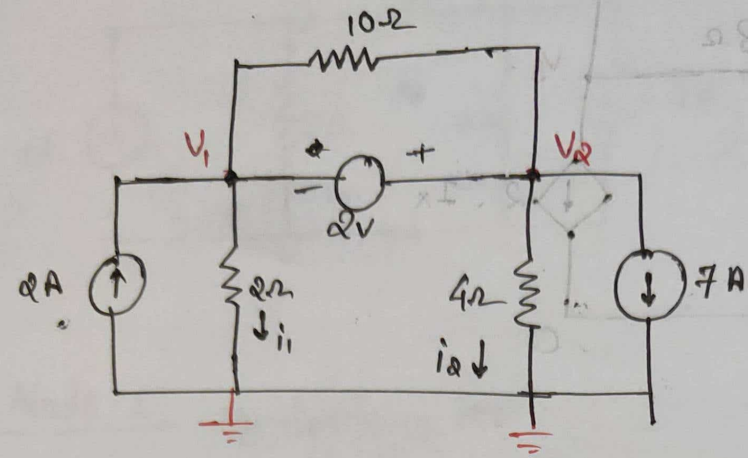
$$-9V_1 + 6V_2 + 3V_3 = 0$$

$$\boxed{V_1 = -2.4V}$$

$$\boxed{V_2 = -4.8V}$$

$$\boxed{V_3 = 2.4V}$$

Q.) Find the node volts



⇒

$$2 + \frac{V_1 - V_2}{10} + \frac{V_1}{2} - 2 = 0$$

⇒ Supernode Analysis

- For the above Circuit voltage source is present b/w two non reference source. which forms a Super node. In such cases we apply both KCL & KVL to determine node voltages.

- A Super node is formed by enclosing dependent or Independent source connected with the two non-reference ~~source connected~~ node & any element connected in parallel with it.

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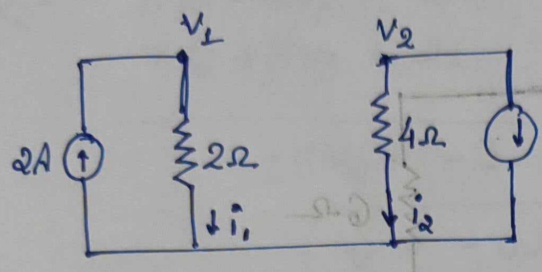
- The super node contains 2 volt source

* Step-1 ⇒ Remove voltage source & any other branches in parrel with the super node.

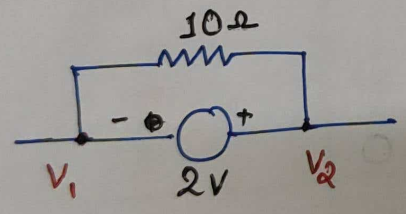


- apply KCL at super node →

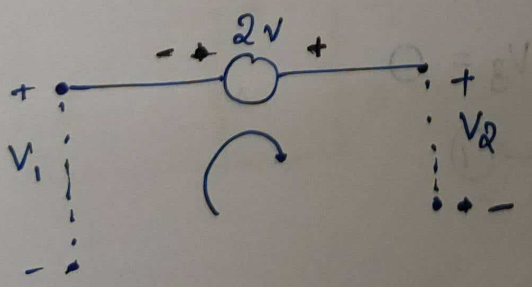
$$-2 + \frac{V_1}{2} + \frac{V_2}{4} + 7 = 0$$

$$2V_1 + V_2 = -20 \quad \text{—— (1)}$$

- Restore super node elements & aply KVL →



Apply KVL,



$$V_1 + 2 - V_2 = 0 \quad \text{—— (2)}$$

$$V_1 - V_2 = -2$$

from eqn (1) & (2)

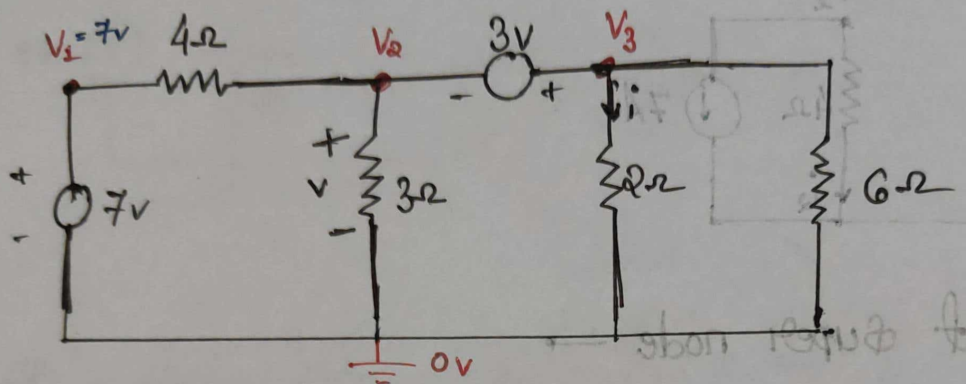
$$3V_1 = -22$$

$$\boxed{V_1 = -7.33} \text{ v}$$

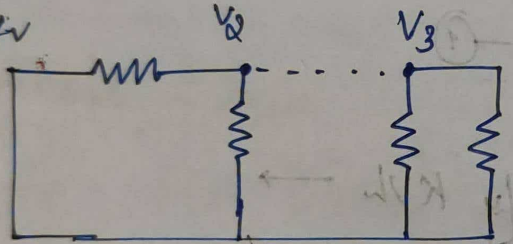
$$\boxed{V_2 = -5.33} \text{ v}$$

Note → 10Ω Resistor does not make any diff. because it is connected across super Node.

Q.2) ⇒



①



KCL →

$$\frac{V_2-7}{4}+\frac{V_2}{3}+\frac{V_3}{2}+\frac{V_3}{6}=0$$

$$3V_2-21+4V_2+6V_3+2V_3=0$$

$$7V_2+8V_3=21 \quad — ①$$

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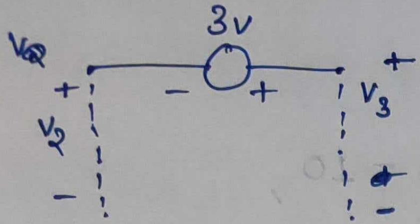
(ii)



KVL ⟶

$V_2 + 3 - V_3 = 0$

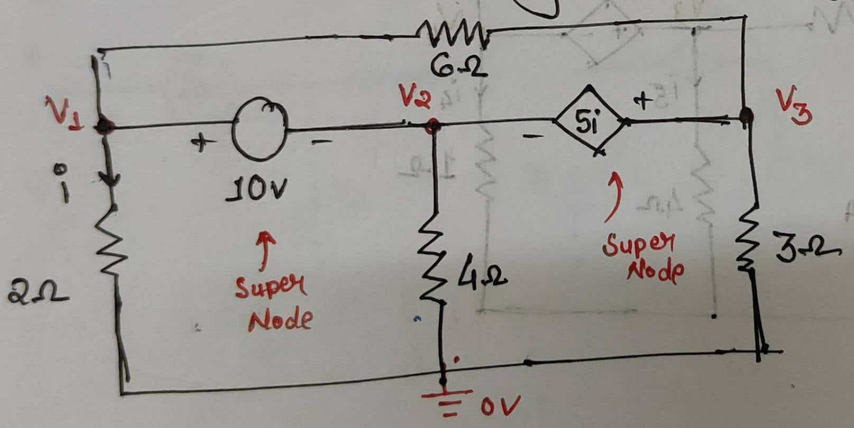
$$\cancel{7V_2} \qquad \begin{aligned} 8V_2 - 8V_3 &= -24 \\ 7V_2 + 8V_3 &= 21 \\ \hline 15V_2 &= -3 \end{aligned}$$

$$\boxed{V_2 = -0.2\,v}$$

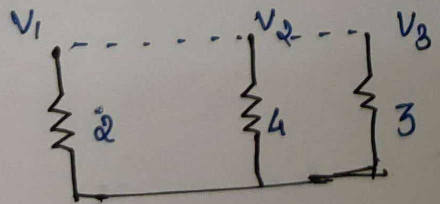
$$\boxed{V_3 = 2.8\,v}$$ Ans

$i = \frac{V_3}{2} = \frac{2.8}{2} = 1.4\,Amp$

Que.) Find V_1, V_2, V_3 using nodal Analysis.



(i)

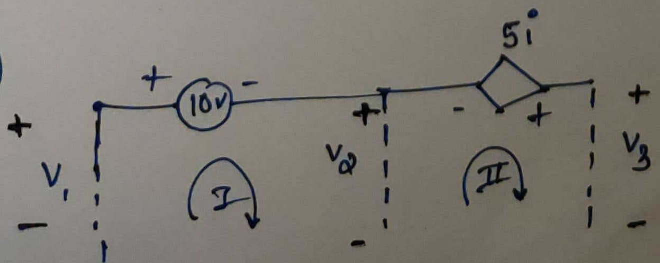


KCL ⟶

$\frac{V_1}{2} + \frac{V_2}{4} + \frac{V_3}{3} = 0$

$6V_1 + 3V_2 + 4V_3 = 0$ —— (1)

(ii)



KVL ⟶

$V_1 - 10 - V_2 = 0$ —— (2)

$V_2 + 5i - V_3 = 0$ —— (3)

$i = \frac{V_1}{2}$

$2V_2 + 5V_1 - 2V_3 = 0$, $V_1 - V_2 = 10$,

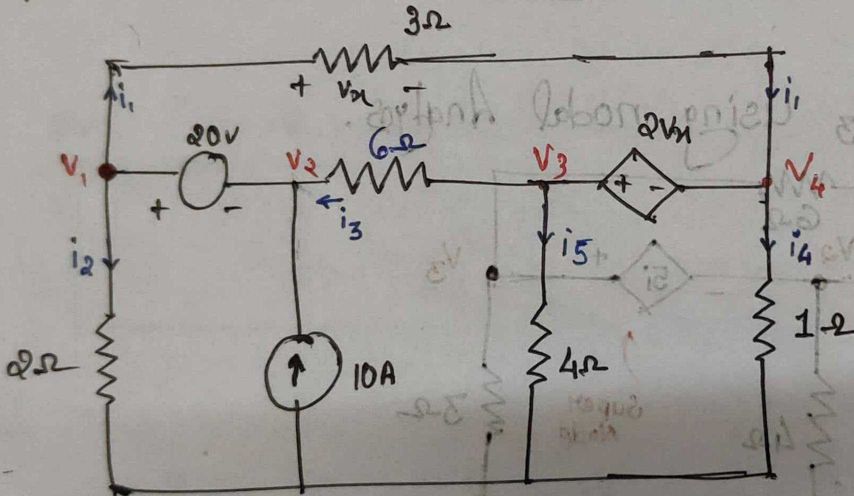
$6V_1 + 3V_2 + 4V_3 = 0$

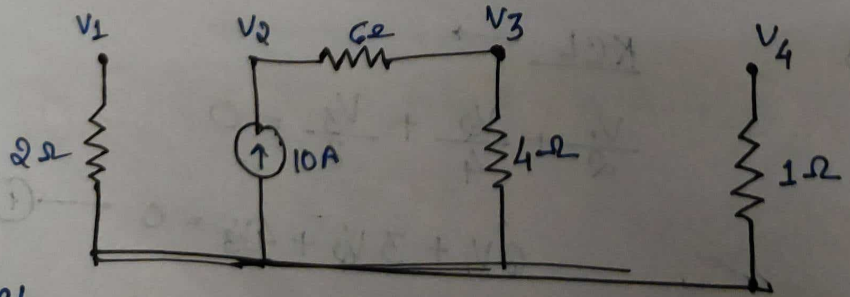
$\boxed{V_1 = 3.04\,v}$

$\boxed{V_2 = -6.95\,v}$

$\boxed{V_3 = 0.65\,v}$

Que.) Find the node-Voltage.





KCL

$\cancel{\frac{V_1}{2}}$ 10

$$i_3 + 10 = i_1 + i_2$$

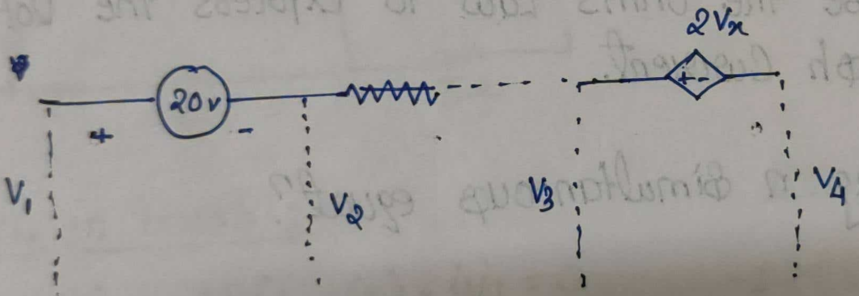
$$\frac{V_3 - V_2}{6} + 10 = \frac{V_1 - V_4}{3} + \frac{V_1}{2}$$

$$5V_1 + V_2 - V_3 - 2V_4 = 60 \quad (1)$$

$$i_1 = i_4 + i_3 + i_5$$

$$\frac{V_1 - V_4}{3} = \frac{V_4}{1} + \underbrace{\frac{V_3 - V_2}{6}}_{12} + \frac{V_3}{4}$$

$$4V_1 + 2V_2 - 5V_3 - 16V_4 = 0 \quad (2)$$



Mesh Analysis

↳ It is a loop that does not contain any other loop inside it.

A Mesh is a loop that

- Mesh analysis is applicable to planar of ckt only.
- A planar ckt is one that can be drawn in plane with no branches crossing one another.

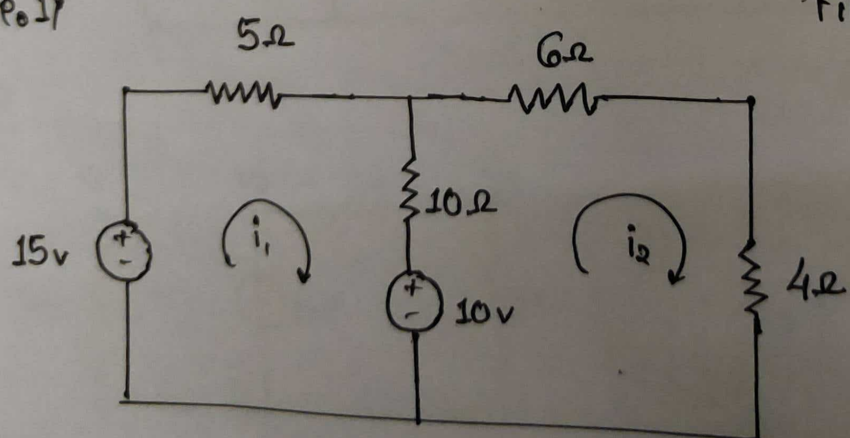
Steps to solve ⇒

(i) Identify no. of meshes and assign a mesh current $i_1, i_2, \ldots i_n$.

(ii) Apply KVL and use the ohm's Law to express the voltages in terms of mesh current.

(iii) Solve the resulting n simultaneous equat^n.

Que. 1) Find the mesh current in ckt ?



⇒

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KVL in mesh-1 ⇒

$$15 - 5i_1 - 10(i_1 - i_2) - 10 = 0$$

$$-15 i_1 + 10 i_2 = -5 \quad (1)$$

KVL in mesh-2 ⇒

$$10 - 10(i_2 - i_1) - 6i_2 - 4i_2 = 0$$

$$10 i_1 - 20 i_2 = -10 \quad (2)$$

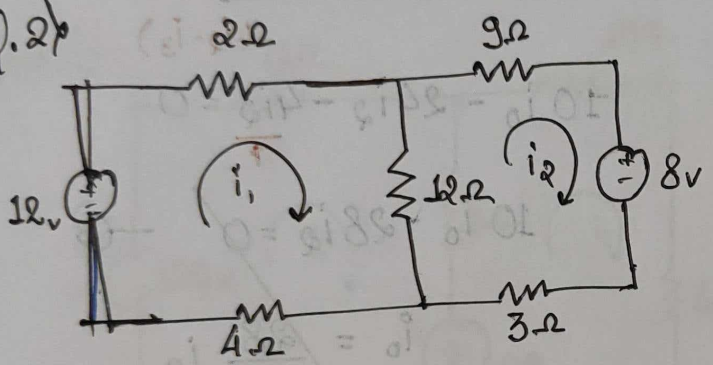
~~$i_T = 0$~~

~~$i_2 = 0.5$~~

$\boxed{i_1 = 1 \text{ Amp}}$

$\boxed{i_2 = 1 \text{ Amp}}$

Q.2)



⇒

KVL in mesh-1

$$12 - 2i_1 - 12(i_1 - i_2) - 4i_1 = 0$$

$$-18 i_1 + 12 i_2 = -12 \quad (1)$$

KVL in mesh-2

$$-12(i_2 - i_1) - 9i_2 - 8 - 3i_2 = 0$$

$$12 i_1 - 24 i_2 = 8 \quad (2)$$

By solving eqn (1) & (2)

$\boxed{i_1 = 0.66}$

$\boxed{i_2 = 0 \text{ Amp}}$

Super Mesh Analysis

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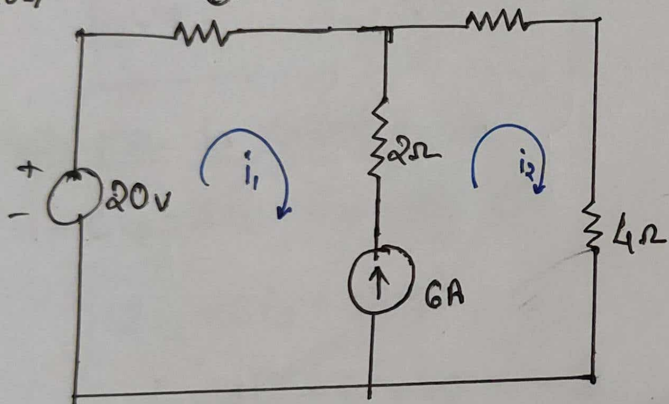
Q. (i) When a current source exist b/w two mesh, we create a super mesh by ~~exp~~ excluding the current source and any element connected ~~b/w~~ with it in series.

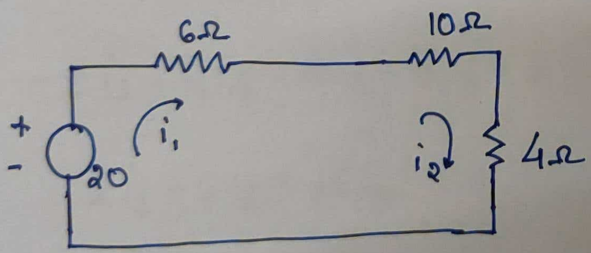
(ii) Remove the current source in super mesh & apply KVL.

(iii) Restore the current source in super mesh & apply KCL at corresponding node.

Que. 1)



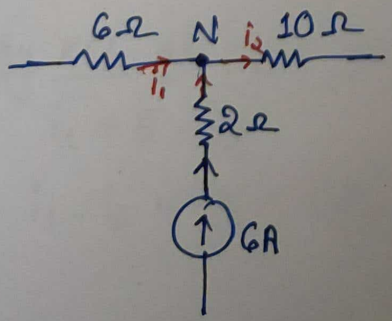
⇒



Applying KVL to super mesh

$$20 - 6i_1 - 10i_2 - 4i_2 = 0$$

$$6i_1 + 14i_2 = 20 \quad \text{— (1)}$$



Applying KCL at node N

$$-i_1 - 6 + i_2 = 0$$

$$i_1 - i_2 = -6 \quad \text{— (2)}$$

~~$i_1 = 5.2$ Amp~~

~~$i_2 = -0.8$ Amp~~

$i_1 = -3.2$ Amp

$i_2 = 2.8$ Amp

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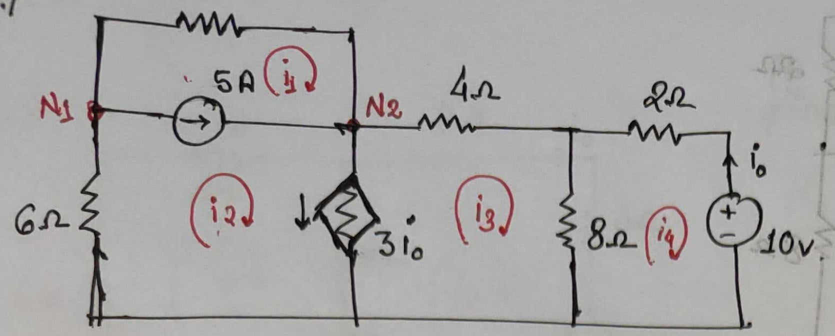
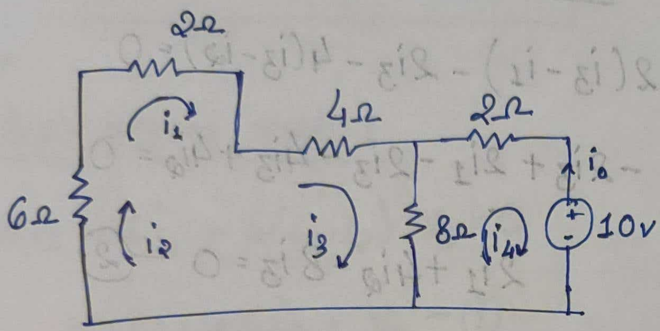
Q.)





Apply KVL in Super mesh.

$$-6i_2 - 2i_1 - 4i_3 - 8(i_3 - i_4) 0$$

$$\cancel{2i_1 + 6i_2 + 12i_3 = 0}$$

$$\cancel{i_1 + 3i_2 + 6i_3 = 0} \quad — (1)$$

$$-8(i_4 - i_3) - 2i_4 - 10 = 0$$

$$-10i_4 + 8i_3 = 10$$

$$8i_3 - 10i_4 = 10 \quad — (2)$$

$$-2i_1 - 6i_2 - 4i_3 - 8i_3 + 8i_4 = 0$$

$$2i_1 + 6i_2 + 12i_3 - 8i_4 = 0$$

$$i_1 + 3i_2 + 6i_3 - 4i_4 = 0 \quad — (1)$$

Apply KCL at N_1 & N_2.

N_1

$$i_1 + 5 = i_2$$

$$i_1 - i_2 = -5 \quad — (3)$$

N_2

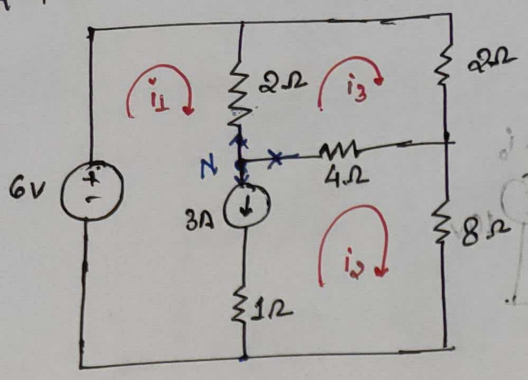
$$5 + i_1 - 3i_0 - i_3 = 0$$

$$i_1 - i_3 + 3i_4 = -5 \quad — (4)$$

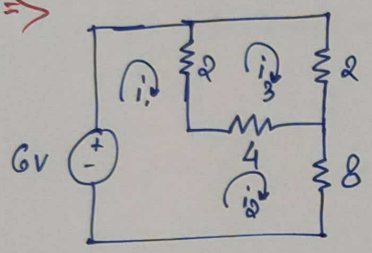
✓ $i_1 = -7.5$ Amp $\quad i_3 = 3.9$ Amp

$i_2 = -2.5$ Amp $\quad i_4 = 2.14$ Amp

(Q.2)



⇒



KVL in mesh

$$-2(i_3-i_1) - 2i_3 - 4(i_3-i_2) = 0$$

$$-2i_3 + 2i_1 - 2i_3 - 4i_3 + 4i_2 = 0$$

$$2i_1 + 4i_2 - 8i_3 = 0 \quad \text{— (2)}$$

$$6 - 2(i_1-i_3) - 4(i_2-i_3) - 8i_2 = 0$$

$$6 - 2i_1 + 2i_3 - 4i_2 + 4i_3 - 8i_2 = 0$$

$$-2i_1 - 12i_2 + 6i_3 = -6 \quad \text{— (1)}$$

KCL at Node

$\cancel{i_1 + i_3 = 3}$ — (3)

$\cancel{(i_3-i_1) + (i_3-i_2) = 3}$

$\cancel{-i_1 - i_2 + 2i_3 = 3}$ — (3)

$$(i_3-i_1) + (i_2-i_3) + 3 = 0$$

$$-i_1 + i_2 = -3 \quad \text{— (3)}$$

At Node take all current outward

~~$i_1 = 2.18$ Amp~~
~~$i_2 = 0.545$ Amp~~
~~$i_3 = 0.818$ Amp~~

✓
$i_1 = 3.4$ Amp
$i_2 = 0.47$ Amp
$i_3 = 1.1$ Amp

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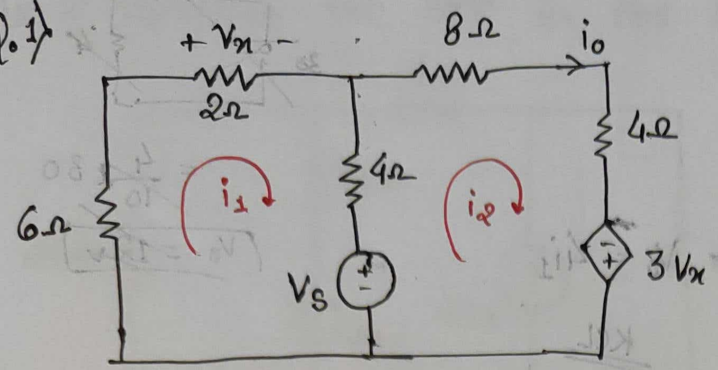
Circuit Theorem ⇒

Q.1)



find i_0, when $V_S = 12v$ & $24v$.

$\boxed{V_x = 2i_1}$

$\boxed{i_0 = i_2}$

⇒

Apply KVL in mesh-1

$-6i_1 - 2i_1 - 4(i_1 - i_2) - V_S = 0$

$-12i_1 + 4i_2 = V_S$ — (1)

mesh-2

$-8i_2 - 4i_2 + 3V_x + V_S - 4(i_2 - i_1) = 0$

$4i_1 - 16i_2 + 3V_x = -V_S$ — (2)

$10i_1 - 16i_2 = -V_S$

~~2+~~ Add (1) & (2)

$-2i_1 - 12i_2 = 0$

$\boxed{i_1 = -6i_2}$ — (3)

Substitute (3) in (1)

$76\, i_2 = V_S$

$i_2 = \frac{V_S}{76} \longrightarrow i_1 = -\frac{V_S}{12.66}$

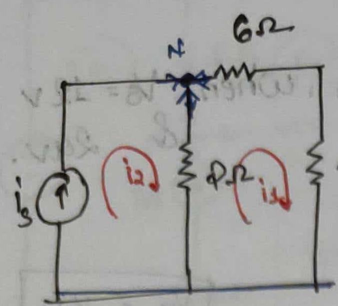
✓ $V_S = 12v \Rightarrow i_2 = 0.157$ Amp

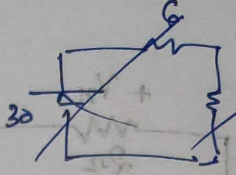
✓ $V_S = 24v \Rightarrow i_2 = 0.315$ Amp

Q.) For the Ckt find 'V_0' when $i_s = 15A$ & $i_s = 30A$

$V = IR$

⇒





$= \frac{4}{10} \times 30$

$\boxed{V_0 = \cancel{12v}}$

$V_0 = 4i_1$

⇒ KVL

$-2(i_1 - i_2) - 6i_1 - 4i_1 = 0$

$-12i_1 + 2i_2 = 0$

$\boxed{i_2 = 6i_1}$

KCL

$i_s + (i_1 - i_2) - i_1 = 0$

$i_s = i_2 \Rightarrow \boxed{i_1 = \frac{i_s}{6}}$

✓ $\boxed{V_0 = \frac{4i_s}{6}}$

•) Superposition Theorem ⇒

•) It states that the response in linear ckt having more than one independent source can be obtain by adding the responses caused by the sources, each acting one at a time.

•) When a single source is considered the other independent sources are de energised.

Volt ⟶ Short Ckt

Current ⟶ Open Ckt

} only for independent sources

{ If dependent source is present don't remove it. }

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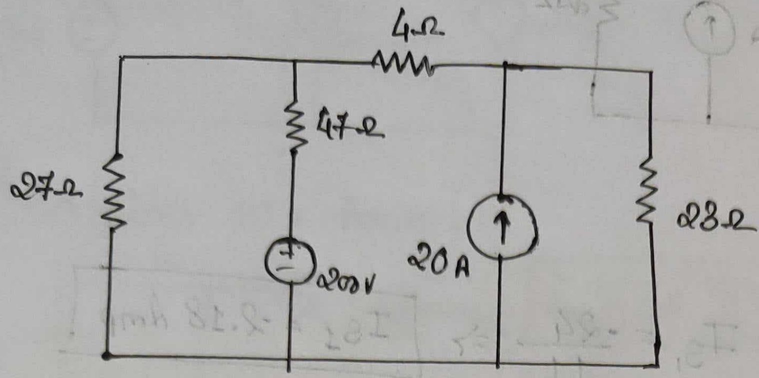
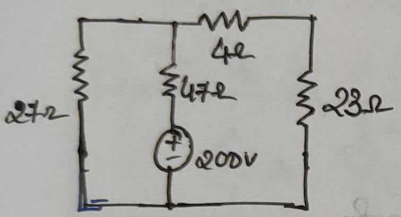
Circuit Theorem :

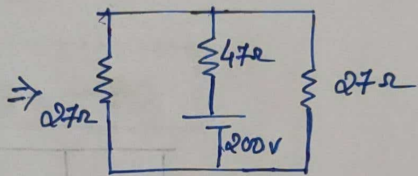
Que. 1) Compute the ~~ckt~~ current in the 23 Ω resistor.



⇒ (i) Consider 200 V source.



⇒



$$\Rightarrow R_{eq} = 47 + \frac{27}{2}$$

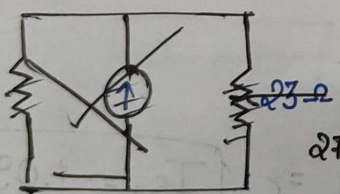
$$\boxed{R_{eq} = 60.5\,\Omega}$$

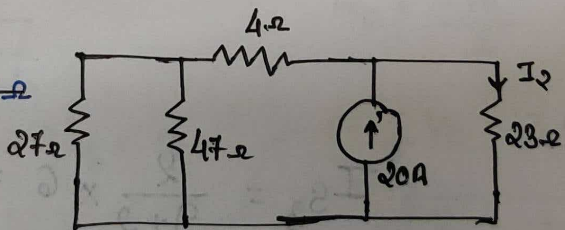
$$I = \frac{200}{60.5} = 3.3\text{ Amp}$$

$$I_{27\Omega} = I_1 = \frac{3.3}{2} = 1.65\text{ Amp}$$

$$\boxed{I_1 = 1.65\text{ Amp}}$$

(ii) Consider 20A current source.





$V = IR$

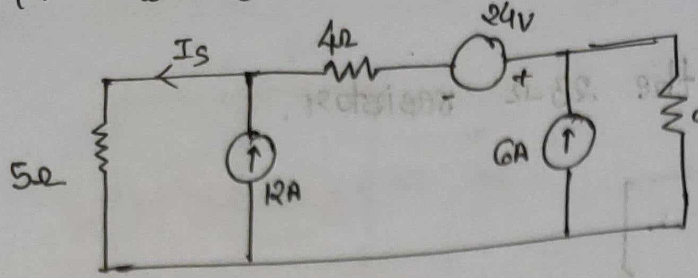
$$R_{eq_1} = 4 + \frac{27 \times 47}{27 + 47} = 21.15\,\Omega$$

$$I_2 = \frac{21.15}{21.15 + 23} \times 20 \Rightarrow \boxed{I_2 = 9.58\text{ Amp}}$$

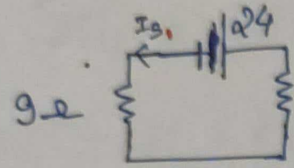
$$\text{Total Current} = I_1 + I_2$$

$$\boxed{= 11.23\text{ Amp}}$$

Q.) Find I_s in ckt.

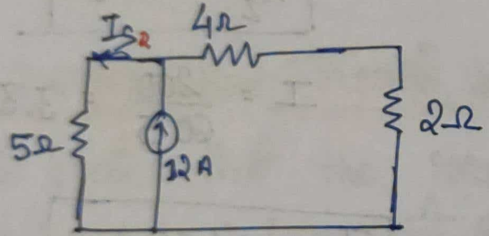


Consider 24 V source,

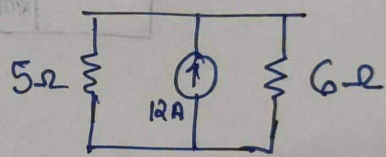


$$I_{s_1} = \frac{-24}{11} \Rightarrow \boxed{I_{s_1} = -2.18 \text{ Amp}}$$

Consider 12 A source,

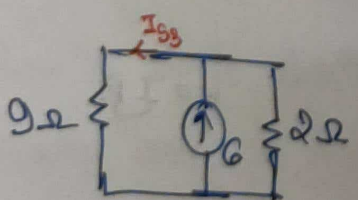


$\Rightarrow$



$$I_{s_2} = \frac{6}{5+6} \times 12 \Rightarrow \boxed{I_{s_2} = 6.54 A}$$

Consider 6A source,



$$I_{s_3} = \frac{2}{9+2} \times 6 \Rightarrow \boxed{I_{s_3} = 1.09 A}$$

$$I_{Total} = I_s = I_{s_1} + I_{s_2} + I_{s_3}$$

$$\boxed{I_s = 5.45 \text{ Amp}}$$

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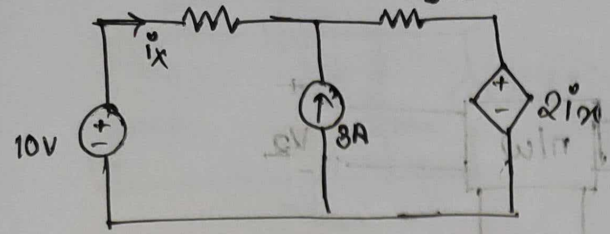
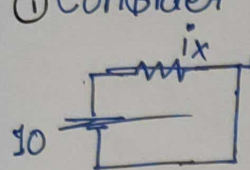
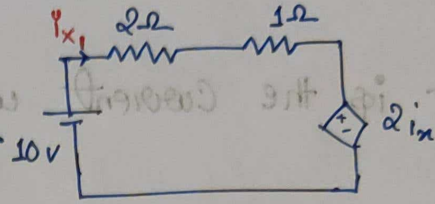
Q.3) Find i_x using Super-pos. Theorem



(i) Consider 10v source.



$i_{x_1} = \frac{10}{2} \Rightarrow \boxed{\cancel{i_{x_1} = 5A}}$

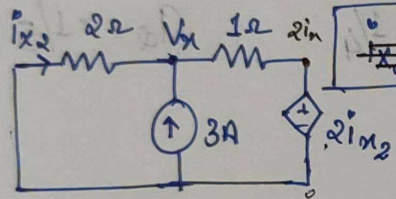


KVL

$10 - 2i_{x_1} - i_{x_1} - 2i_{x_1} = 0$

$\boxed{i_{x_1} = 2A}$

(ii) Consider 3A source.



$\boxed{\cancel{i_{x_2} = -3A}}$

Apply KCL at V_x.

$\boxed{\cancel{i_{x_2} = -1 \text{ Amp}}}$

$\boxed{i_{x_2} = -0.6 A}$

$\frac{V_x}{2} + (-3) + \frac{V_x - 2i_x}{1} = 0$

$i_{x_2} = \frac{-V_x}{2}$

$\boxed{\cancel{V_x = 2v}}$

$-i_{x_2} - 3 + V_x - 2i_{x_2} = 0$

$\frac{5}{2}V_x = 3$

$V_x = 3i_{x_2} + 3$

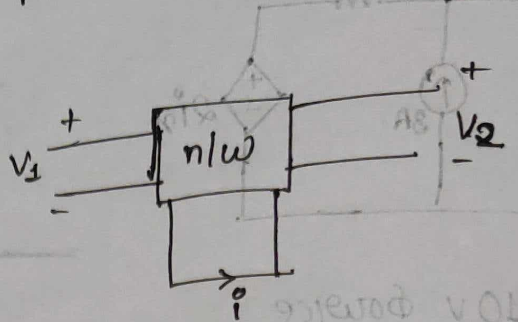
$\boxed{V_x = 1.2v}$

Total $i_x = i_{x_1} + i_{x_2}$

$\boxed{i_x = 1.4 \text{ Amp}}$

Q.) Measurement obtained for the n/w is given as.

V_1	V_2	I
4	0	1A
0	5	-1A



what is the current when $V_1 = 10\,v$
$V_2 = 5v$.

$$I = f(V_1, V_2)$$

$$I = a_1V_1 + a_2V_2$$

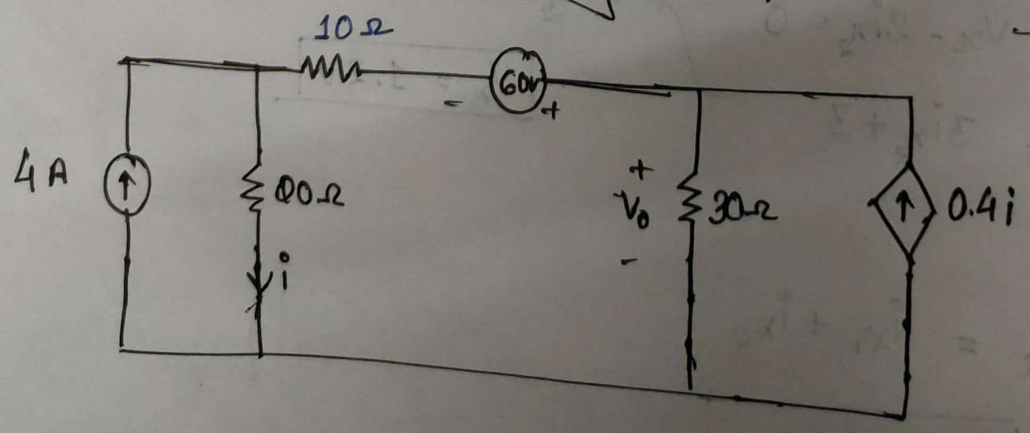
$\cancel{4V_1 = 1}$ $\quad 4a_1 = 1 \quad , \quad 5a_2 = -1$

$\cancel{V_1 = 4}$ $\quad a_1 = 1/4 \quad\quad a_2 = -1/5$

$$I = \frac{V_1}{4} - \frac{V_2}{5}$$

$$= \frac{10}{4} - \frac{5}{5} \Rightarrow \boxed{I = 1.5A}$$

Que.) Find V_o in the ckt Using superposit^n. $\boxed{V_o = 82.56\,v}$



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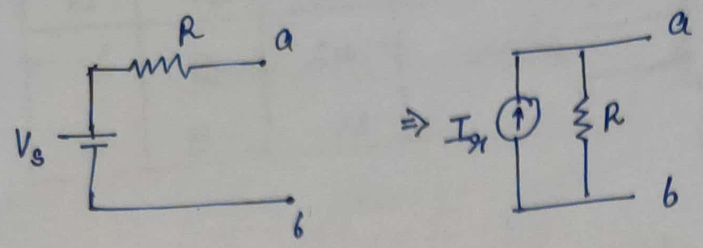
#) Source Transformation ⇝



$$I_r = \frac{V_s}{R}$$

- Source ~~trans~~ transf. is another tool for simplifying the ckt
This tool works on concept of Equivalence.

- Equivalent whose VI characteristic ~~are~~ ~~is~~ identical with Original ckt.

- Source transformatⁿ is process of replacing the voltage source ~~to~~ in series with Resistor 'R' with Current source ~~with~~ ~~R~~ in parallel with R.

- Above two ckts are equivalent, provided they have same Voltage Current relation at terminals a & b.

- If the sources are turned off the equivalent resistance of both the ckts is R.

- When terminal a, b are short circuited, the short circuited current going from a to b is $I_{sc} = \frac{V_s}{R}$

& $I_s = I_{sc}$

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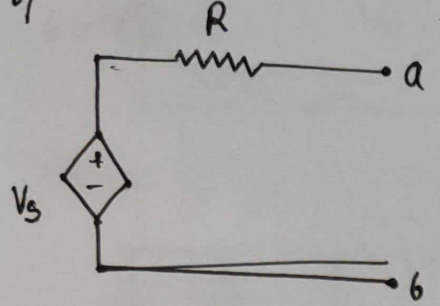
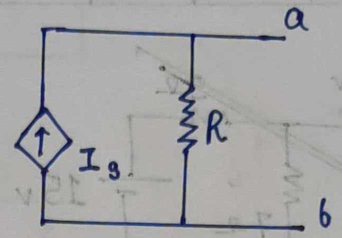
• Thus $\frac{V_s}{R} \simeq I_s$ in order for ckt to be equivalent.

$$\boxed{V_s = I_s R}$$

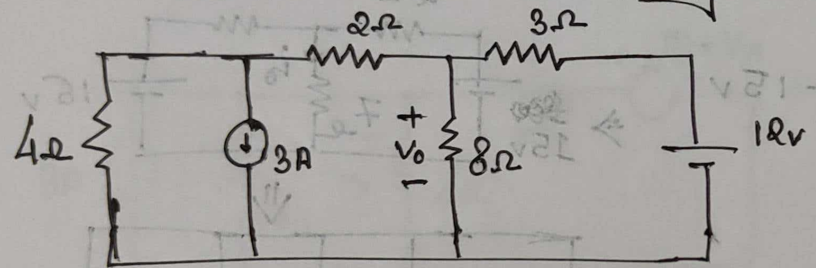
o)



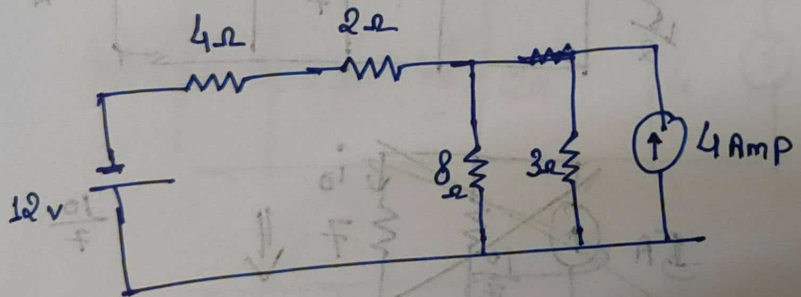
⇒



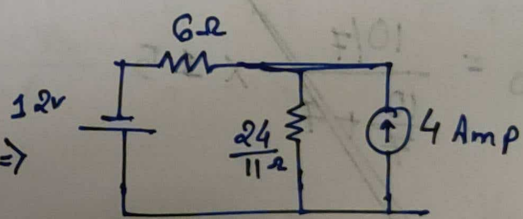
Que.1) Find Vo in the ckt, using source transformat^n.



⇒



⇒



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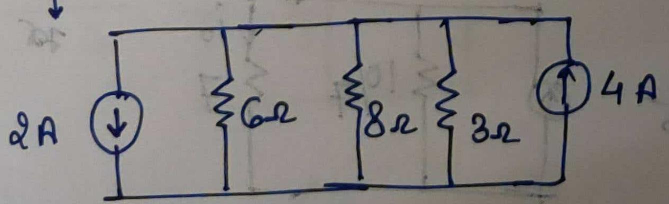
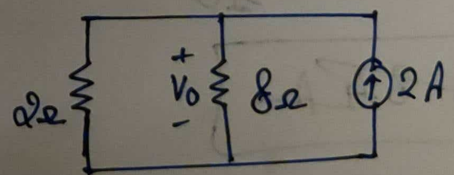


⇒

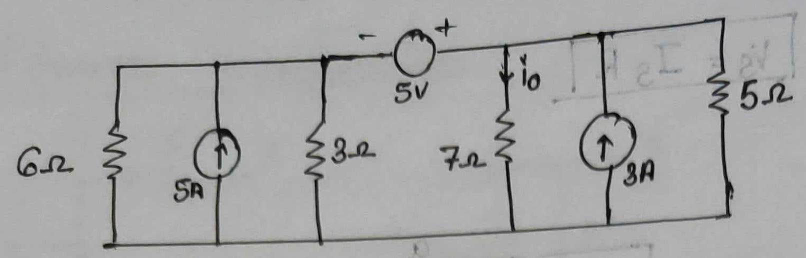


$$I_{8\Omega} = \frac{2}{8+2} \times 2 = 0.4 \text{ A}$$

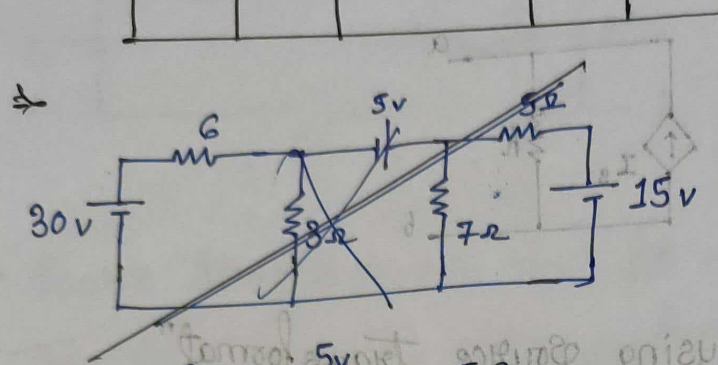
$$V_o = 0.4 \times 8$$

$$\boxed{V_o = 3.2 \text{ v}}$$

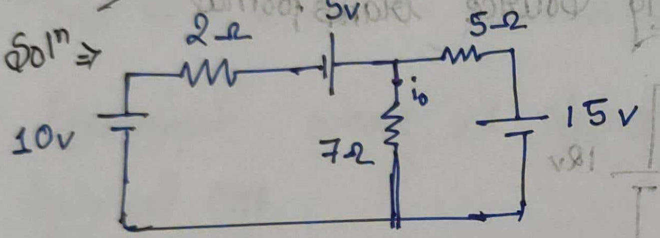
Que. 2) Find i_o in the ckt using Source Transformation

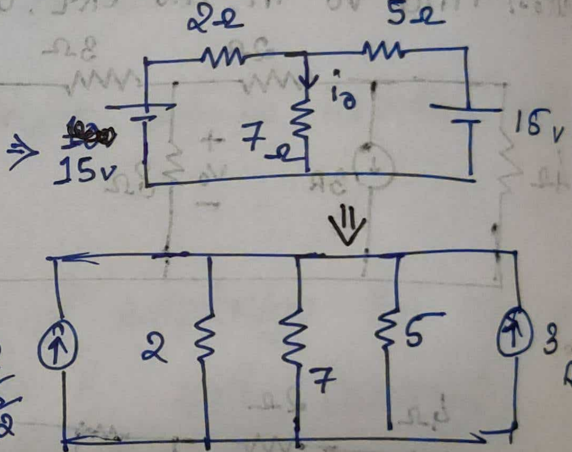


⇒



Sol^n ⇒

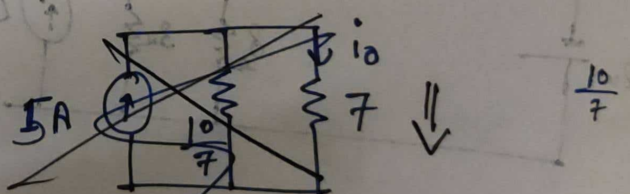


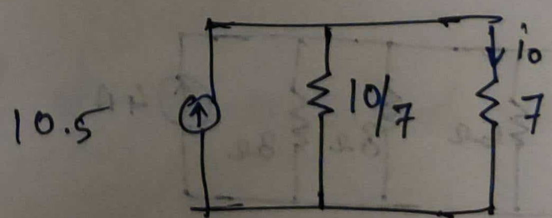


$$\cancel{i_o = \frac{10/7}{\frac{10}{7}+7} \times 15}$$

$$\cancel{i_o = \frac{10}{7} \times \frac{59}{10} \times 5}$$

$$\cancel{\boxed{i_o = 8.4\ A}}$$



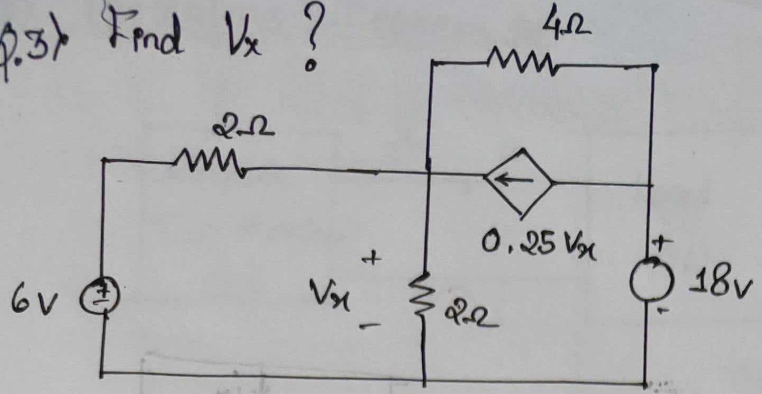


$i_o =$

$$i_o = \frac{10/7}{\frac{10}{7}+7} \times 10.5 = \frac{10}{7} \times \frac{7}{59} \times 10.5$$

$$\boxed{i_o = 1.78\ A}$$

Q.3) Find V_x ? 14/Aug/24



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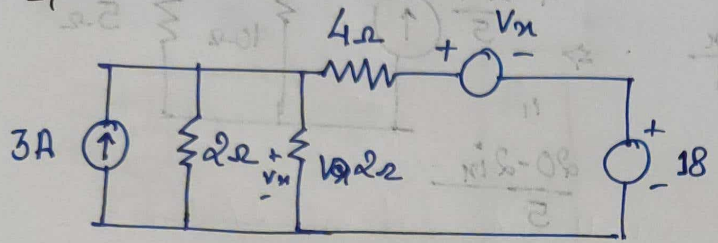
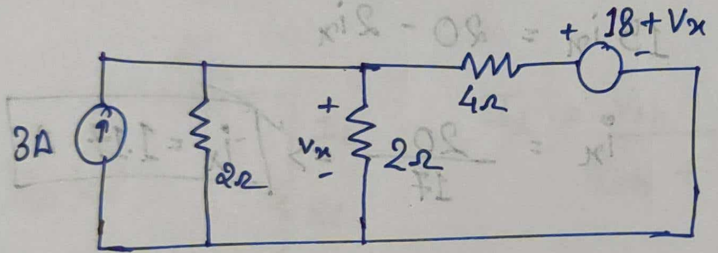
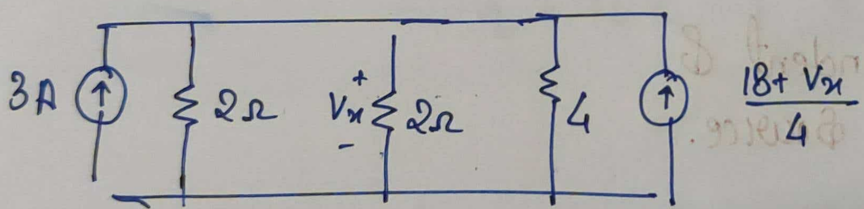
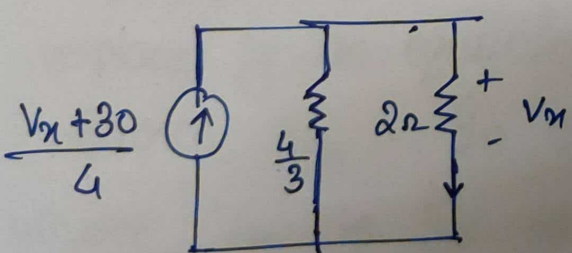






$$\frac{18+V_x}{4}+3=\frac{V_x+30}{4}$$



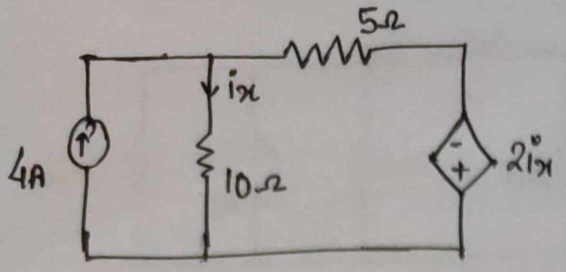
$$I_{2\Omega} = \frac{4/3}{\frac{4}{3}+2} \times \frac{V_x+30}{\cancel{4}} = \frac{V_x+30}{10}$$

$$2 \times I_{2\Omega} = V_x$$

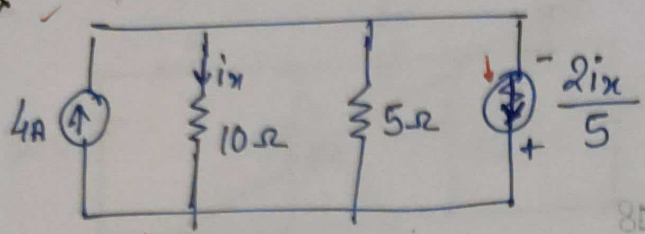
$$\cancel{2}\left(\frac{V_x+30}{\cancel{10}\ 5}\right) = V_x \Rightarrow 4V_x = 30$$

$$\boxed{V_x = 7.5\ V}$$

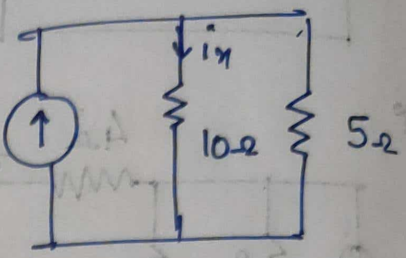
Q) Find i_x using S.T.



⇒



⇒ $4 - \frac{2i_x}{5} = \frac{20-2i_x}{5}$

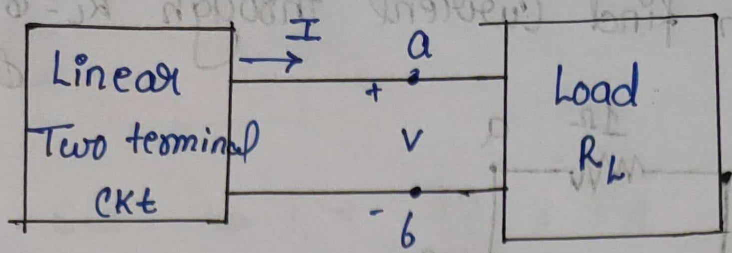


$i_x = \frac{\cancel{5}}{15} \times \frac{20-2i_x}{\cancel{5}}$ ⇒ $15 i_x = 20 - 2i_x$

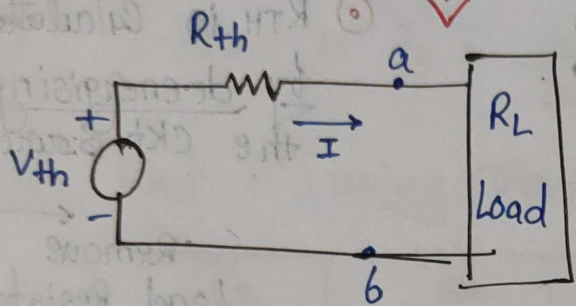
$i_x = \frac{20}{17}$ ⇒ $\boxed{i_x = 1.17\ A}$

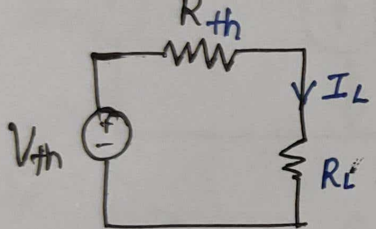
Don't club dependent & independent source.

#) Thevinin's Theorem ⇒



⇓



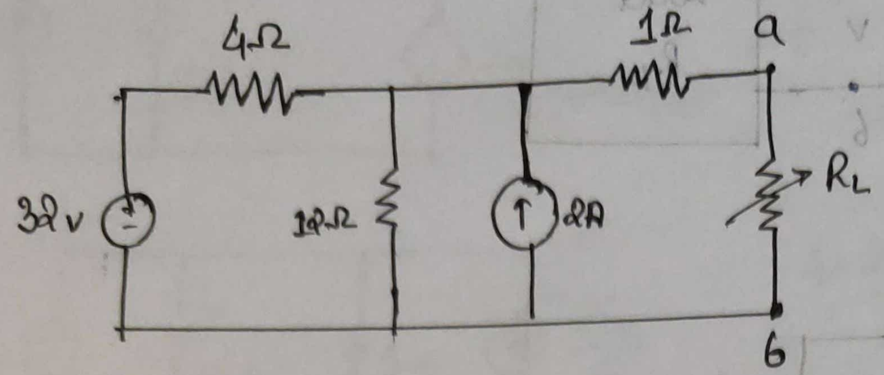


$$I_L = \frac{V_{th}}{R_{th} + R_L}$$

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

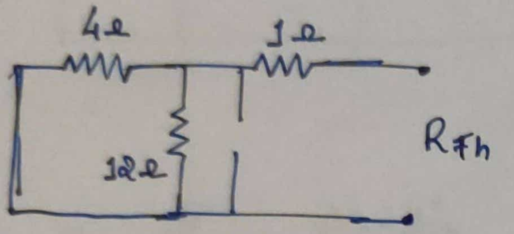
⇒ It states that a linear two terminal circuit can be replace by an equivalent ckt consisting of voltage source V_{th}. In series with Resistor 'R_{th}', where V_{th} is the open ckt voltage under terminals & R_{th} is the equivalent resistance at the —,— . when a independent sources are turned off

Q9) Find the thevinin's equivalent ckt, to the left of terminals a, b. Then find current through $R_L = 6, 16$ & $32\,\Omega$

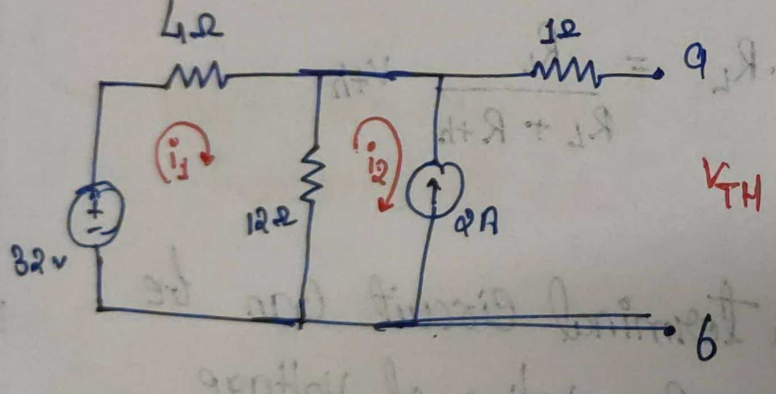


- R_{TH} is calculated by de-energising the ckt source.
- Remove Load Resistance

⇒



$$R_{TH} = \frac{4 \times 12}{16} + 1 = 4\,\Omega$$



KVL in mesh-1

$$32 - 4i_1 - 12(i_1 - i_2) = 0$$

$$-16 i_1 + 12 i_2 + 32 = 0$$

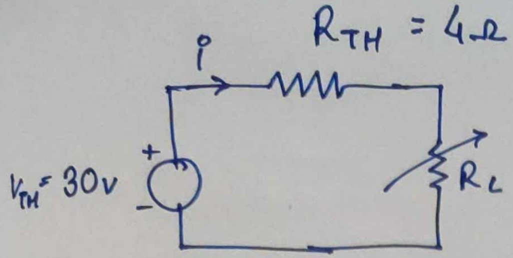
$$\boxed{i_1 = 0.5\,A}$$

KVL in mesh-2

$$\cancel{12(i_2 - i_1) - 2 = 0}$$

$$\boxed{i_2 = -2}$$

$$V_{TH} = 12(i_1 - i_2) \Rightarrow \boxed{V_{TH} = 30\,v}$$



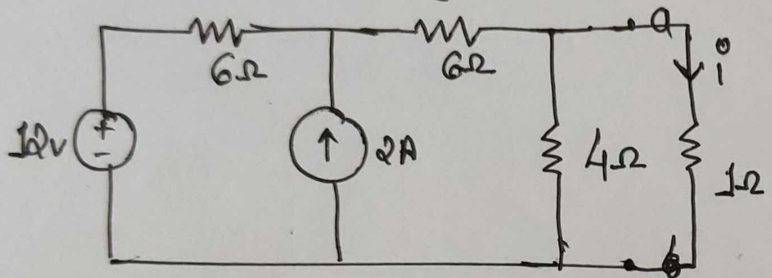
(i) $R_L = 6\Omega \Rightarrow i_1 = \frac{30}{10} = 3A$

(ii) $= 16\Omega \Rightarrow i_2 = \frac{30}{20} = 1.5A$

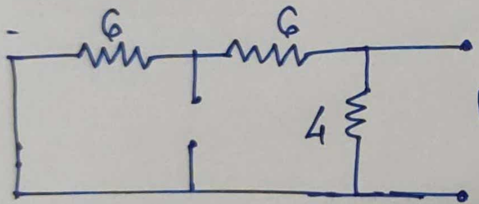
(iii) $= 32\Omega \Rightarrow i_3 = \frac{30}{36} = 0.83A$

{Where we want to calc. current, that Resistor will be load Resistance}

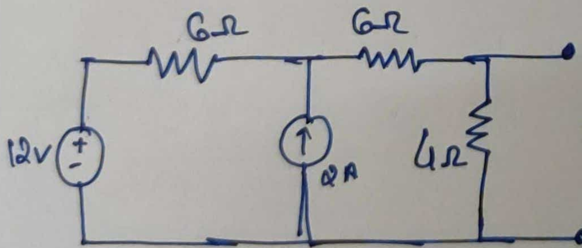
Q.2) Find 'i' using Thevinin's Theo.



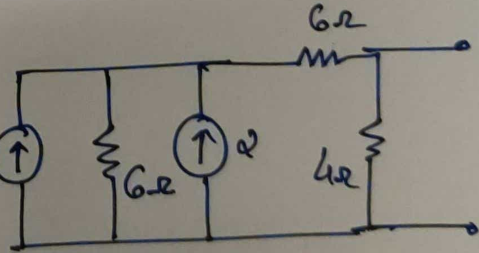
$\Rightarrow$



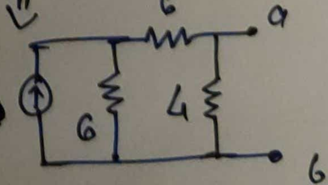
$R_{TH} = \frac{12 \times 4}{16} \Rightarrow R_{TH} = 3\Omega$



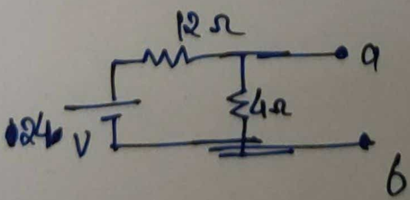
$V_{TH} \Rightarrow$



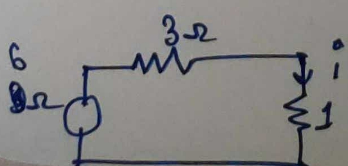
$\Downarrow$



$\Leftarrow$



$V_{TH} = \frac{4}{4+12} \times 24 = 6\Omega$



$$\boxed{i = \frac{6}{4} = \cancel{0.75}A \quad 1.5A}$$

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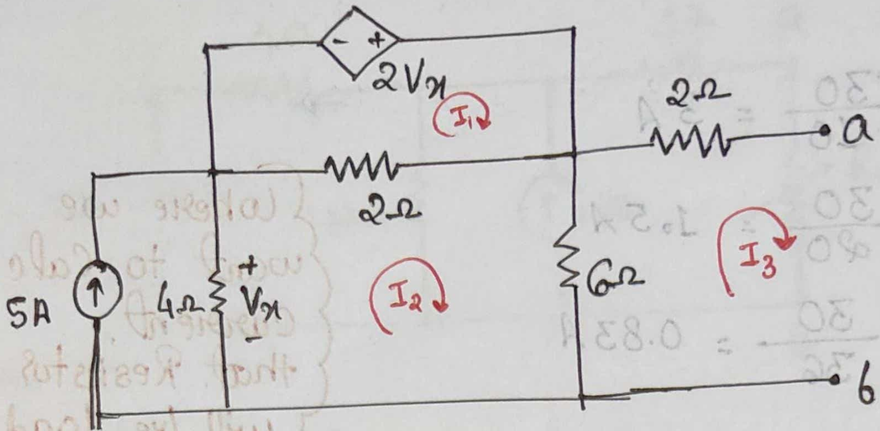
Q.) Find The thevinin's equivalent ckt.



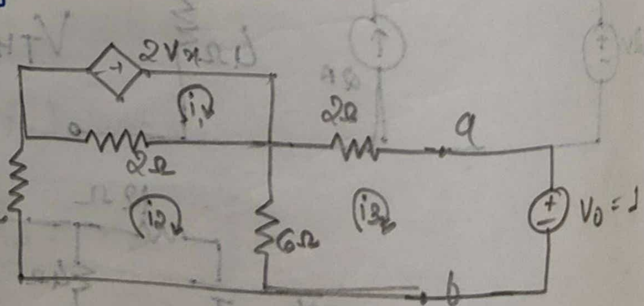
⇒

i) Circuit Contains dependent source & resistance of source is unknown.

ii) To calculate R_{TH} set $V_0 = 1V$, b/w terminals a & b. and assume that Current flowing b/w terminal a & b is i_0.

Then, $R_{TH} = \frac{V_0}{i_0}$

iii) Alternatively we may apply 1 Amp current source & find the Corresponding Voltage V_0 to obtain the $R_{TH} = \frac{V_0}{1}$



Applying KVL in mesh-1

$\cancel{2}V_x - \cancel{2}(i_1 - i_2) = 0$

$i_1 - i_2 = V_x$ —(1)

↪ $(-4i_2)$

$i_1 + 3i_2 = 0$

$-\cancel{2}(i_2 - i_1) - \overset{3}{\cancel{6}}(i_2 - i_3) + \cancel{V_x} = 0$

$-\overset{2}{\cancel{4}}i_2 = 0$

$i_1 - \overset{6}{\cancel{2}}i_2 + 3i_3 = 0$ —(2)

mesh-3

$-6(i_3-i_2)-2i_3-1=0$

$6i_2-8i_3=1$ — (3)

$i_1 = 0.166$ Amp

$i_2 = -0.05$ Amp

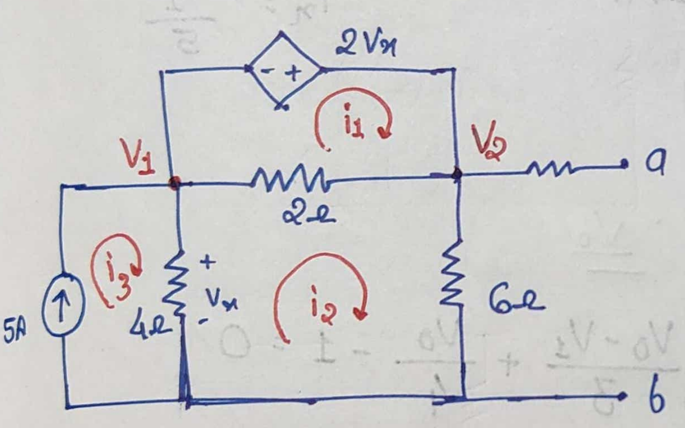
$i_3 = -0.166$ Amp

$i_0 = -i_3 \Rightarrow \boxed{i_0 = 0.166\ A}$

$R_{TH} = \dfrac{V_0}{i_0} = \dfrac{1}{0.166}$

$\boxed{R_{TH} = 6\ \Omega}$

Now. for V_{TH} →



Nodal Analysis at V_1

$i_3 = 5$ A

mesh-1

$2V_x - 2(i_1-i_2) = 0$

$i_1 - i_2 = V_x$

$\hookrightarrow +4(i_2-i_3)$

$i_1 - i_2 = +4(i_2-5)$

$i_1 + 3i_2 = 20$

~~$i_1 - 5i_2 = -20$~~

$\boxed{\begin{array}{l} i_2 = 10/3\ A \\ i_1 = 10 \end{array}}$

mesh-2

$-\cancel{2}(i_2-i_1)-\overset{3}{\cancel{6}}(i_2)-\overset{2}{\cancel{4}}(i_2-\overset{=5}{i_3})=0$

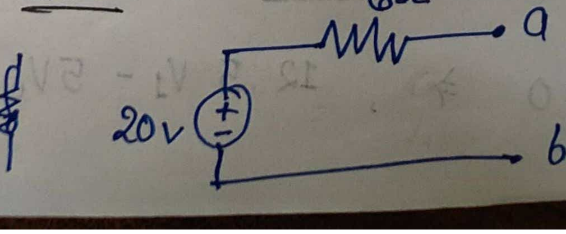
$-i_2+i_1-3i_2-2i_2+10=0$

~~$-i_1-4i_2=-10$~~

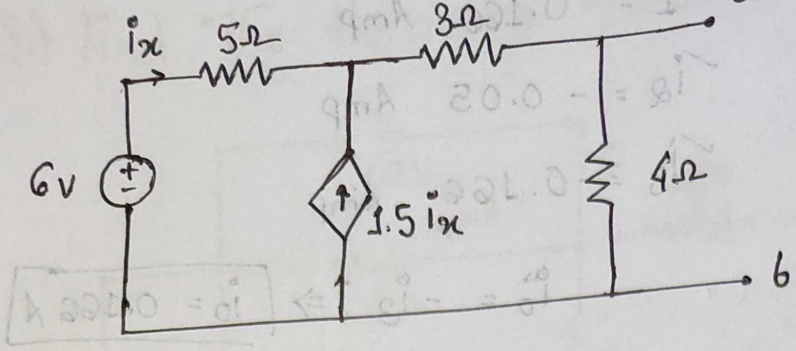
$i_1-6i_2=-10$

• $V_{TH} = 6i_2 \Rightarrow \boxed{V_{TH} = 20V}$

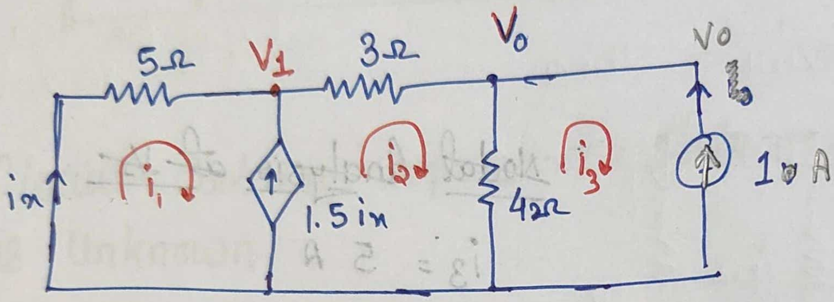
Thevinins eqn ckt →



Q.2 Find thev. Eq. ckt



→ <u>For R_{TH}</u> →



Nodal Analysis at V_1, & V_0.

V_1

$$-i_x - 1.5\,i_x + \frac{V_1 - V_0}{3} = 0$$

$$-2.5\,i_x + \frac{V_1 - V_0}{3} = 0$$

$$\cancel{+\frac{2V_1}{5} + \frac{V_1 - V_0}{3} = 0}$$

$$\cancel{+6V_1 + 5V_1 - 5V_0 = 0}$$

$$\cancel{-5V_0 + 11V_1 = 0}$$

$$R_{TH} = \frac{V_0}{1} \Rightarrow \cancel{\boxed{R_{TH} = 2.315\,\Omega}}$$

$$\frac{2.5}{5}V_1 + \frac{V_1 - V_0}{3} = 0 \Rightarrow 12.5\,V_1 - 5V_0 = 0 \quad \text{—— (1)}$$

V_0

$$\frac{V_0 - V_1}{3} + \frac{V_0}{4} - 1 = 0$$

$$4V_0 - 4V_1 + 3V_0 - 12 = 0$$

$$7V_0 - 4V_1 = 12 \quad \text{—— (2)}$$

$$i_x = -\frac{V_1}{5}$$

$$\cancel{V_0 = 2.315\,V}$$

$$\cancel{V_1 = 1.052\,V}$$

$$\boxed{\begin{aligned} V_0 &= 2.22\,V \\ V_1 &= 0.88\,V \end{aligned}}$$

~~Now for V_{TH}~~ →

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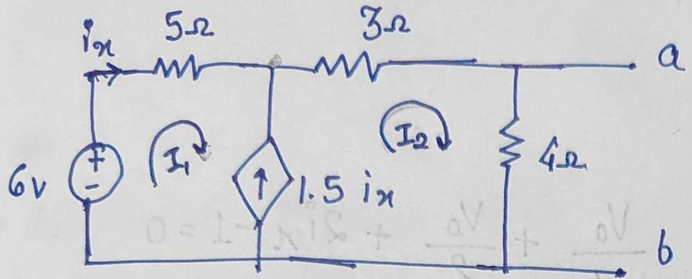
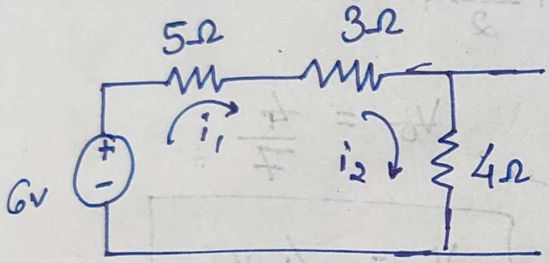
$$R_{TH} = \frac{V_0}{1} \Rightarrow \boxed{R_{TH} = 2.22\,\Omega}$$

Now for V_{TH} →



Super mesh analysis

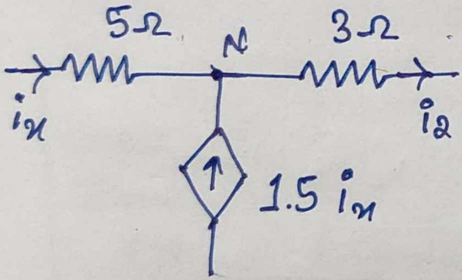


Applying KVL,

$\boxed{i_1 = i_x}$

$$6 - 5i_1 - 7i_2 = 0$$

$$5i_x + 7i_2 = 6 \quad \text{—} (1)$$



Applying KCL at N

$$i_x + 1.5i_x = i_2$$

$$i_2 = 2.5i_x \quad \text{—} (2)$$

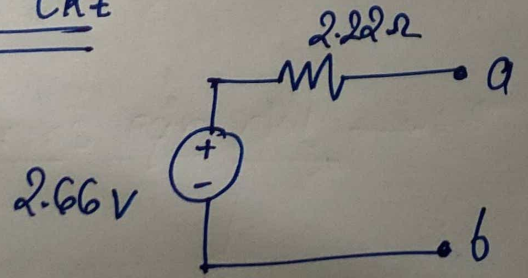
from (1) & (2)

$$\boxed{i_x = 0.266\ A}$$

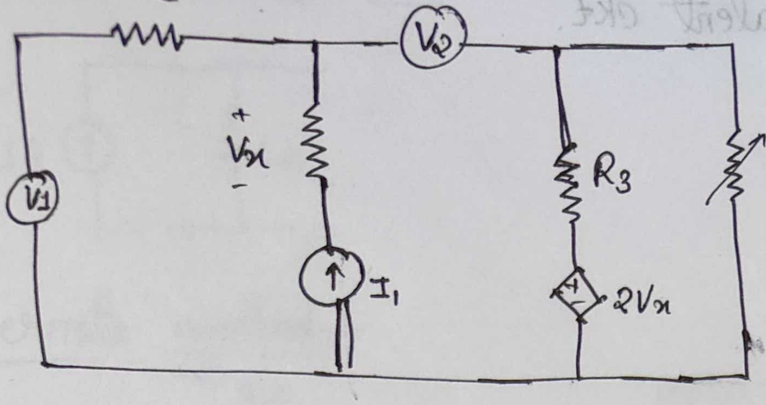
$$V_{TH} = 4 \times 2.5\,i_x$$

$$\boxed{V_{TH} = 2.66\,V}$$

Eqn ckt



Que.)



Norton's Theorem :-

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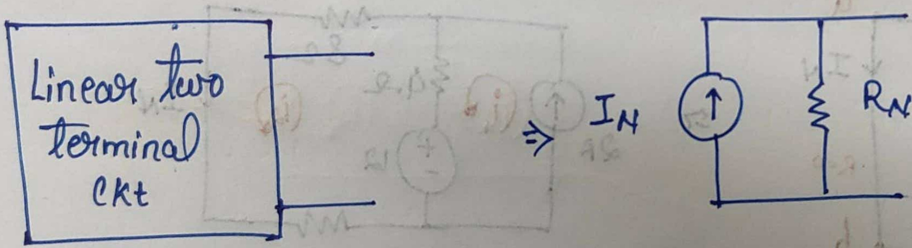
Source transformation of Thevnin's TH ckt.

- Norton's theorem state that linear two terminal ckt can be replaced by an equivalent ckt consisting of current source I_N in parallel with a resistor R_N, where I_N is the short ckt current to the terminal and R_N is the equivalent resistance at terminal. when the independent source are turned off.

- $R_N = R_{TH}$



- Norton's eq. ckt can be obtained by doing source transformation of thevnin's equivalent ckt.

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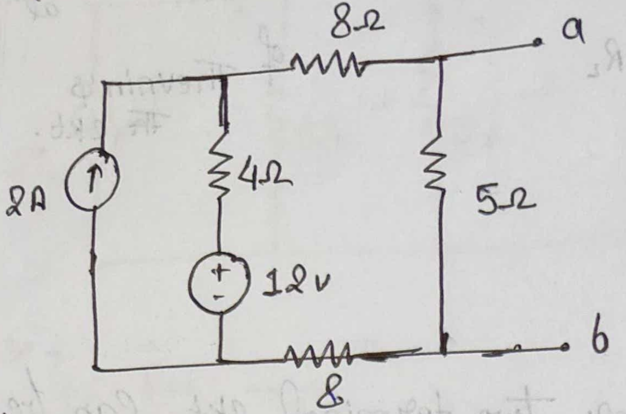
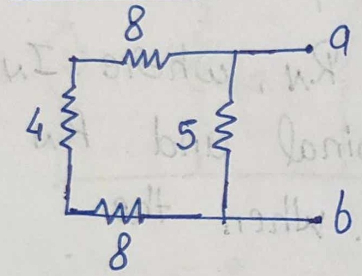
Q.1) Find the Norton's Equivalent ckt.



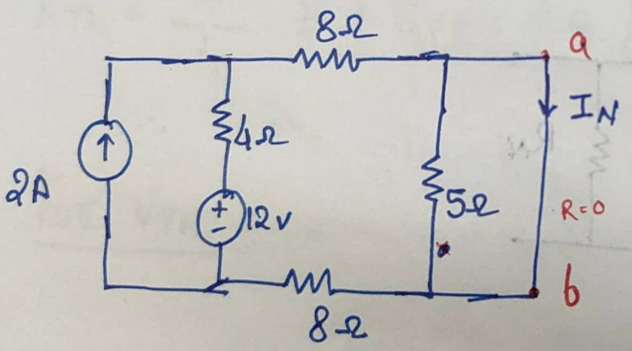
Calc. R_N →



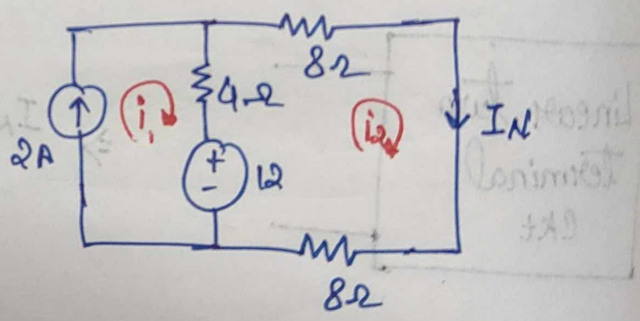
$\Rightarrow R_N = \cancel{\dfrac{12\times 5}{17}} \quad \dfrac{20\times 5}{25}$

$\boxed{R_N = 4\,\Omega}$

Calc. of I_N →



There is no effect of 5Ω Resistor



mesh-1

$\boxed{i_1 = 2}$

Applying mesh Analysis

mesh-2

$12 - 4(i_2 - i_1) - 8i_2 - 8i_2 = 0$

$12 - 4i_2 + 8 - 16i_2 = 0$

$\boxed{i_2 = 1 \text{ Amp}}$

$\boxed{i_N = i_2 = 1 \text{ Amp}}$

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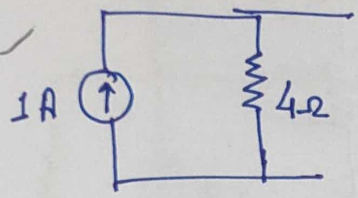
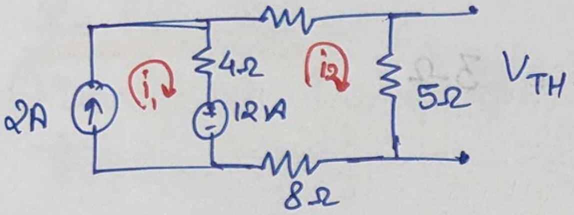
Norton's equivalent ckt →



Alternate method →



mesh-1

$i_1 = 2A$

mesh-2

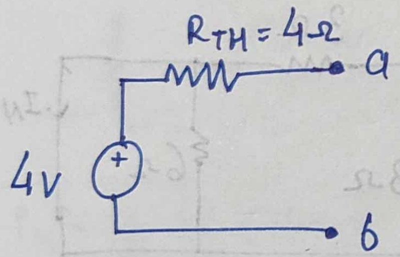
$12 - 4(i_2 - i_1) - 21 i_2 = 0$

$12 - 4i_2 + 8 - 21 i_2 = 0$

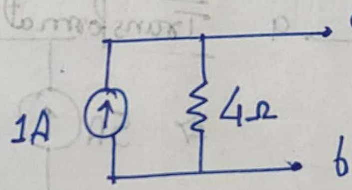
$i_2 = \frac{20}{25}$

$\boxed{i_2 = 0.8\ A}$

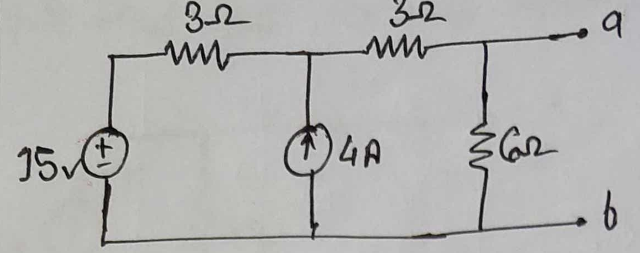
$V_{TH} = 5 \times 0.8 \Rightarrow \boxed{V_{TH} = 4\ v}$



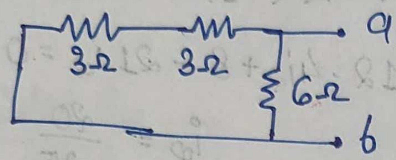
⇒



Que.2 Find the Norton's Equi. ckt.

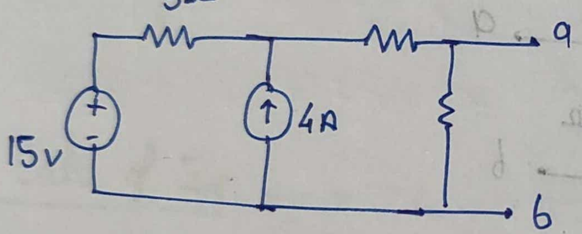


→ Cal. R_N

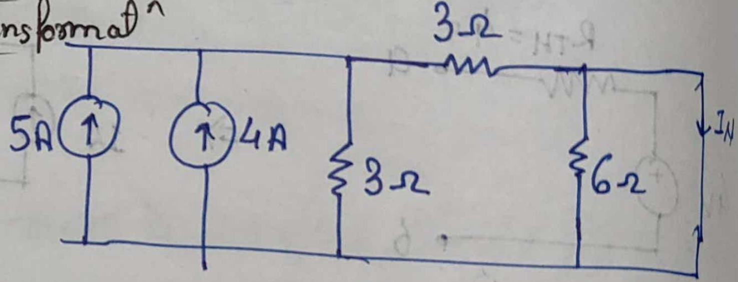


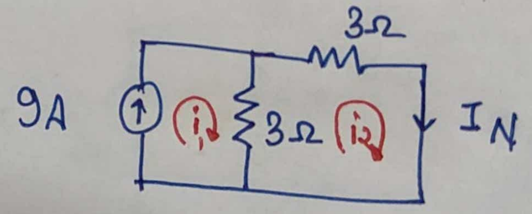
$\Rightarrow R_N = \frac{6 \times 6}{12} = 3\Omega$

Cal. I_N



Source Transformat^n





mesh-1

$i_1 = 9A$

mesh-2

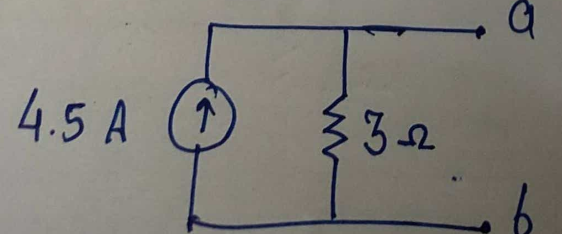
$3(i_2 - i_1) - 3i_2 = 0$

$3i_2 - 27 - 3i_2 = 0$

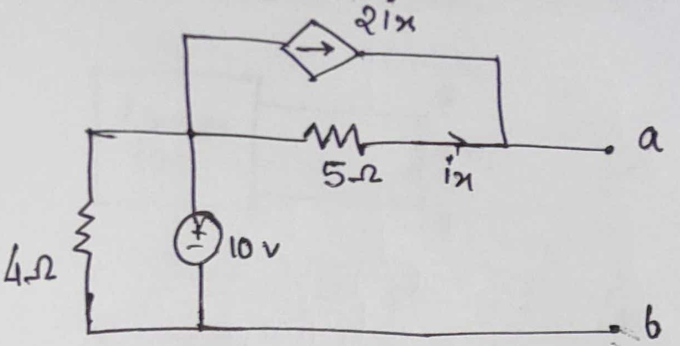
$i_2 = \frac{27}{6} \Rightarrow \boxed{i_2 = 4.5\,A}$

$\boxed{I_N = 4.5A}$

Norton's ckt



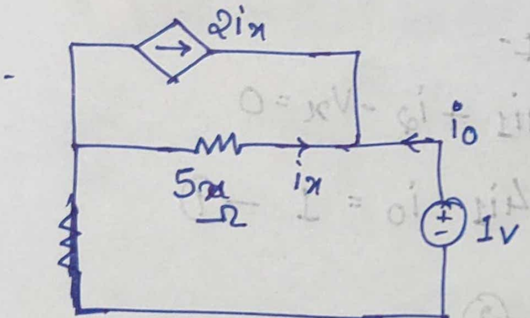
Que. 3) Find Norton's equ. ckt. 21/Aug/24



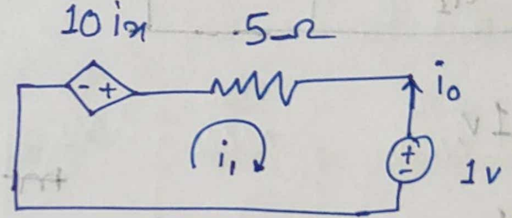
⇒

R_N Calculat^n ⇒

(i) Denergize independent sources & apply 1v source across teominal a&b.



⇒



$$10\,i_x - 5i_1 - 1 = 0$$

$$\boxed{i_x = \frac{-1}{5}} = \frac{-V_0}{5}$$

$$i_1 = \frac{10\,i_x - 1}{5}$$

$$i_0 = -i_1$$

$$i_0 = \frac{1 - 10\,i_x}{5}$$

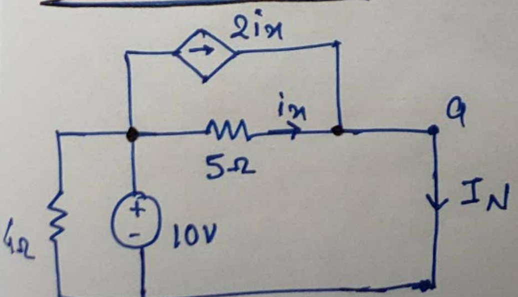
$$\cancel{i_0 = -\frac{1}{2}}$$

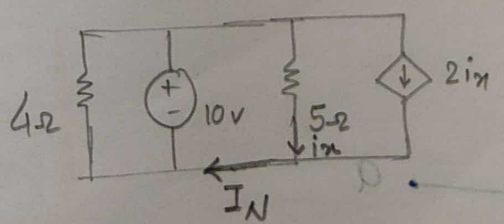
$$\cancel{i_0 = -0.5\ A}$$

$$\boxed{i_0 = 3/5\ A}$$

$$R_N = \frac{V_0}{i_0} = \cancel{2\Omega} \Rightarrow \boxed{\cancel{R_N = 2\Omega}} \quad \checkmark\ \boxed{R_N = 1.67\ \Omega}$$

I_N Calculat^n ⇒





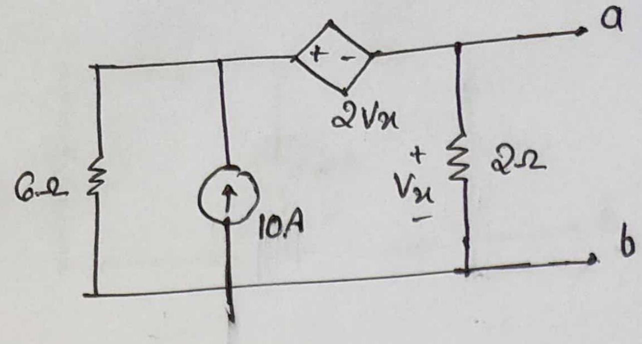
$$i_x = \frac{10}{5} = 2A$$

$$I_N = i_x + 2i_x = 6\ A$$

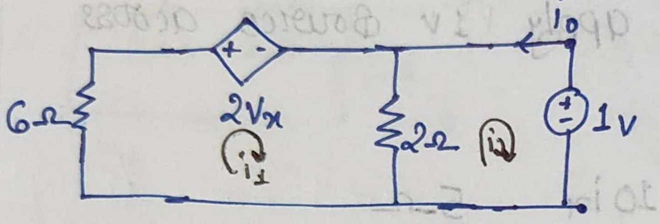
$$\checkmark\ \boxed{I_N = 6\ A}$$

$R_N = 1\Omega$
$I_N = 10A$

Que.4) Find Norton's equ. ckt.



⇒ **For R_N ⇒**



$i_2 = -i_0$

mesh-2

$-\cancel{6}^{3}i_1 - \cancel{2}V_x - \cancel{2}(i_1 - i_2) = 0$

$\cancel{-8i_1}$

$-4i_1 + i_2 - V_x = 0$

$V_x = 1v$

$-4i_1 - i_0 = 1$ — (1)

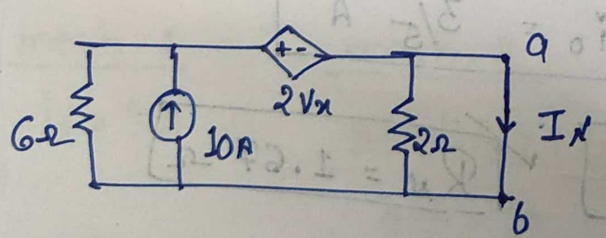
mesh-1

$-1 - 2(i_2 - i_1) = 0 \Rightarrow -2i_1 - 2i_0 = -1$ — (2)

from (1) & (2) $\boxed{i_0 = 1\,Amp}$

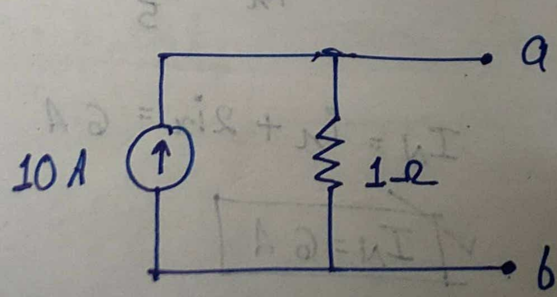
$R_N = \frac{V_0}{i_0} \Rightarrow \boxed{R_N = 1\Omega}$

For I_N ⇒



$\Rightarrow \boxed{I_N = 10A}$

Norton's ckt ⇒



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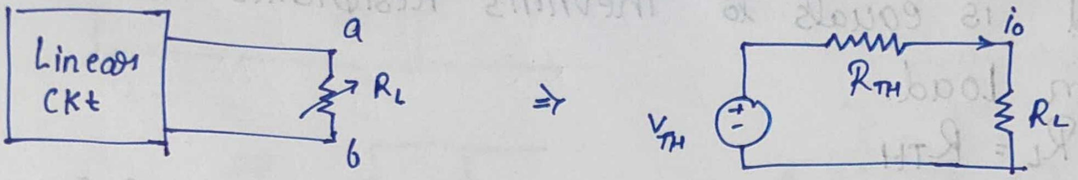
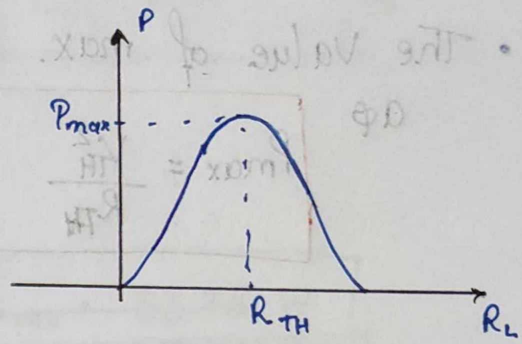
⇒ Maximum Power Transfer Theorem



$$P = i^2 R_L$$



$$= \left[\frac{V_{TH}}{R_{TH}+R_L}\right]^2 R_L \quad \text{—— (1)}$$

To find max 'P' w.r.t. R_L

$$\frac{\partial P}{\partial R_L} = V_{TH}^2\left[\frac{(R_{TH}+R_L)^2 - 2R_L\cdot(R_{th}+R_L)}{(R_{th}+R_L)^4}\right]$$

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

$$R_{TH} + R_L - 2R_L = 0$$

$$\boxed{R_L = R_{TH}}$$

$$\therefore\ P_{max} = \left(\frac{V_{TH}}{R_{TH}+R_{TH}}\right)^2 \times R_{TH}$$

$$\boxed{P_{max} = \frac{V_{th}^2}{R_{th}}}$$

- It state that max. power can be transfer to load when load is equals to Thevnin's Resistance as seen from Load.

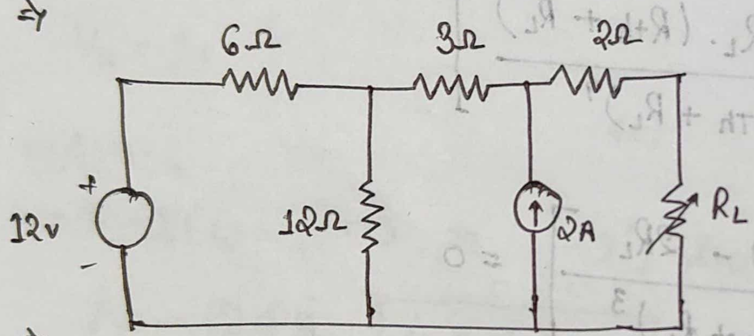
$$R_L = R_{TH}$$

- The value of max. power when $R_L = R_{TH}$ is Calculated as

$$\boxed{P_{max} = \frac{V_{TH}^2}{R_{TH}}}$$

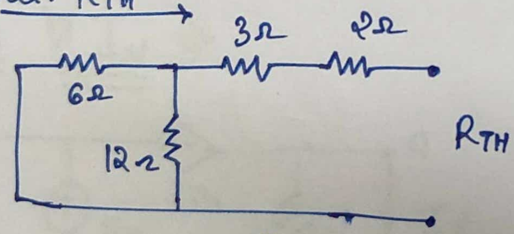
Que. 1) Find P_{max}.

⇒

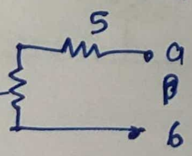


⇒

① Cal. R_{TH}

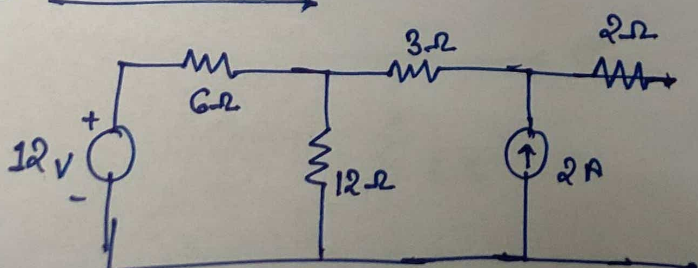


$$\boxed{R_{TH} = 9\Omega}$$

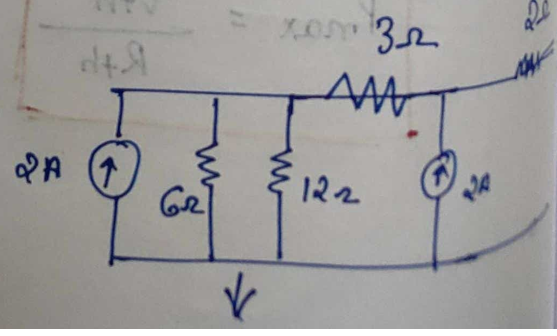


$\frac{6 \times 12}{18} = 4\Omega$

② Calc. V_{TH}



⇒



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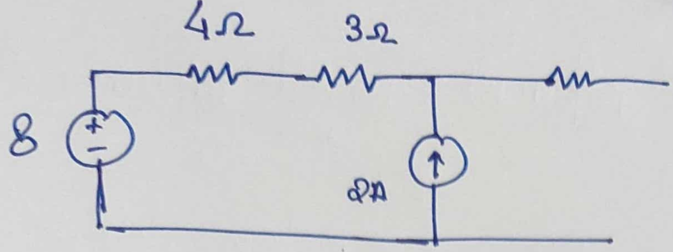

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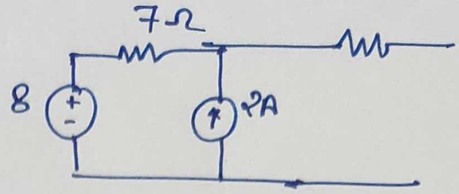

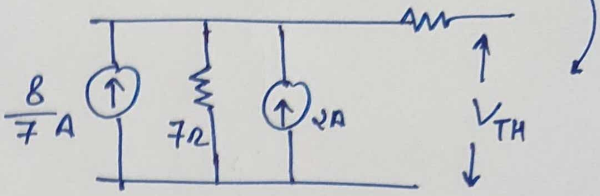

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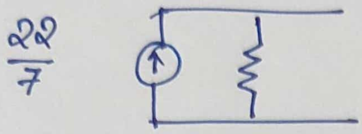

$$V_{TH} = \frac{22}{7} \times 7 \Rightarrow \boxed{V_{TH} = 22\ V}$$

$$\therefore\ P_{max} = \frac{V_{TH}^2}{4R_{TH}} = \frac{(22)^2}{9 \times 4} \Rightarrow \boxed{\cancel{P_{max} = 53.78\ W}}$$

✓ $\boxed{P_{max} = 13.44\ W}$

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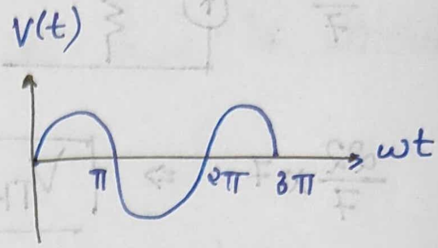
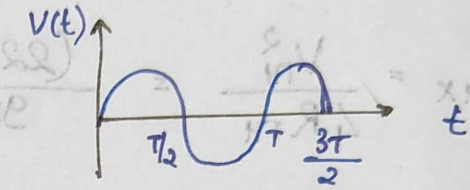
AC Circuits

- Sinusoid $\Rightarrow$ It represent mathematical function either in Sine or Cosine form.



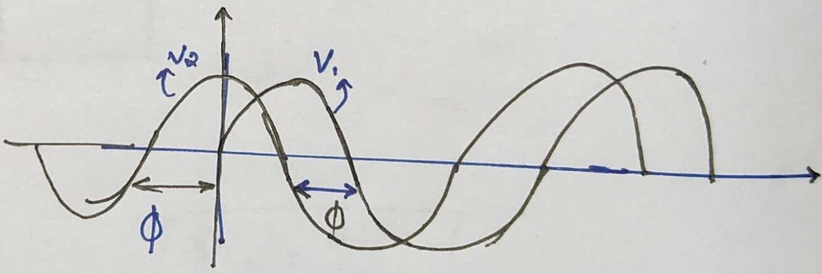
$v(t) = V_m \sin(\omega t)$

$V_m \longrightarrow$ Amplitude
$\omega t \longrightarrow$ Argument
$\omega \longrightarrow$ Angular freq.
$t \longrightarrow$ Second



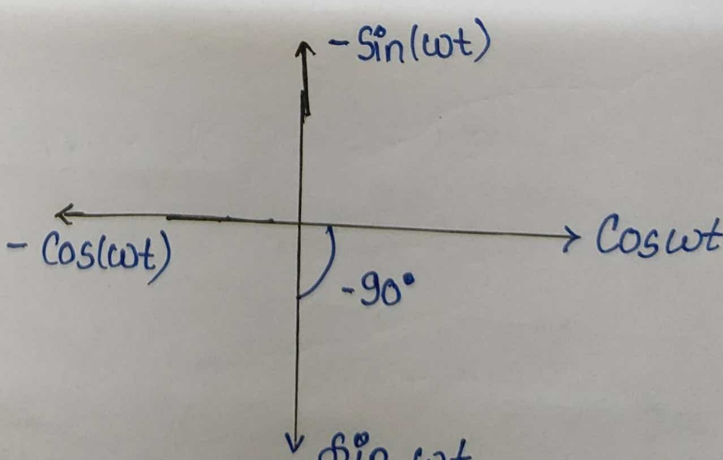
- A funct^n $f(t)$ is called periodic when $f(t+T) = f(t)$.

$$\begin{cases} V_1 = V_m \sin(\omega t) \\ V_2 = V_m \sin(\omega t + \phi) \end{cases}$$



$V_1 = V_m \sin(\omega t)$

$V_2 = V_m \cos(\omega t)$



$\cos(\omega t - 90) = \sin(\omega t)$

$\cos(\omega t + 90) = -\sin(\omega t)$

$\cos(\omega t \pm 180^\circ) = -\cos(\omega t)$

$\Downarrow$ +ve

cw angle $\Downarrow$ -ve

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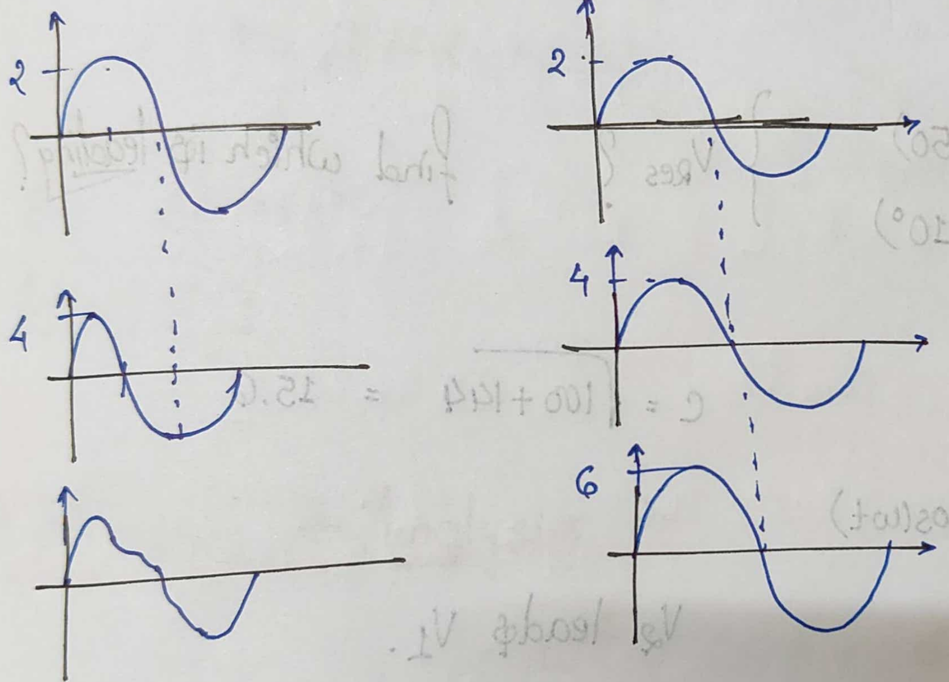
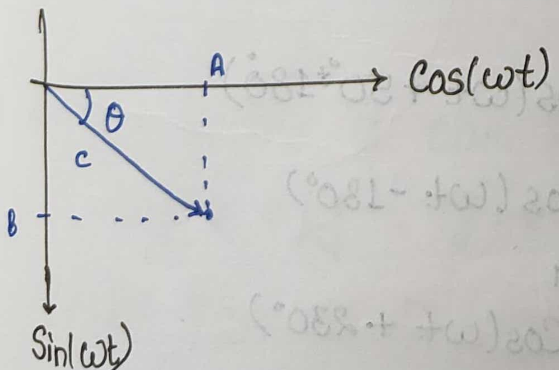
→ To compare two sinosoids express both of them either in Sine or Cosine with +ve amplitudes.

→ When two sinosoids are added. the result will be in sinosoid provided both of ~~temp~~ them should have same frequency.

$$\underbrace{A\cos(\omega t) + B\sin(\omega t)}_{\text{Same frequency}} = C\cos(\omega t - \theta)$$





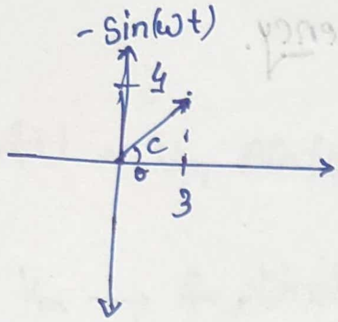
$C = \sqrt{A^2 + B^2}$, $\theta = \tan^{-1}(B/A)$

Eg) $3\cos\omega t - 4\sin\omega t = 5\,C\cos(\omega t - \theta)$

A ↑ B ↑

$\theta = \tan^{-1}\left(\frac{B}{A}\right) = \tan^{-1}\left(-\frac{4}{3}\right)$

$C = 5$, $\theta =$



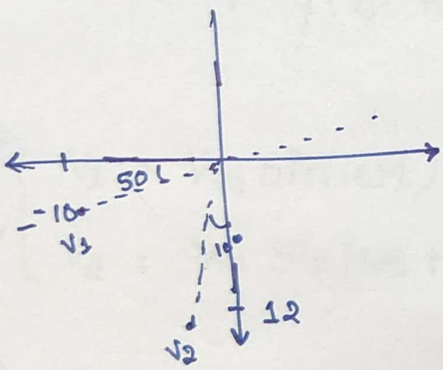
$\Rightarrow 5\cos(\omega t + 53^\circ)$

Q) $V_1 = -10\cos(\omega t + 50)$

$V_2 = 12\sin(\omega t - 10^\circ)$

} V_{Res} ? find which is leading?

$\Rightarrow$



$C = \sqrt{100 + 144} = 15.6$

V_2 leads V_1.

$V_1 = 10\cos(\omega t + 50^\circ \pm 180^\circ)$

$V_{2} = 10\cos(\omega t - 130^\circ)$

or

$= 10\cos(\omega t + 230^\circ)$

$V_2 = 12\cos(\omega t - 10 - 90^\circ)$

$V_2 = 12\cos(\omega t - 100^\circ)$

$\phi = 30^\circ$

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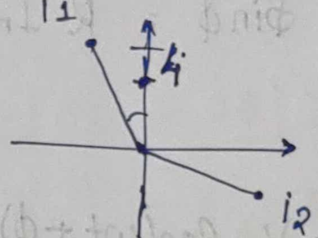
$V_1 = -10\cos(\omega t + 50) = 10\sin(\omega t + 50 - 90°) = 10\sin(\omega t - 40°)$

$V_2 = 12\sin(\omega t - 10°)$

Q.1) Find phase diff b/w

$i_1 = -4\sin(377t + 25°)$

$i_2 = 5\cos(377t - 40°)$



⇒

$i_1 = 4\cos(377t + 25° + 90°)$

$= 4\cos(377t + 115°)$

i_1 leads i_2 by 155°

$\phi = 115° + 40°$

$\boxed{\phi = 155°}$

#) Phasor Analysis ⇒

$e^{j\phi} = \cos\phi + j\sin\phi$

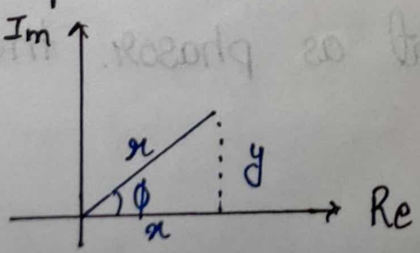
Euler's

- A Complex no. Z can be expressed in rectangular form.

$Z = x + jy \quad , \quad j = \sqrt{-1}$

polar form ⇒ $Z = r\angle\phi$

Exponential form ⇒ $Z = r \cdot e^{j\phi}$



$\rightarrow$ $Z = x + iy = r\angle\phi$

$= r(\cos\phi + j\sin\phi)$

which shows that, $\cos\phi$ & $\sin\phi$ as real & Imaginary point of $e^{j\phi}$

$\therefore \cos\phi = Re[e^{j\phi}]$

$\sin\phi = Im[e^{j\phi}]$

$\rightarrow$ Que.)

$v(t) = V_m \cos(\omega t + \phi) = Re[V_m . e^{j(\omega t + \phi)}]$

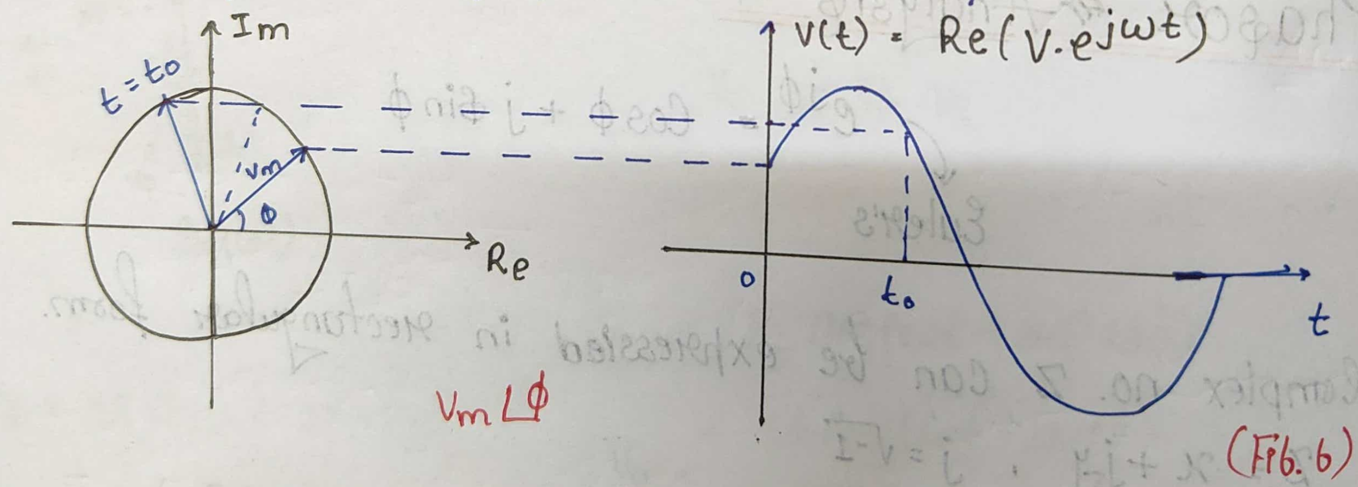
$= Re[V_m . e^{j\omega t} . e^{j\phi}]$

$= Re[V . e^{j\omega t}]$ —— ①

where,

$V = V_m e^{j\phi} = V_m \angle\phi$ —— ②

$V \rightarrow$ is known as phasor represent of sinusoidal $v(t)$.



(Fig. 6)

- If we project every point on $V.e^{j\omega t}$ on real axis it will appear like a sinusoid (fig 6)
- Whenever a sinusoid is represent as phasor, the term $e^{j\omega t}$ implicitly present.

• from a given phasor V to obtain a corresponding sinusoid multiply the phasor V by the time factor $e^{j\omega t}$ & take the real part.

• To get the phasor corresponding to sinusoid, we first express sinusoid in Cosine form. so that sinusoid can be written as real part of Complex No.

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Phasor Domain ⇒

Time Domain Representatⁿ	Phasor-Domain
$V_m \cos(\omega t + \phi)$	$V_m \angle \phi$
$V_m \sin(\omega t + \phi)$ $\hookrightarrow \cos(\omega t + \phi - 90^\circ)$	$V_m \angle \phi - 90^\circ$

$I = I_m \cos(\omega t + \phi)$

$I = I_m \angle \phi$

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

$\frac{di}{dt} = -I_m \sin(\omega t + \phi) . \omega$

$= - I_m \omega \cos(\omega t + \phi + 90^\circ)$

$= Re[I_m . \omega . e^{j(\omega t + \phi + 90^\circ)}]$

$= Re[I_m \omega . e^{j\omega t} . e^{j\phi} . e^{j 90^\circ}]$ → $\cos(90^\circ) + j \sin(90^\circ) = j$

$= Re[I \ \omega . e^{j\omega t} . j] = Re[I . j\omega . e^{j\omega t}]$

$\hookrightarrow \cos(\omega t) + j \sin(\omega t)$

$\frac{di(t)}{dt} = I . j\omega$

$I . (j\omega \cos(\omega t) - \omega \sin(\omega t)$

$I \omega ($

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Time Domain	Phasor Domain
$\dfrac{dv(t)}{dt}$ →	$j\omega . V$
$\int v(t)\,dt$ →	$\dfrac{V}{j\omega}$

Que.) $[40\angle 50 + 20\angle -30]^{1/2}$ → ★★ $\sqrt{r\angle\phi} \Downarrow \sqrt{r}\,\angle\phi/2$

$\Rightarrow$

$(38.59 - 10.49j + 3.08 + 19.76j)^{1/2}$

$= (41.67 + 9.27j)^{1/2}$

$= (42.68\angle 0.21)^{1/2}$

$= 6.53\angle 0.21$

$= 6.9\angle 12°$ Ans ✓

Soln $\Rightarrow (47.72\angle 25.62°)^{1/2}$

$= \sqrt{47.72}\ \angle\dfrac{25.62}{2}$

$= 6.9\angle 12.8°$ Ans

(2) $\dfrac{10\angle -30 + (3 - j4)}{(2+j4)(3-j5)^{*}}$ → conjugate → $(3+j5)$

$\Rightarrow$

$\dfrac{\ldots - 5j + 3 - j4}{4.47\angle 63.43 \times 5.83\angle -59.03}$ $26.06\angle 4.4$

$= 0.56\angle -160°$

Ans

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Q1) Transform the sinusoidals to phasors.

(i) $v(t) = -4 \sin(30t + 50^\circ)$

$\Rightarrow \quad = 4 \cos(30t + 140^\circ)$

$= 4 \angle 140^\circ$ ✓

(ii) $i(t) = 6 \cos(50t - 40^\circ)$

$= 6 \angle -40^\circ$ ✓

Q.2) Find the sinusoides for the given phasor.

(i) $I = -3 + j4$ $\quad r = \sqrt{x^2 + y^2} \Rightarrow r = 5$

$= 5 \angle 126.86^\circ$ $\quad \cancel{\theta = \tan^{-1}\left(\frac{4}{3}\right)} =$

$= 5 \cos(\omega t + 126.86^\circ)$

(ii) $V = j \cdot 8 \cdot e^{-j20}$ $\rightarrow 8 \cos(\omega t + 70^\circ)$ Ans $\quad j = 1 \angle 90^\circ$

$= 1 \angle 90^\circ \times 8 \angle -20^\circ$

$= 8 \angle 70^\circ$

$= 8 \cos(\omega t + 70^\circ)$ ✓

(iii) $i_1(t) = 4 \cos(\omega t + 30^\circ)$ $\Rightarrow I_1 = 4 \angle 30^\circ$

$i_2(t) = 5 \sin(\omega t - 20^\circ)$ $\Rightarrow I_2 = 5 \angle -110^\circ$

$\quad \hookrightarrow \cos(\omega t - 110^\circ)$

$I_1 + I_2$?

$i_1 + i_2 = 3.21 \angle -56.9^\circ$

$= 3.21 \cos(\omega t - 56.9^\circ)$

Steps →
1. Convert to polar form.
2. Add.
3. Convert to time domain form.

(iv) $V_1 = -10 \sin(\omega t + 30^\circ)$ $\hookrightarrow 10\cos(\omega t + 120^\circ)$

$V_2 = 20 \cos(\omega t - 45^\circ)$ } $V_1 + V_2$ (Ans should be in Time domain form)

$10.66 \cos(\omega t - 30.9)$ Ans

$\Rightarrow$

$V_1 + V_2 = 10 \angle 120^\circ + 20 \angle -45^\circ$

$= 10.66 \angle -30.9^\circ$

$= 10.66 \cos(\omega t - 30.9^\circ)$ ✓

(v) $4\, i(t) + 8 \int i(t)\, dt - 3 \dfrac{di(t)}{dt} = 50 \cos(2t + 75^\circ)$

using the phasor approach, determine i.

$\boxed{\omega = 2}$

(i) Time domain to phasor domain

$4I + 8\dfrac{I}{j\omega} - 3I(j\omega) = 50 \angle 75^\circ$

~~4I + 48I~~

$4I - 4Ij - 6Ij = 50 \angle 75^\circ$

$4I - 10Ij = 50 \angle 75^\circ$

$I = \dfrac{50 \angle 75^\circ}{4 - 10j}$

$I = \dfrac{50 \angle 75^\circ}{10.77 \angle -68.19}$

$I = 4.64 \angle 143.19^\circ$

✓ $I = 4.64 \cos(2t + 143.2^\circ)$

Phasor - Relationship for Circuit Elements

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	Time-domain	Phasor-domain
R	$v(t) = R.i(t)$	$V = RI$
L	$v(t) = L.\frac{di(t)}{dt}$	$V = j\omega L.I$
C	$v(t) = \frac{1}{C}\int i(t).dt$	$V = \frac{I}{j\omega C}$

$Z = \frac{V}{I}$ is called Impedance of ckt.

L , when $\omega = 0$, $Z_L = 0$ ⇒ DC

$\omega = \infty$, $Z_L = \infty$

C

$\omega = 0$, $Z_C = \infty$ ⇒ DC

$\omega = \infty$, $Z_C = 0$

eg)

$$2\frac{dv}{dt} + 5V(t) + 10\int V(t).dt = 20\cos(5t - 30^\circ)$$

$\omega = 5$

⇒

$$2j\omega V + 5V + 10\frac{V}{j\omega} = 20\angle -30^\circ$$

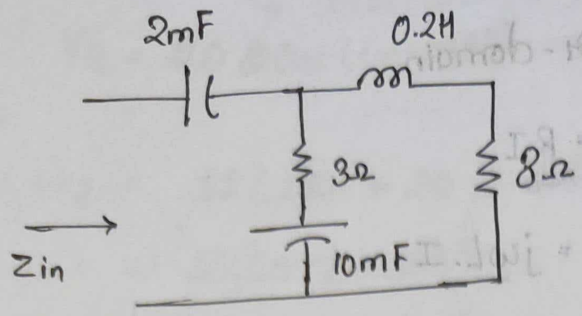
$$10jV + 5V + \frac{2V}{j} = 20\angle -30^\circ$$

$$5V + 8jV = 20\angle -30^\circ$$

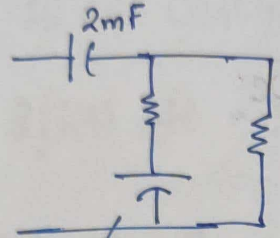
$$V = \frac{20\angle -30^\circ}{5 + 8j} = 2.119\angle \overset{-87.99^\circ}{\cancel{27.99^\circ}}$$

✓ $V(t) = 2.119\cos(5t + \overset{-87.99^\circ}{\cancel{27.99^\circ}})$ Ans

Q.1) Find the i/p impendance of ckt, assuming the $\omega = 50$ rad/s



→



$Z_1 = 10j + 8$

$Z_2 = 3 + \frac{1}{0.5j} = 3 - 2j$

$Z_{12} = \frac{(10j+8)(-2j+3)}{8j+11}$

$Z_{12} = 3.39 \angle -18.37$

$Z_{12} = 3.217 - 1.06j$

$Z_{in} = \frac{1}{\frac{2 \times 50}{\cancel{1000}\ 10}j} + 3.217 - 1.06j$

$= -10j + 3.217 - 1.06j$

$\cancel{Z_{in} = 3.217 - 2.06j}$

$Z_{in} = 3.217 - 11.06j$ Ans

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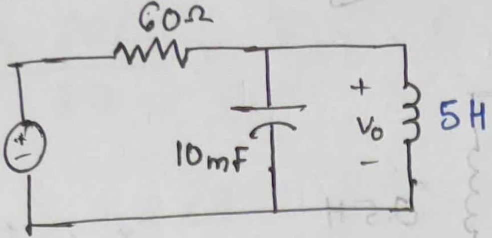
Q.2) Determine the V_o in th ckt

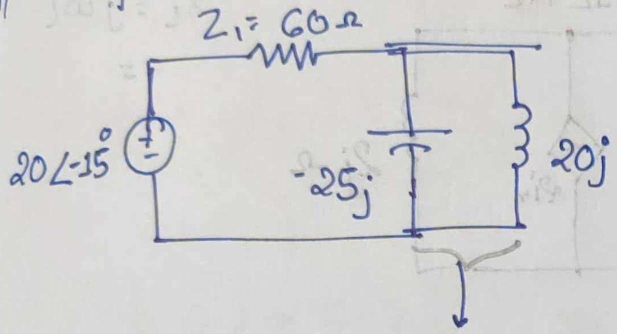
$X_C = \frac{1}{j\omega C}$

$X_L = j\omega L$



20 Cos(4t − 15°)

i) Transform all the elements present in ckt in phasor domain.



$X_L = j\omega L$

$X_L = j \times 4 \times 5$

$X_L = 20j$

$\omega = 4$

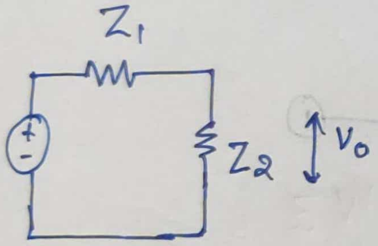
$X_C = \frac{1}{j \times \frac{4 \times 10}{1000}}$

~~$X_C = -20j$~~

$X_C = -25j$

$Z_2 = \frac{X_L X_C}{X_L + X_C}$

$Z_2 = 100j$



~~$Z_{Res} = 60 + 100j$~~

~~$V_o = \frac{20\angle -15°}{60 + 100j} = 0.047 - 0.165j$~~

~~$V_o = 0.175 \angle -74.0°$~~

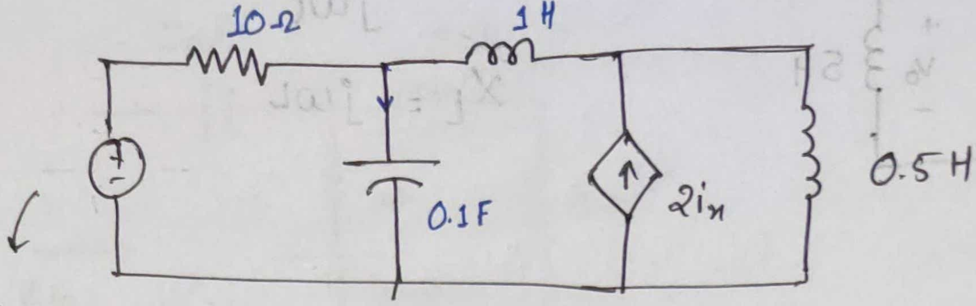
$V_o = V \times \frac{Z_2}{Z_1 + Z_2}$

$V_o = \frac{100j \times 20\angle -15°}{60 + 100j}$

$V_o = 17.15 \angle 15.96°$

$V_o = 17.15 \, Cos(4t + 15.96°)$

Q.3) Find i_x in the ckt using Nodal Analysis



20 cos(4t)

$X_c = \frac{1}{j \times 4 \times 0.1}$

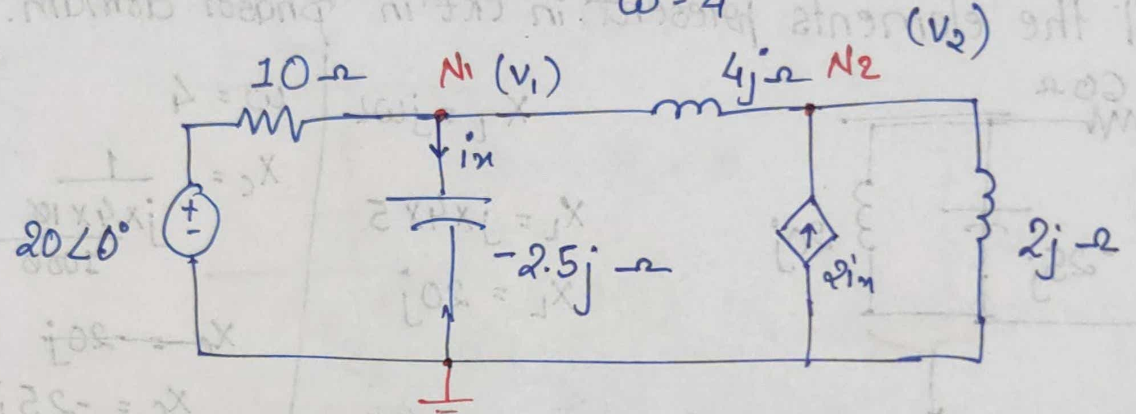
$X_c = -2.5j$

$\omega = 4$

$X_L = j\omega L$

=

⇒



Nodal Analysis ~~at N1~~

KCL at N1 ⇒

$$\frac{V_1 - 20\angle 0^\circ}{10} + \frac{V_1 - V_2}{4j} + \frac{V_1}{-2.5j} = 0 \quad \text{— (1)}$$

$$\frac{V_1 - 20\angle 0^\circ}{10} + \frac{V_2 - V_1}{4} j + \frac{V_1 j}{2.5} = 0$$

$$i_x = \frac{V_1}{-2.5j}$$

KCL at N2 ⇒

$$\frac{V_2 - V_1}{4j} - 2i_x + \frac{V_2}{2j} = 0 \quad \text{— (2)}$$

$$\frac{V_1 - V_2}{4} j - \frac{V_1}{2.5} j - \frac{V_2 j}{2} = 0$$

$$\frac{V_1 - 20\angle 0^\circ}{10} - \frac{V_2}{2} j = 0$$

$$\frac{V_1}{10} - 2\angle 0^\circ - \frac{V_2}{2} j = 0$$

- 0.25
+ 0.4

$$V_1 \left(\frac{1}{10} - \frac{j}{4} + \frac{j}{2.5} \right) V_1 + \left(\frac{j}{4} \right) V_2 = 2\angle 0^\circ$$

$$\left(\frac{j}{4} - \frac{j}{2.5} \right) V_1 + \left(\frac{-j}{4} - \frac{j}{2} \right) V_2 = 0$$

$$\left(\frac{1}{10}\, 0.1 + 0.15j \right) V_1 + (0.25j) V_2 = 2\angle 0^\circ$$

$$(-0.15j)\, V_1 + (0.75j)\, V_2 = 0$$

$$\begin{bmatrix} \overset{(A)}{0.1 + 0.15j} & \overset{(B)}{0.25j} \\ \underset{(C)}{-0.15j} & \underset{(D)}{0.75j} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} \overset{(E)}{2\angle 0^\circ} \\ \underset{(F)}{0} \end{bmatrix}$$

$$V_1 = \frac{\Delta}{\Delta_1} = \frac{AD - BC}{ED - FB} = \frac{0.168\angle 153.43^\circ}{1.5\angle 90^\circ} = 0.112\angle 63.43^\circ$$

$$V_1 = 0.054 + 0.109j$$

$$V_2 = \frac{\Delta_2}{\Delta} = \frac{AF - CE}{AD - BC} = \frac{0.3i}{-0.15 + 0.075i} = 0.8 - 1.6i$$

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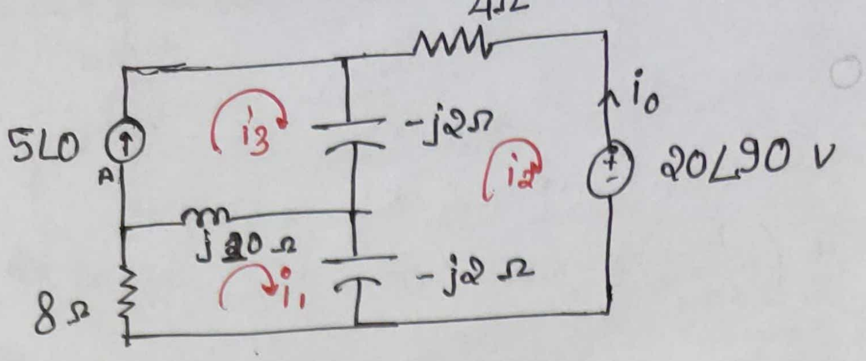
Q.1 Determine the current i_o in the ckt using mesh An...



⇒

KVL

Mesh-1

$$-8i_1 - 10j(i_1 - i_3) - (-j2)(i_1 - i_2) = 0$$

$$-8i_1 - 10j\, i_1 + 10j\, i_3 + 2j\, i_1 - 2j\, i_2 = 0$$

$$(-8-8j)i_1 - (2j)\, i_2 + (10j)\, i_3 = 0 \quad \text{— (1)}$$

mesh-2

$$-(-2j)(i_2 - i_3) - (-2j)(i_2 - i_1) - 4i_2 - 20\angle 90 = 0$$

$$(2j)i_2 - (2j)i_3 + (2j)i_2 - (2j)i_1 - 4i_2 = 20\angle 90$$

$$(-2j)\, i_1 + (-4+4j)i_2 + (-2j)i_3 = 20\angle 90 \quad \text{— (2)}$$

Mesh-3

$i_3 = 5\angle 0$

$$-(10j)(i_3 - i_1) - (-2j)\cancel{(i_3 - i_2)}\ \cancel{+5\angle 0} = 0$$

$$\cancel{(-10j)i_3} + (10j)\, i_1 + (2j)\, i_3 + (-2j)\, i_2 = \cancel{-5\angle 0}$$

$$-(-2j)(5\angle 0 - i_2) - (10j)(5\angle 0 - i_1) = 0$$

$$2j \cdot 5\angle 0 + (-2j)\, i_2 - 10j \cdot 5\angle 0 + (10j)\, i_1 = 0$$

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$$\begin{array}{cc} A & B \\ \end{array}$$

$$\begin{bmatrix} 8+8j & 2j \\ 2j & 4-4j \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} 50j \\ -30j \end{bmatrix}$$

$$\begin{array}{ccc} C & D & \\ \end{array} \quad E = 50j, \; F = -30j$$

$$i_1 = \frac{\Delta_1}{\Delta} = \frac{ED - BF}{AD - BC} = \frac{140 + 200j}{68} = 140 + 2.94j$$

$$i_2 = \frac{\Delta_2}{\Delta} = \frac{AF - CE}{AD - BC} = \frac{340 - 240i}{68} = 5 - 3.529i$$

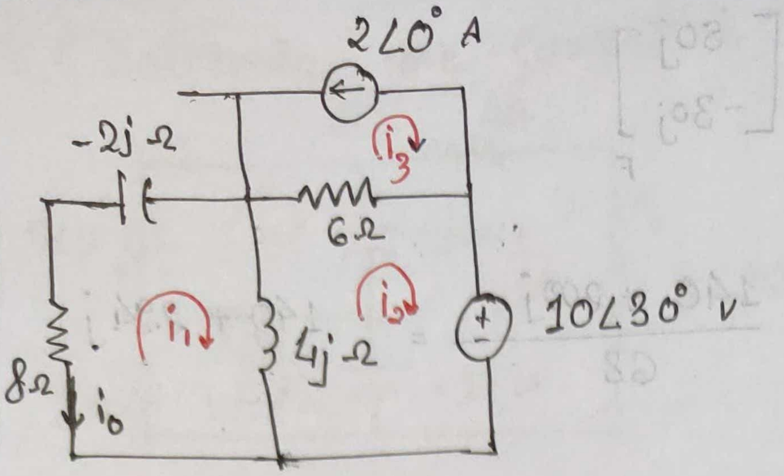
$$i_1 = 140 \angle 1.2^\circ$$

$$\mathring{i}_2 = 6.12 \angle -35.2^\circ$$

$$\mathring{i} = -6.12 \angle -35.2^\circ$$

Que.2)

$i_0 = ?$



⇒ KVL

Mesh-1

$-(-2j)i_1 - (4j)(i_1 - i_2) - 8i_1 = 0$

$2j\,i_1 - 4j\,i_1 + 4j\,i_2 - 8i_1 = 0$

$(-8-2j)\,i_1 + (4j)\,i_2 = 0$ — ①

Mesh-3

$i_3 = -2\angle 0°$

Mesh-2

$-(4j)(i_2 - i_1) - 6(i_2 + 2) = 10\angle 30°$

$-4j\,i_2 + 4j\,i_1 - 6i_2 - 12\angle 0° = 10\angle 30°$

$(4j)\,i_1 + (-6-4j)\,i_2 = \cancel{-3.34+5j}$ $21.256\angle 13.6°$ — ②

$$\begin{array}{ccc} (a) & (b) & \\ \end{array}$$

$$\begin{bmatrix} -8-2j & 4j \\ 4j & -6-4j \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} 0 \\ \cancel{-3.34+5j} \end{bmatrix}$$

(c) (d) (E) (f)

$f = 21.256\angle 13.6°$

$i_1 = \dfrac{\Delta_1}{\Delta} = \dfrac{ED - FB}{AD - BC} = \cancel{0.336 - 0.026j} = \cancel{0.337\angle 4.41°}$

$1.19 \angle -114.5°$

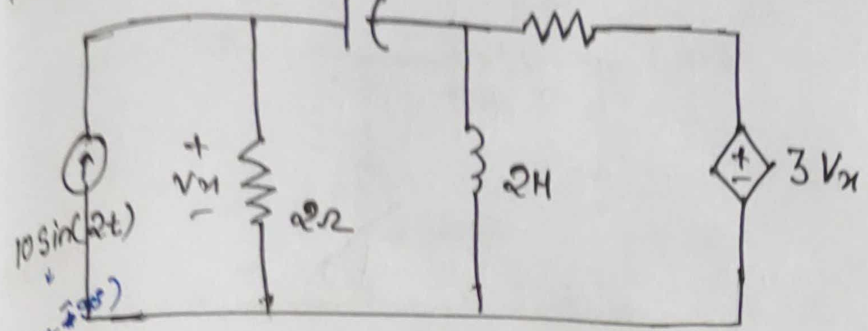
$i_2 = \dfrac{\Delta_2}{\Delta} = \dfrac{AF - CE}{AD - BC} = \cancel{0.696\angle -80.37°}$

$i_0 = -i_1 = -1.19\angle -114.5°$

Ans

Que. 3) Find the node Voltages ?

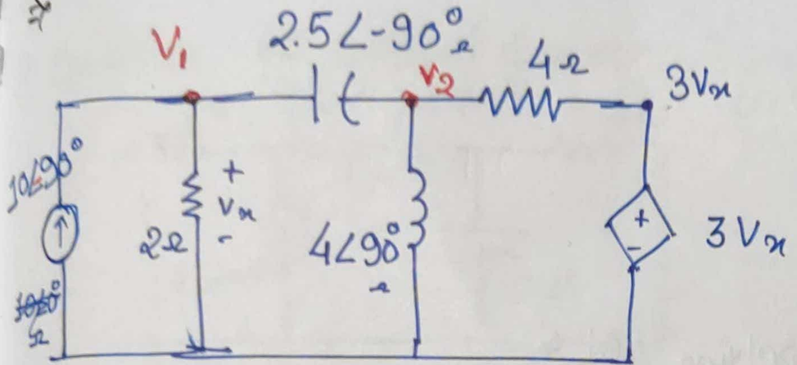
04/Sep/24



$\omega = 2$

$X_C = \frac{1}{j\omega C}$

$X_L = j\omega L$



$V_1 = V_x$

$V_x = \cancel{\frac{V_1}{2}}$

At V_1

$$-10\angle 90^\circ + \frac{V_1}{2} + \frac{V_1 - V_2}{2.5\angle -90^\circ} = 0$$

At V_2

$$\frac{V_2 - V_1}{2.5\angle 90^\circ} + \frac{V_2}{4\angle 90^\circ} + \frac{V_2 - 3V_x}{4} = 0$$

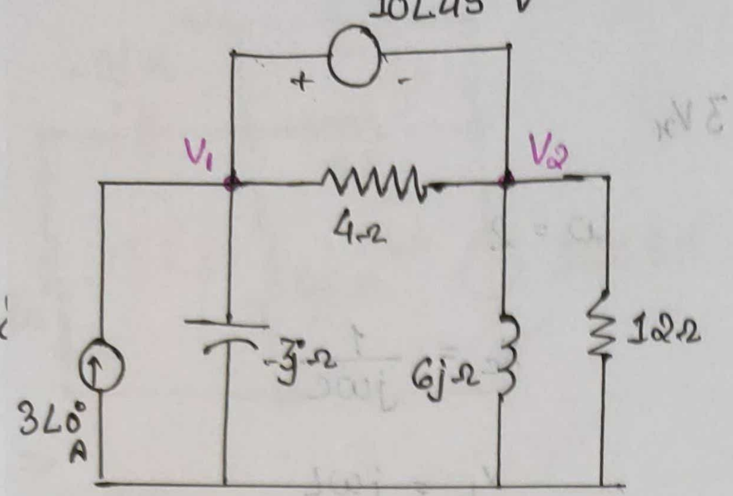
$$+\frac{V_1}{2} + \frac{V_1}{2.5\angle -90^\circ} - \frac{V_2}{2.5\angle -90^\circ} = 10\angle -90^\circ \quad (1)$$

$$\frac{V_2}{2.5\angle 90^\circ} - \frac{V_1}{2.5\angle 90^\circ} + \frac{V_2}{4\angle 90^\circ} + \frac{V_2}{4} - \frac{3V_1}{4} = 0$$

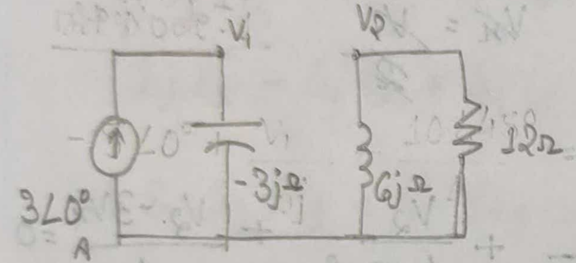
$$\left(\frac{-1}{2.5\angle 90^\circ} - \frac{3}{4}\right)V_1 + \left(\frac{1}{4} + \frac{1}{2.5\angle 90^\circ} + \frac{1}{4\angle 90^\circ}\right)V_2 = 0$$

$V_1 = \cancel{54.63\angle 99.72^\circ}$

Que.1) Find Node Voltage



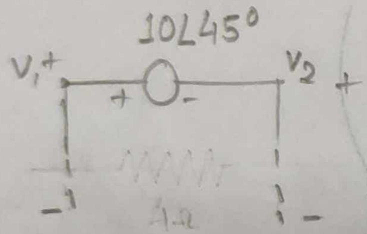
Applying Super Node Analysis ⟶



Applying KCL ⇒

$$-3\angle 0^\circ + \frac{V_1}{-3j} + \frac{V_2}{6j} + \frac{V_2}{12} = 0$$

$$\left(\frac{j}{3}\right)V_1 + \left(\frac{-j}{6} + \frac{1}{12}\right)V_2 = 3\angle 0^\circ \quad \text{—(1)}$$



Applying KVL ⇒

$$V_1 - 10\angle 45^\circ - V_2 = 0$$

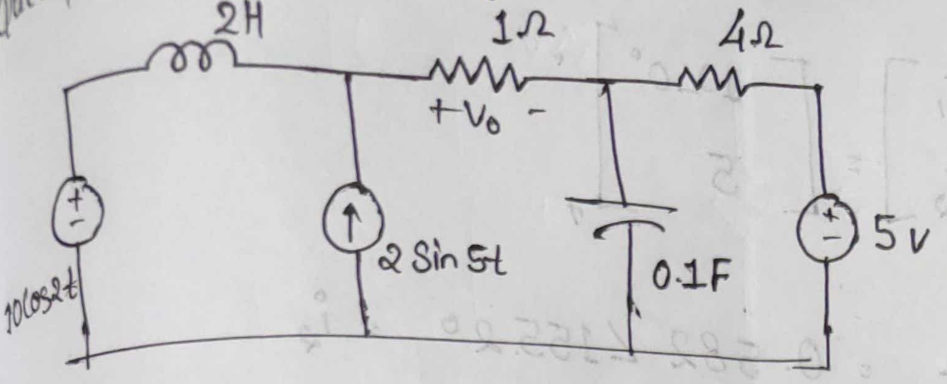
$$V_1 - V_2 = 10\angle 45^\circ$$

$$\begin{bmatrix} \frac{j}{3} & \frac{-j}{6} + \frac{1}{12} \\ 1 & -1 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 3\angle 0^\circ \\ 10\angle 45^\circ \end{bmatrix}$$

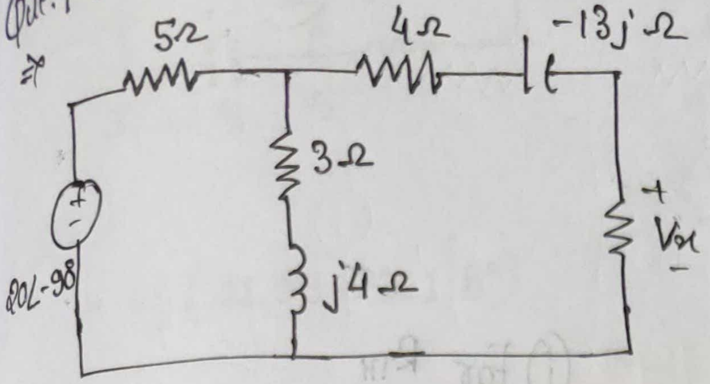
$$V_1 = \frac{\Delta_1}{\Delta} = \frac{ED - FC}{AD - BC} = 25.78\angle -70.48^\circ \checkmark$$

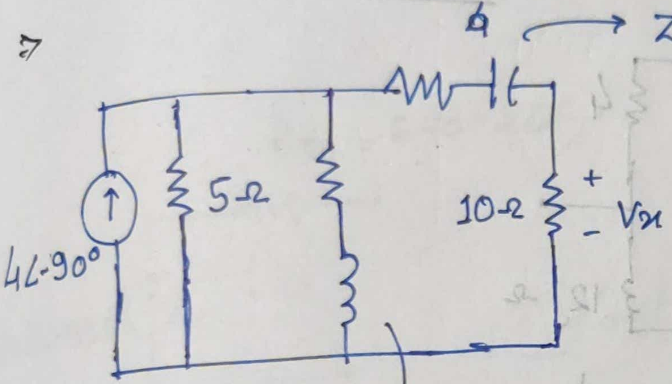
$$V_2 = \frac{\Delta_2}{\Delta} = \frac{AF - CE}{AD - BC} = 31.4\angle -87.18^\circ \checkmark$$

Que.2} Find $V_o(t)$ using superposition theorem. 04/Sep/24



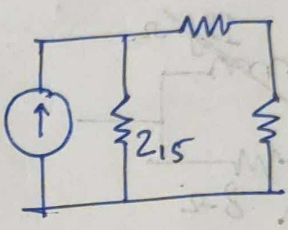
Que.) Calculate V_x in the ckt, using source Transformat^n 06/Sep/24





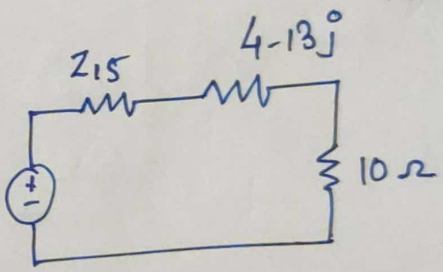
$Z_2 = 4 - 13j$

$Z_1 = 3 + 4j$



$$Z_{15} = \frac{\cancel{15+} \; 25\angle 53.1^\circ}{8.94\angle 26.56^\circ}$$

$$Z_{15} = 2.796\angle 26.54^\circ$$



$11.184\angle -63.46^\circ \; V$

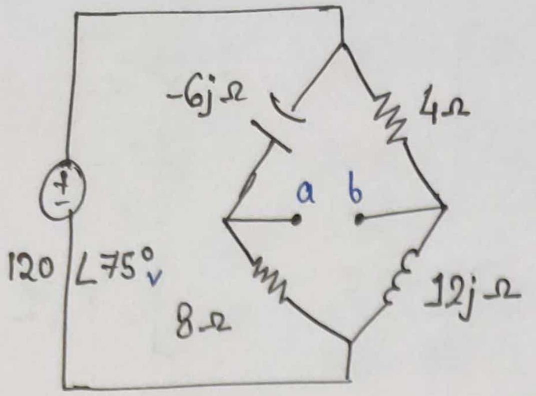
$$I = \frac{11.184\angle -63.46^\circ}{\quad}$$

$I = 0.552\angle -28^\circ$

$V_x = 5.52\angle -28^\circ$ ✓ ⇒ $V_x = 4.874 - 2.59j$

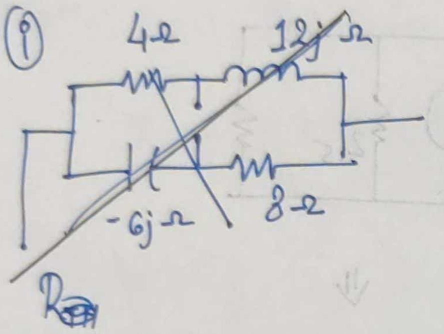
$V_x = \cancel{48.74 - 25.9}\, j$

Que.) Obtain the thevinin's Equ. ckt

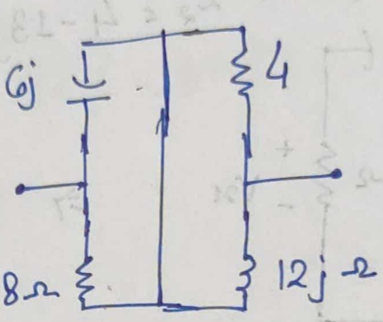


Sol

(i)



(i) For R_{TH}



$Z_1 = -6j \parallel 8.$ $\quad Z_2 = 4 \parallel 12j$

$Z_{TH} = Z_1 + Z_2$

$Z_{TH} = 2.88 - 3.84j + 3.6 + 1.2j$

$Z_{TH} = 6.48 - 2.64j$

(ii) For V_{TH}

$\cancel{I_1 = \frac{4+12j}{12+6j} \times I}$

$I = \frac{120\angle 75^\circ}{4+12j \parallel 8-6j}$

$\cancel{V_a = \frac{-6j}{8-6j} \times 120\angle 75^\circ}$

$I_1 = \frac{120\angle 75^\circ}{8 + -6j}$

$I_2 = \frac{120\angle 75^\circ}{4+12j}$

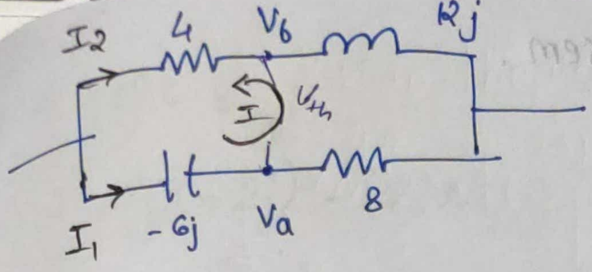
$I_1 = -4.47 + 11.13j$

$I_1 = 11.99 \angle 111.8^\circ$

$I_2 = 9.469 + 0.568j$

$9.48 \angle 3.43^\circ$

06/Sep/24



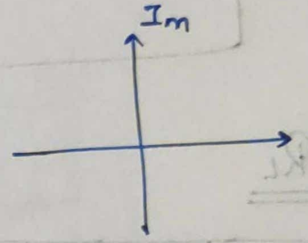
$$V_{TH} + (-6j)\, i_1 - 4 i_2 = 0$$

KVL

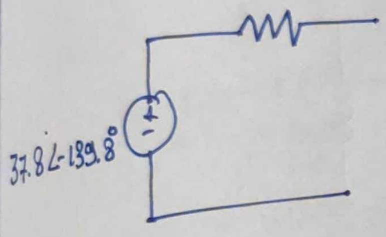
$-6j\,(11.99 \angle 111.8^\circ)$

$$V_{TH} = 4 i_2 + 6j\, i_1$$

$$V_{TH} = 37.8 \angle -139.8^\circ$$

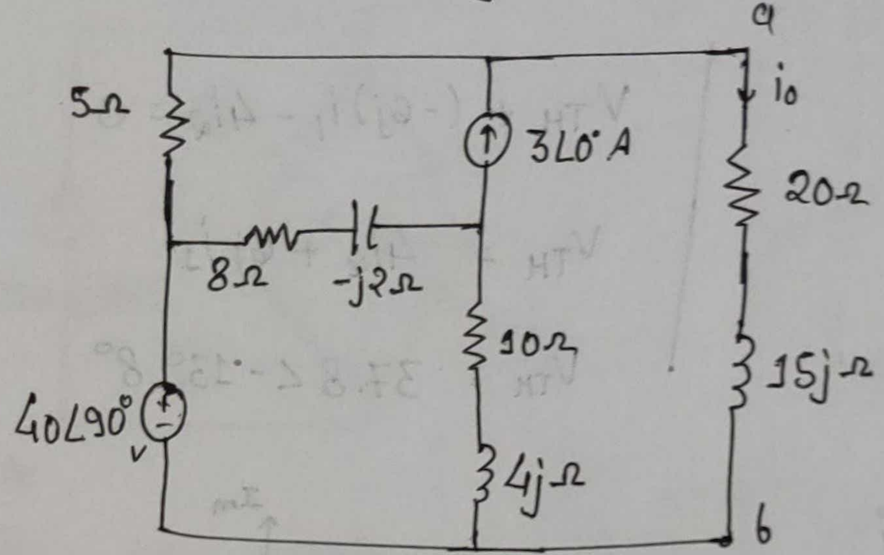


$R_{TH} = 6.48 - 2.64j$

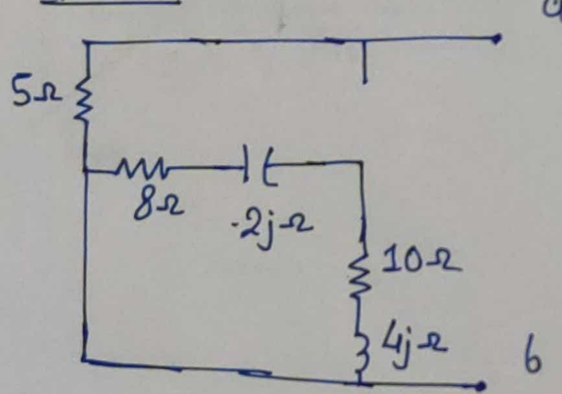


Q.4) obtain i_o using Norton's Theorem.

$i_o = 1.46 \angle 38.6$



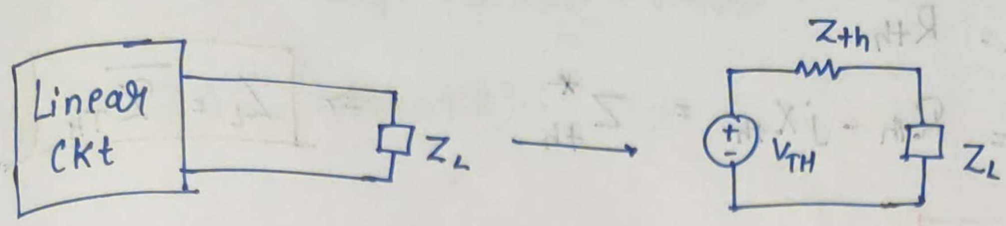
⇒ For R_L



$R_N = 5\Omega$

Maximum Power Transfer

10/Sep/24



$Z_{th} = R_{th} + jX_{th}$, $Z_L = R_L + jX_L$

Current through the load = $I_L = \dfrac{V_{th}}{Z_{th} + Z_L} = \dfrac{V_{th}}{\sqrt{(R_{th}+R_L)^2 + (X_{th}+X_L)^2}}$

Average power delivered to load, $P = \frac{1}{2} I^2 R_L$

$\boxed{I_{rms} = \dfrac{I_m}{\sqrt{2}}}$

$$= \frac{\frac{|V_{th}|^2 R_L}{2}}{(R_{th}+R_L)^2 + (X_{th}+X_L)^2}$$

For max Power

$$\frac{\partial P}{\partial X_L} = \frac{-(V_{th})^2 . R_L . (X_{th}+X_L)}{[(R_{th}+R_L)^2 + (X_{th}+X_L)^2]^2}$$

$$\frac{\partial P}{\partial R_L} = \frac{(V_{th})^2 . [(R_{th}+R_L)^2 + (X_{th}+X_L)^2 - (2R_L(R_{th}+R_L))]}{2[(R_{th}+R_L)^2 + (X_{th}+X_L)^2]^2}$$

$\dfrac{\partial P}{\partial X_L} = 0 \Rightarrow \boxed{X_L = -X_{th}}$ —— 1

$\dfrac{\partial P}{\partial R_L} = 0 \Rightarrow \boxed{R_L = \sqrt{R_{th}^2 + (X_{th}+X_L)^2}}$ —— 2 from ① & ②, for max. Power transfer

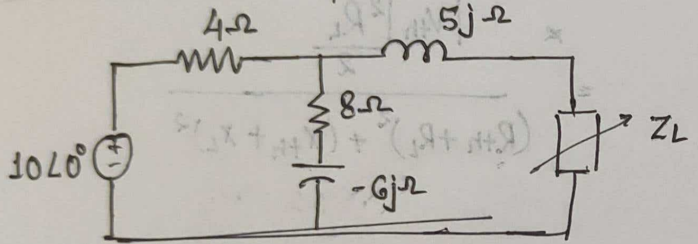
$X_L = -X_{th}$, $R_L = R_{th}$

$Z_L = R_L + jX_L = R_{th} - jX_{th} = Z_{th}^{*}$ $\Rightarrow$ $\boxed{Z_L = \overline{Z}_{TH}}$

$$\boxed{P_{max} = \frac{|V_{th}|^2}{8R_{th}}}$$

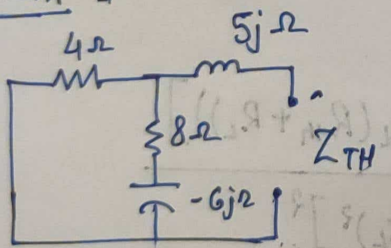
↳ Condition for max Power

Que.1) Determine the load impedance for max. power
Calc. Max power



⇒

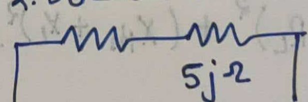
For Zth ⇒



⇒

2.98 ∠-10.3°

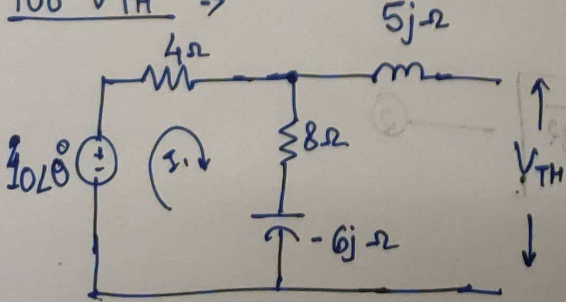
~~2.98∠-0.179~~



~~$Z_{th} = 5.343 \angle 0.989°$~~ ~~radian~~

$Z_{Th} = 5.343 \angle 56.7°$

For V_{TH} ⇒



~~V_{TH}:~~

$10\angle 0° - 4I_1 - 8I_1 + 6jI_1 = 0$

$$I_1 = \frac{10\angle 0°}{12 - 6j}$$

$I_1 = 0.745 \angle \cancel{0.463°}$ $\angle 26.56°$

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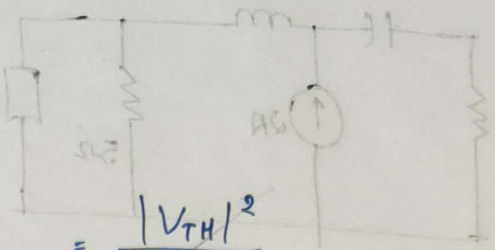
$$V_{TH} = (8 - 6j)(0.745 \angle 0.463^\circ)$$

$$V_{TH} = 7.45 \angle \cancel{-0.179^\circ} - 10.30^\circ$$



$$P_{max} = \frac{(7.45 \angle -0.179^\circ)^2}{8\,(5.343 \angle 0.989^\circ)} = \frac{|V_{TH}|^2}{8 R_{TH}}$$

$$P_{max} = 1.299 \angle -1.348^\circ$$

$$V_{TH} = (8-6j)(0.745 \angle 26.56^\circ)$$

$$V_{TH} = 7.45 \angle -10.3^\circ$$

$$P_{max} = \frac{|V_{TH}|^2}{8 R_{TH}} = \frac{(7.45)^2}{8 \times 2.933}$$

$$P_{max} = 2.365\ W$$

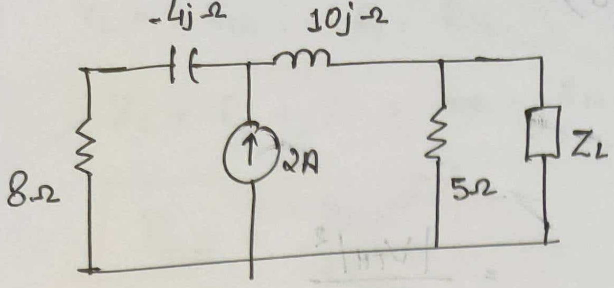
$$Z_{TH} = 2.933 + 4.465j$$

$$Z_L = Z_{TH}^*$$

$$Z_L = 2.933 - 4.465j$$

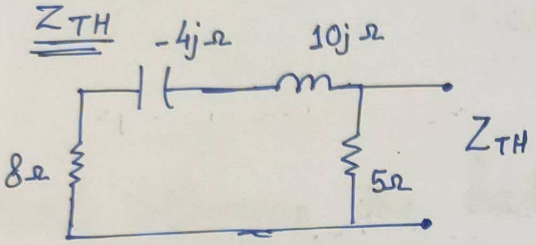
$$R_{TH} = 2.933$$

Q.2) Determine the load —



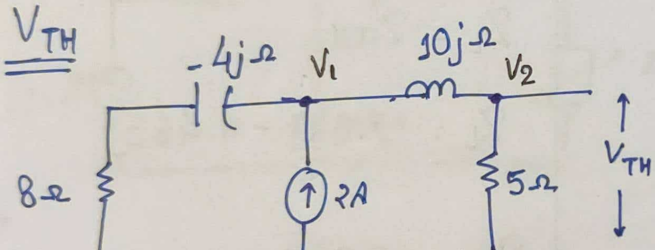
⇒

$\underline{Z_{TH}}$



$Z_{TH} = 3.49 \angle 12.09^\circ$

$\underline{V_{TH}}$



$$\frac{V_1 - 0}{8-4j} + (-2) + \frac{V_1 - V_2}{10j} = 0 \qquad \Bigg| \qquad \frac{V_2 - V_1}{10j} + \frac{V_2}{5} = 0$$

$$\left(\frac{1}{8-4j} + \frac{1}{10j}\right) V_1 + \left(\frac{-1}{10j}\right) V_2 = 2 \quad \text{—(1)} \qquad \Bigg| \qquad \left(\frac{-1}{10j}\right) V_1 + \left(\frac{1}{5} + \frac{1}{10j}\right) V_2 = 0$$

$$\begin{bmatrix} \overset{a}{\frac{1}{8-4j} + \frac{1}{10j}} & \overset{b}{\frac{-1}{10j}} \\ \underset{c}{\frac{-1}{10j}} & \underset{d}{\frac{1}{5} + \frac{1}{10j}} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 2 \\ 0 \end{bmatrix} \begin{array}{l} e \\ f \end{array}$$

$$V_2 = \frac{AF - CE}{AD - BC} =$$

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$I_5 = \frac{Z_2}{Z_1+Z_2} \times I = \frac{(8-4j)}{(5+10j+8-4j)} \times 2$

$I_{5\Omega} = 1.249 \angle -51.34°$

$V_{TH} = 5 I_5$

$V_{TH} = 6.247 \angle -51.34°$

$P_{max} = \frac{(V_{TH})^2}{8 R_{TH}} \Rightarrow P_{max} = \cancel{0.223} \; \cancel{\angle -127.8°}$

$Z_{TH} = 3.412 + 0.731 j$

$Z_L = Z_{TH}^*$

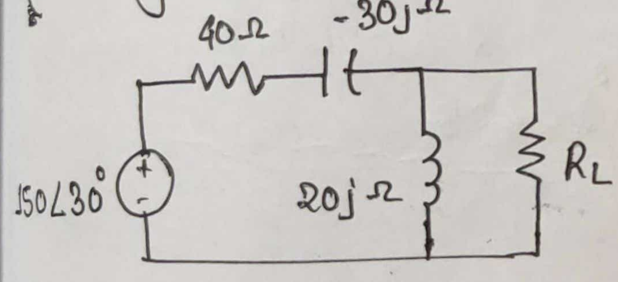
$= 3.412 - 0.731 j$

R_{TH}

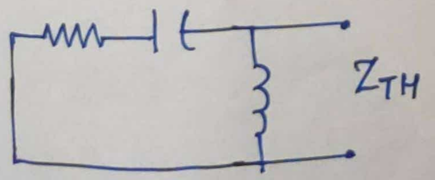
$P_{max} = \frac{(6.247)^2}{8 \times 3.412}$

$P_{max} = 1.43 \text{ W}$ ✓

Que.3) Find the value of R_L that will absorb the max. avg. power.



⇒ For Z_{TH}



$Z_{TH} = \frac{(40-30j)\,20j}{40-10j}$

$Z_{TH} = 24.25 \angle 67.16°$

$= 9.41 + 22.35 j$

For V_{TH}

$$V_{TH} = \frac{20j}{40-10j} \times 150\angle 30^\circ$$

$$V_{TH} = 72.76\angle 134^\circ \quad V$$

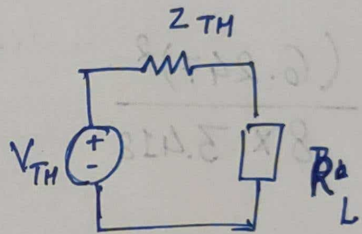
$\therefore \; x_L = 0 \Rightarrow R_L = |Z_{TH}|$

$Z_L = Z_{TH}^*$

$R_L = R_{TH} - X_{TH}\,j$

$$R_L = \sqrt{(9.41)^2 + (22.35)^2}$$

$$R_L = 24.25\ \Omega$$



$$P_{max} = \frac{|V_{TH}|^2}{8R_L}$$

?

$= 27.288$ W

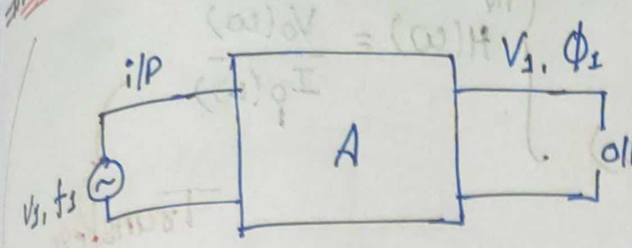
$$P_{max} = \frac{1}{2} I_L^2 R_L = \frac{1}{2} \times \left(\frac{V_{TH}}{R_L + Z_{TH}}\right)^2 \times R_L$$

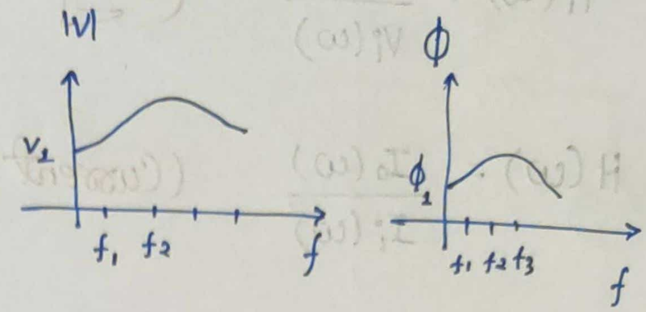
$$= \frac{1}{2} \times \left(\frac{72.76\angle 134^\circ}{24.25 + (9.41 + 22.35j)}\right)^2 \times 24.25$$

✓ $P_{max} = 39.31$ W

Frequency Response ⇒

11/Sep/24





→ when i/P or freq. changed how the o/P V or ϕ changes

- If the amp. of sinosoidal source remains const. & vary the freq. we obtain the ckt frequency response.
- The frequency response of the ckt is the variation in his behaviour with change in signal freq.
- The transfer function also called as Newtor funct^n is a useful analytical tool for finding a frequency response of ckt.
- The transfer funct^n of the Circuit is the frequency dependent ratio of phasor o/P $y(\omega)$ to phasor i/P $x(\omega)$. (x & y can be either Voltage or Current)

$$x(\omega) \text{ (i/P)} \longrightarrow \boxed{H(\omega)} \xrightarrow{y(\omega)} \text{o/P}$$

$$\boxed{H(\omega) = \frac{y(\omega)}{x(\omega)}}$$

→ Transfer funct^n "or" Network funct^n

i) $H(\omega) = \dfrac{V_0(\omega)}{V_i(\omega)}$ = (Voltage Gain)

ii) $H(\omega) = \dfrac{I_0(\omega)}{I_i(\omega)}$ (Current Gain)

iii) $H(\omega) = \dfrac{V_0(\omega)}{I_i(\omega)}$ → Transfer Impedance

iv) $H(\omega) = \dfrac{I_0(\omega)}{V_i(\omega)}$ (Transfer Admittance)

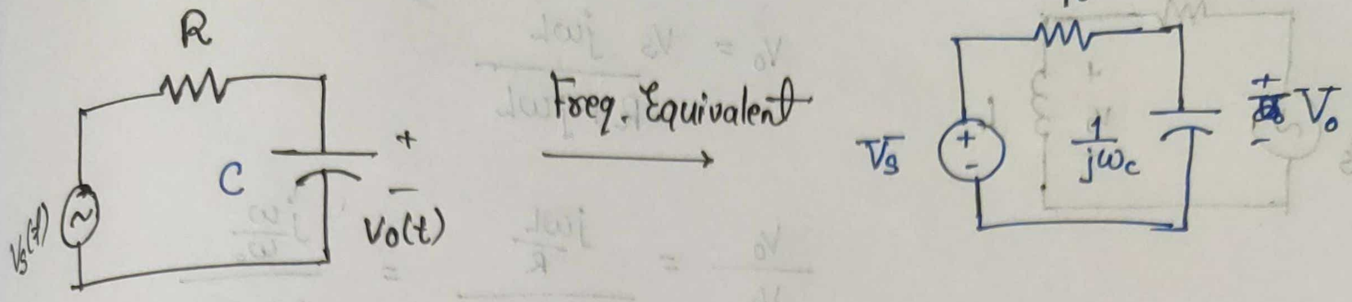
Time Domain		Freq. Domain
R	→	R
L	→	$j\omega L$
C	→	$\dfrac{1}{j\omega C}$

→ $H(\omega) = \dfrac{N(\omega)}{D(\omega)}$

$N(\omega) = 0$
└→ Roots of Neumerator polynomial is Called Zeroes of System

$D(\omega) = 0$
└→ Roots → Poles of System

Q) For the RC Ckt . obtain the ~~transfer~~ functn $\frac{V_o}{V_s}$ and freq. Response 11/Sep/24



$$H(\omega) = \frac{V_o}{V_s} = \frac{1/j\omega C}{R + \frac{1}{j\omega C}} = \frac{1}{1+j\omega RC}$$

$\omega_0 = \frac{1}{RC}$

$$H = \frac{1}{\sqrt{1+\left(\frac{\omega}{\omega_0}\right)^2}} \;\; \angle \tan^{-1}\left(\frac{\omega}{\omega_0}\right)$$

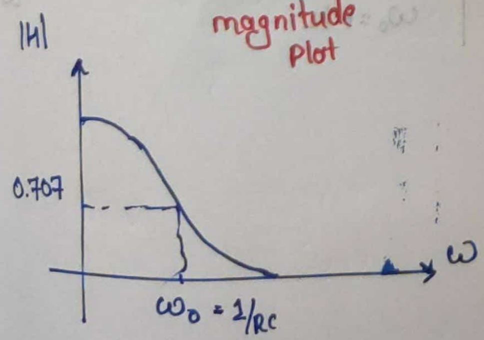
where , $\omega_0 = \frac{1}{RC}$

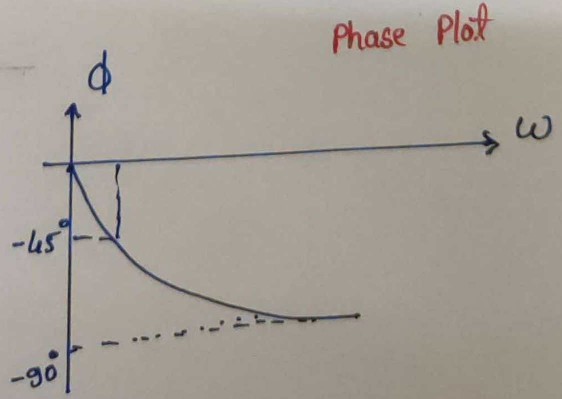
To plot $|H|$ & ϕ

$\omega = 0$, $|H| = 1$, $\phi = 0$

$\omega = \infty$, $|H| = 0$, $\phi = -90°$

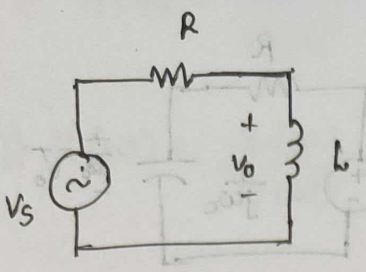
$\omega = \omega_0$, $|H| = \frac{1}{\sqrt{2}}$, $\phi = -45°$





$\omega_0 = \frac{R}{L}$

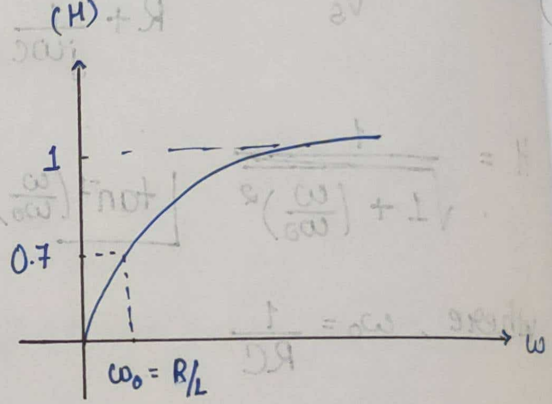
Transfer function of RL Ckt.



$$V_0 = V_S \frac{j\omega L}{R + j\omega L}$$

$$\frac{V_0}{V_S} = \frac{\frac{j\omega L}{R}}{1 + j\frac{\omega L}{R}} = \frac{j\frac{\omega}{\omega_0}}{1 + j\frac{\omega}{\omega_0}}$$

$$H(\omega) = \frac{\frac{\omega}{\omega_0} \angle 90^\circ}{\sqrt{1 + \left(\frac{\omega}{\omega_0}\right)^2} \;\angle \tan^{-1}\left(\frac{\omega}{\omega_0}\right)}$$

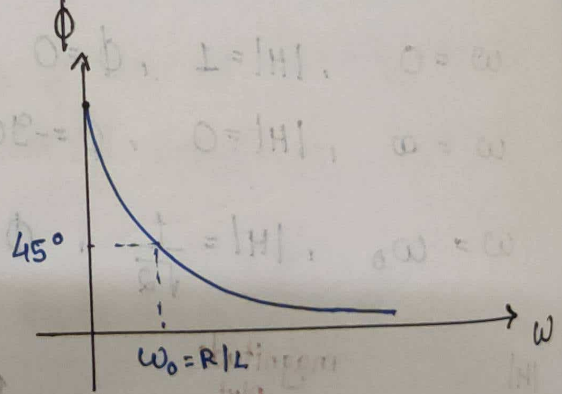


where, $\omega_0 = \frac{R}{L}$

when, $\omega = 0$, $|H| = 0$, $\phi = 90^\circ$

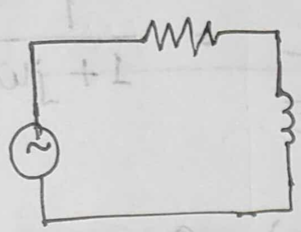
$\omega = \infty$, $|H| = 1$, $\phi = 0$

$\omega = \omega_0$, $|H| = \frac{1}{\sqrt{2}}$, $\phi = 45^\circ$



20/Sep/24

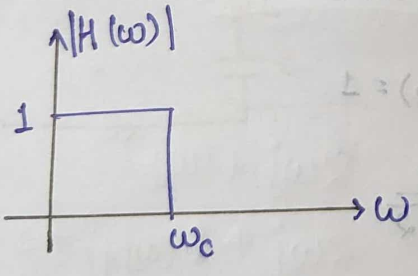
Q.1) Transfer funct^n of R-L ckt.



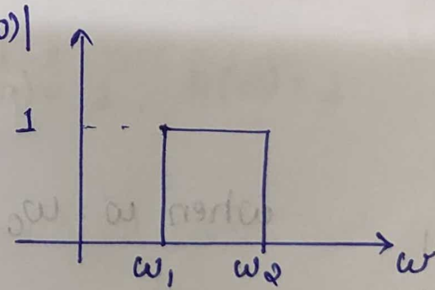
#) Passive Filter ⇒

- It is a ckt that is design ~~to~~ pass the signals with desired freq. & ~~at any~~ attenuate (or Reject) others.
- A filter is a passive filter if it consist of only passive element (R, L, C)
- Active filter consist of OP-Amp, transistor etc.

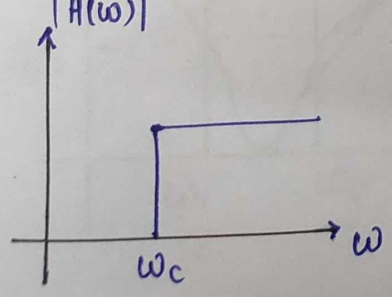
Q.1) *) LPF (Low Pass Filter) :–



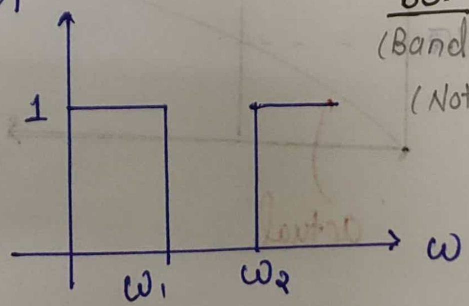
*) BPF :– (Band Pass filter)



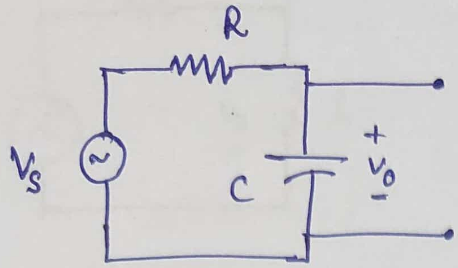
*) High Pass filter (HPF) :–



BSF (Band Stop Fi) (Notch filter)



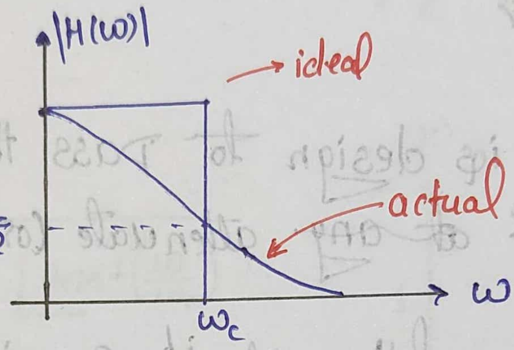
•) LPF is formed when the O/P of RC - ckt is taken - off the Capacitor



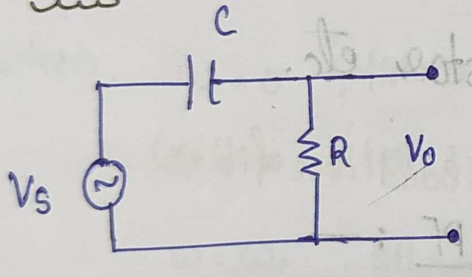
$$H(\omega) = \frac{1/j\omega C}{R + \frac{1}{j\omega C}} = \frac{1}{1 + j\omega RC}$$

$$H(0) = 1 \quad , \quad H(\infty) = 0$$

$$|H(\omega)| = \frac{1}{\sqrt{2}}$$



☆) HPF ⇒

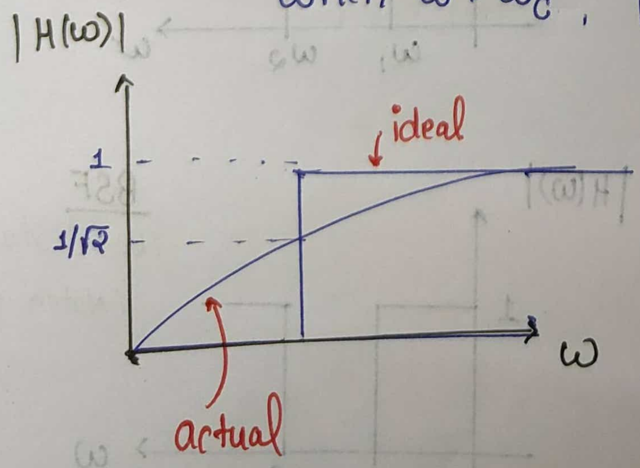


$$H(\omega) = \frac{V_o}{V_i} = \frac{R}{R + \frac{1}{j\omega C}}$$

$$H(\omega) = \frac{j\omega RC}{1 + j\omega RC}$$

$$H(0) = 0 \quad , \quad H(\infty) = 1$$

when $\omega = \omega_c$, $|H(\omega_c)| = \frac{1}{\sqrt{2}}$



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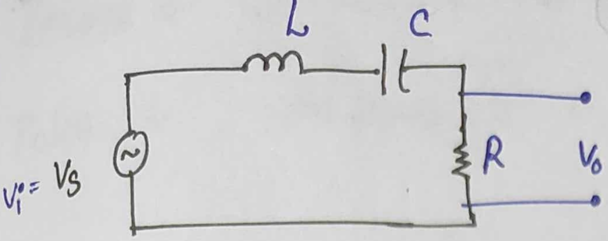
✯ BPF ⇒



$$H(\omega) = \frac{V_0}{V_i} = \frac{R}{R + j\omega L + \frac{1}{j\omega C}}$$

$$H(0) = 0, \quad H(\infty) = 0$$

$$x_L = x_C$$

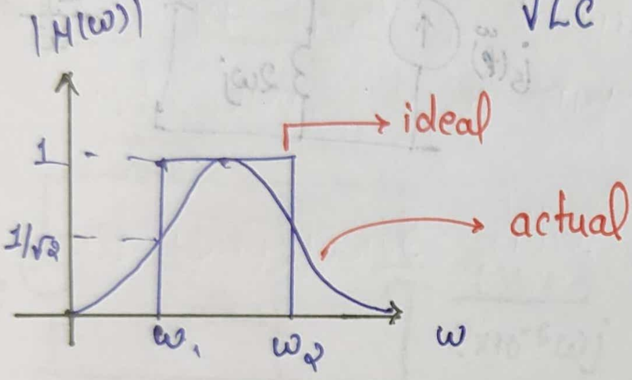
At Resonance, $\cancel{\omega_0 = 1}$

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

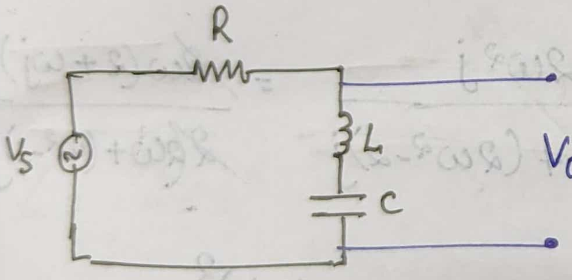
$$\omega^{0} = \frac{1}{\sqrt{LC}}$$

$$\omega_1 = \frac{-R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}$$

$$\omega_2 = \frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}$$

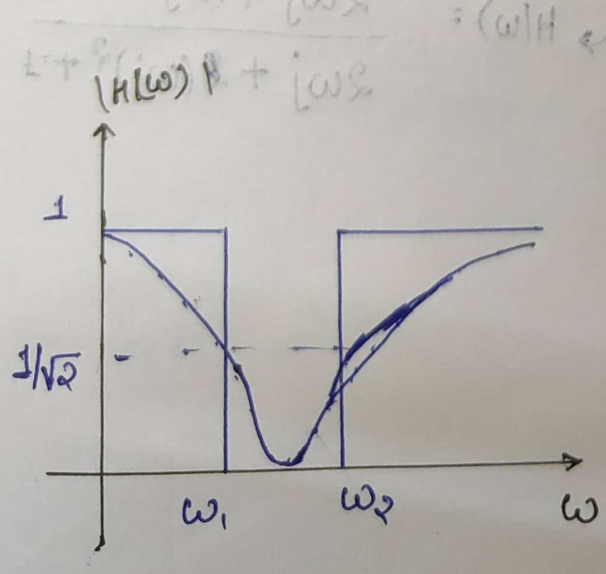


✯ BSF ⇒



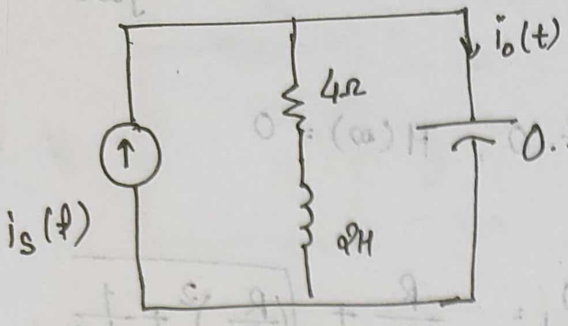
$$H(\omega) = \frac{V_0}{V_i} = \frac{j\left(\omega L - \frac{1}{\omega C}\right)}{R + j\left(\omega L - \frac{1}{\omega C}\right)}$$

$$H(0) = 1, \quad H(\infty) = 1$$



24/Sep/24

Q.1) For the ckt, Calc. the T/F $\frac{I_o(\omega)}{I_s(\omega)}$ and its Poles & Zeroes



⇒

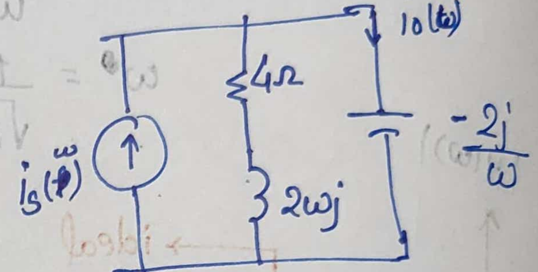
$X_C = \frac{1}{j\omega C}$

$= \frac{-j2}{\omega}$

$= \frac{-2j}{\omega}$

$X_L = j\omega L$

$X_L = 2\omega j$



$$i_o(\omega) = \left(\frac{4+2\omega j}{4+2\omega j-\frac{2j}{\omega}}\right) \times i_s$$

$$\frac{i_o(\omega)}{i_s(\omega)} = \frac{(4+2\omega j)\omega}{4\omega+2\omega^2 j+\frac{2}{j}} = \cancel{\frac{4\omega+2\omega^2 j}{4\omega+(2\omega^2-2)j}} = \cancel{\frac{2\omega(2+\omega j)}{2(2\omega+(\omega^2-1)}}$$

~~for poles ⇒~~ $\cancel{2\omega+(\omega^2-1)} = 0$

$$H(\omega) = \frac{2\omega j+(\omega j)^2}{2\omega j+(\omega j)^2+1}$$

Replace ⇒ $j\omega = s$

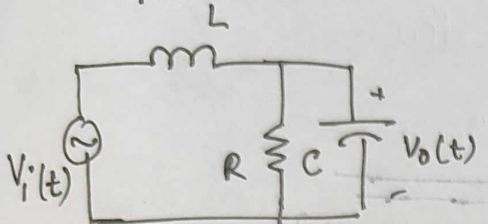
$$\frac{I_o(}{I_s} = \frac{s(s+2)}{s^2+2s+1}$$

24/sep/24

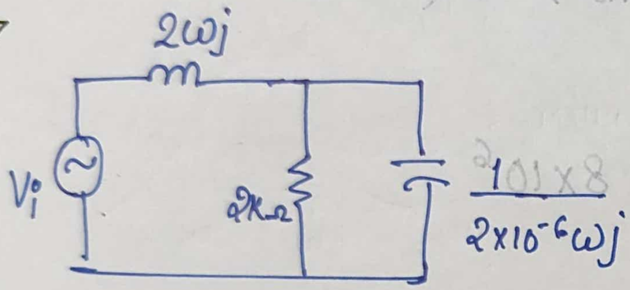
Zeroes $\Rightarrow$ $S(S+2) = 0 \Rightarrow S = 0, -2$

Poles $\Rightarrow$ $S^2 + 2S + 1 = 0 \Rightarrow S = -1, -1$

Q.2) Determine the type of filter and Calculate the Corner freq. Cutt-off freq. $R = 2K\Omega$, $L = 2H$, $C = 2\mu F$



$\Rightarrow$



$$Z = \frac{2K\left(\frac{1}{2\mu F\,\omega j}\right)}{2K\Omega + \frac{1}{2\mu F\,\omega j}}$$

$$Z = \frac{2\times10^3 \times \frac{1}{2\times10^{-6}\omega j}}{2\times10^3 + \frac{1}{2\times10^{-6}\omega j}}$$

$$Z = \frac{2\times10^3}{4\times10^{-3}\omega j + 1}$$

$$V_o = \frac{Z}{Z + 2\omega j} \times V_i$$

$$\frac{V_o}{V_i} = \frac{2\times10^3/(4\times10^{-3}\omega j + 1)}{\frac{2\times10^3}{4\times10^{-3}\omega j + 1} + 2\omega j}$$

$$= \frac{\cancel{2}\times10^3}{\cancel{2}\times10^3 + \cancel{8}^{4}\times10^{-3}(\omega j)^2 + \cancel{2}\omega j}$$

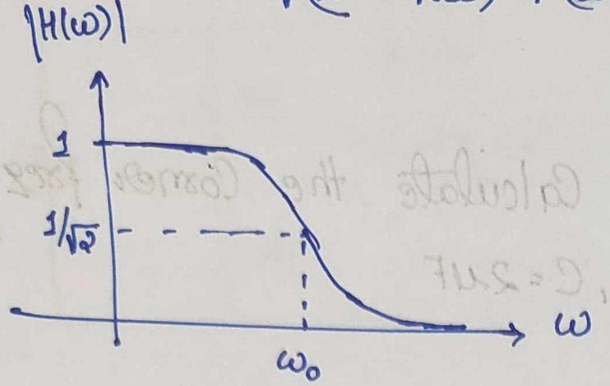
$$H(\omega) = \frac{V_o}{V_i} = \frac{10^3}{10^3 + 4\times10^{-3}(\omega j)^2 + \omega j}$$

$\omega = 0 \Rightarrow H(0) = 1$

$\omega = \infty \Rightarrow H(\infty) = 0$

$\Big\}$ 2nd order Low Pass filter ✓

$$|H(\omega)| = \frac{R}{\sqrt{(R-\omega^2 RLC)^2 + (\omega L)^2}}$$



Cutoff frequency

$\downarrow$

$$|H(\omega)| = \frac{1}{\sqrt{2}}$$

$$\frac{1}{\sqrt{2}} = \frac{2\times 10^3}{\sqrt{(2\times10^{-3} - \omega^2 \times 2\times 10^3 \times 2\times 2\times 10^{-6})^2 + (\omega\times 2)^2}}$$

$$(2\times 10^{-3} - 8\times 10^{-3}\omega^2)^2 + 4\omega^2 = 8\times 10^6$$

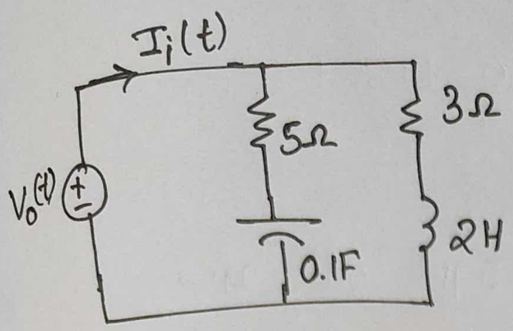
$$\hookrightarrow \quad 16\,\omega_c^4 - 7\,\omega_c^2 - 1 = 0$$

~~$\omega = 489.52$ Hz~~ rad/sec

$\omega = 0.742$ k rad/sec.

$\omega = 742$ rad/sec

Q3) Find $\dfrac{V_o(\omega)}{I_o(\omega)}$ obtain poles & Zeroes.



$$H = \frac{5(s+2)(s+1.5)}{s^2+4s+5}$$

08/oct/24

Transient Analysis

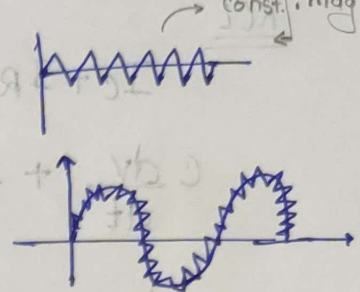
↳ $t \to 0$

Statistic Analysis $\Rightarrow t \to \infty$

DC Transient — more Dangerous

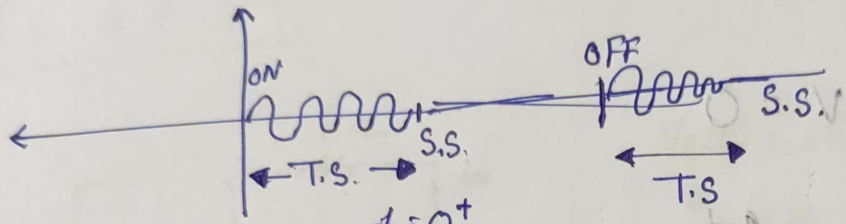
A.C.

const. mag

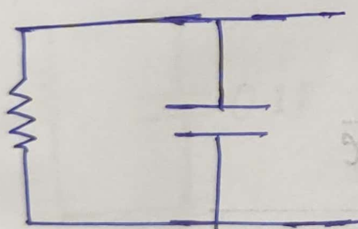


T.S → time $t = 0$ to $t = t$

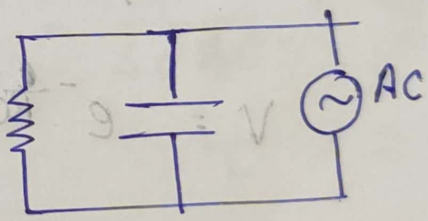
(Switch ON) — Steady State



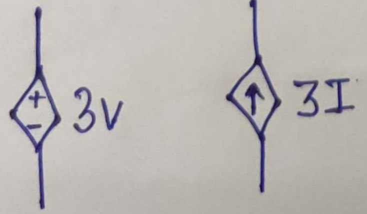
i) Source free Circuit →



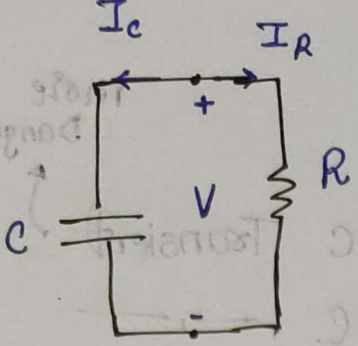
ii) Source Circuit →



iii) Dependent Source ckt →



RC source free ckt



$V_0(0) = V_0$ (Given)

KCL

$$I_C + I_R = 0$$

$$C\frac{dv}{dt} + \frac{V}{R} = 0$$

$$\frac{dv}{dt} + \left(\frac{1}{CR}\right)V = 0$$

$$\text{I.F.} = e^{\int \frac{1}{RC}dt} = e^{\frac{1}{RC}t}$$

$$V.e^{\frac{1}{RC}t} = \int 0.dt + C$$

$$V = e^{-\frac{1}{RC}t}.C$$

$$\cancel{\tau = \frac{1}{RC}}$$

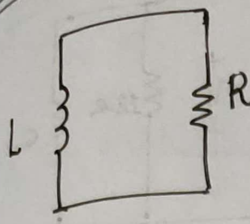
$$\boxed{\tau = RC}$$

$$\cancel{V(t) = A e^{-t/C}}$$

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

$$\boxed{V = V_0 e^{-t/\tau}}$$

for RL



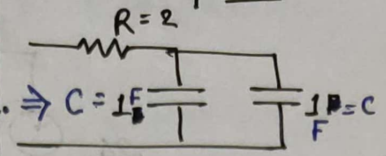
$\cancel{i(t) = A.e^{-\frac{Lt}{R}}}$

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

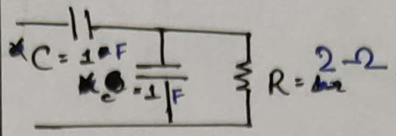
$$\boxed{i(t) = A.e^{-t/\tau}}$$

★ Time const. ⇒

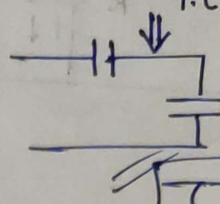
T.C. ⇒



$\tau = \frac{1}{RC_{eq}} = \frac{1}{4}$



⇒

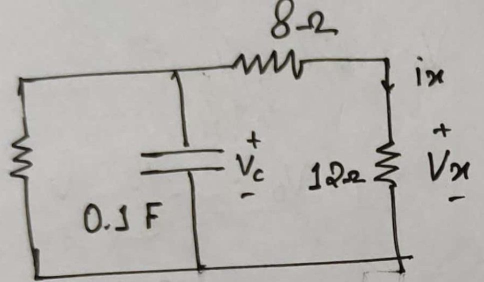


$\tau = \frac{1}{RC_{eq}}$

$\boxed{\tau = 1}$

$C_{eq} = \frac{1 \times 1}{1+1} = \frac{1}{2}$ F

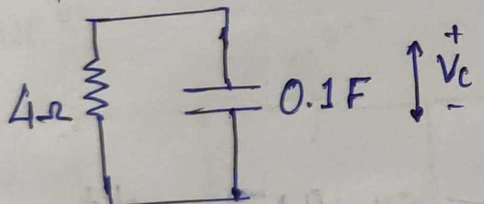
Que.)



$V_c(0) = 15V$

find V_c, V_x, i_x

⇒



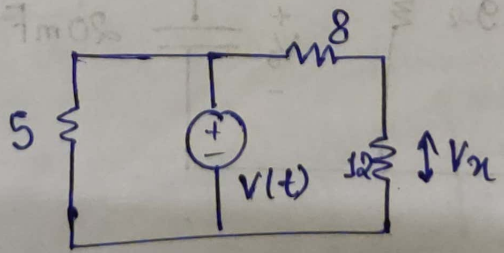
$\tau = \frac{1}{R_{eq}C} = \frac{1}{4 \times 0.1} = \frac{5}{2}$

$\tau = 2.5 \ sec^{-1}$

$V(t) = V_0 e^{-t\tau}$

$V(t) = 15 e^{-2.5t}$

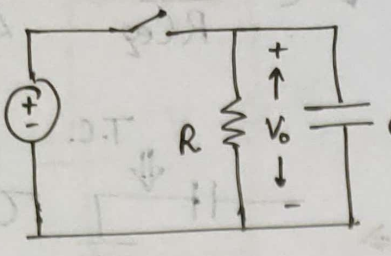
, $i_x = \frac{V_x}{12}$, ~~V_x~~ =

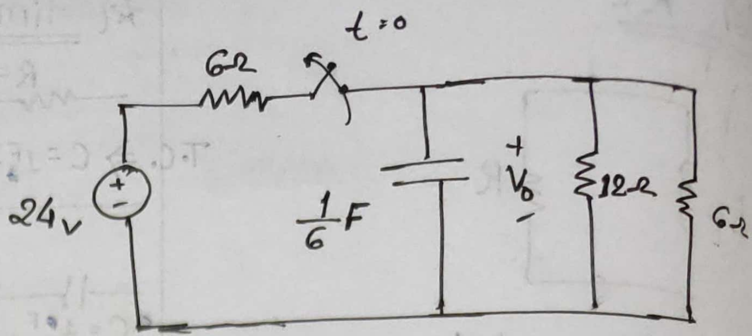


$V_x = \frac{V(t) \times 12}{20}$

05 Oct/24

Q.1)





open at $t=0$
find for $t>0$

$\underline{t \geq 0}$

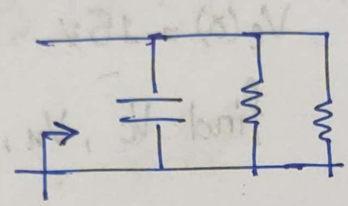
$$V_c = V_0 e^{-t/\tau}$$

$$\tau = RC$$

$$V_c = 9.6 e^{-t/\tau}$$

$$\tau = R_{eq} C$$

$$R_{eq} = 4$$



$$\tau = 4 \times \frac{1}{6} = \frac{2}{3}$$

$$V_c = 9.6 e^{-\frac{3t}{2}}$$ Ans

DC source $\rightarrow$ $X_c = \infty$

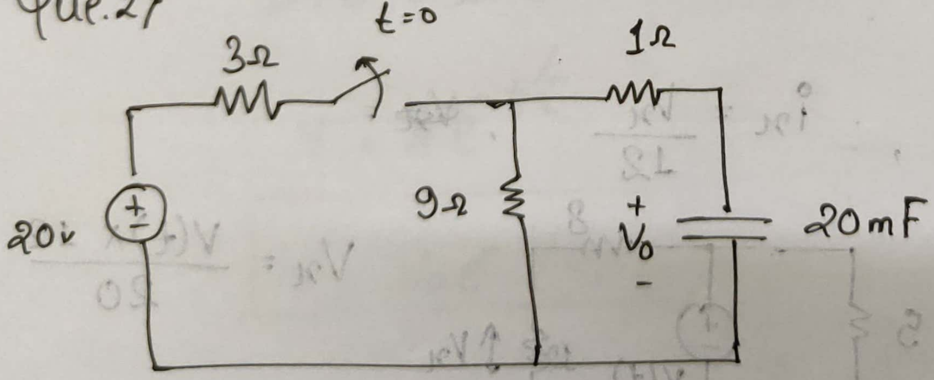
$$\frac{12\times 6}{12+6}$$

$$V_0 = \frac{24\times 4}{6+4}$$

$$V_0 = \frac{48}{5} V$$

$$V_0 = 9.6\ V$$

Que.2)



The switch in a ckt has been close for long time at $t=0$ Switch is open. find V_t at $t \geq 0$. & Calculate initial Energy.

⇒ DC source

$X_C = \infty$

$V_0 = 20 \times \frac{9}{12}$

$V_0 = 15v$

$V_t = V_0 e^{-t/\tau}$

$\tau = R_{eq} C$

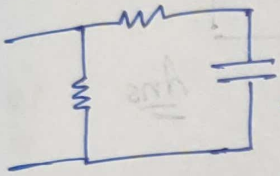
$R_{eq} = \frac{9 \times 1}{9+1} = \frac{9}{10}$

$\tau = \frac{9}{10} \times 20 \times 10^{-3}$

$\tau = 18 \times 10^{-3}$

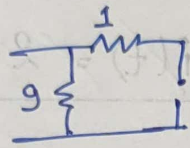
$V_t = 15 e^{-\frac{10^3}{18} t}$

For Req



R_{eq}

⇒



$R_{eq} = 10$

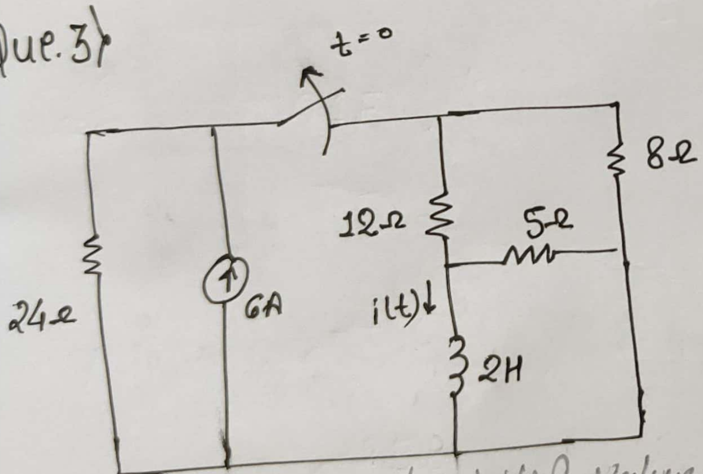
$\tau = R_{eq} C$

$= 10 \times 20 \times 10^{-3}$

$\tau = \frac{2}{10}$

$\boxed{V_t = 15 . e^{-\frac{10t}{2}} \ V}$ Ans

Que. 3)

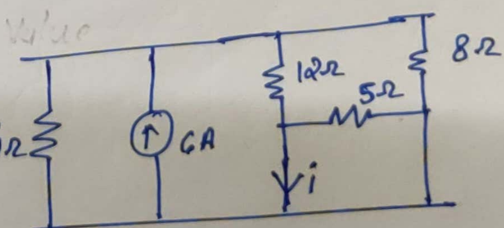


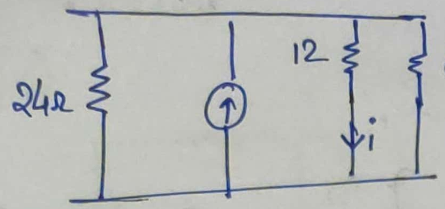
$t = 0 \longrightarrow$ open

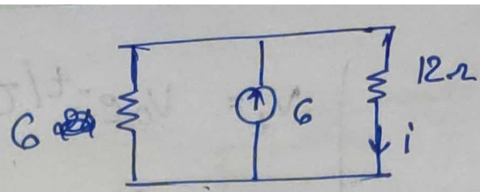
⇒ DC source

$X_L = 0$

for initial value







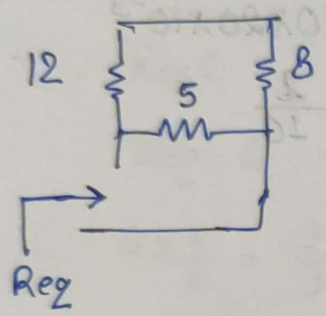
$$i = 6 \times \frac{6}{6+12} = 2\ Amp$$

$$i = i_0 e^{-t/\tau}$$

$$\tau = \cancel{\frac{R_{eq}}{L}}\ \frac{L}{R_{eq}}$$

t=0 (open switch)

<u>for</u> <u>Req</u>



$R_{eq} = 5 \| 20$

$R_{eq} = 4$

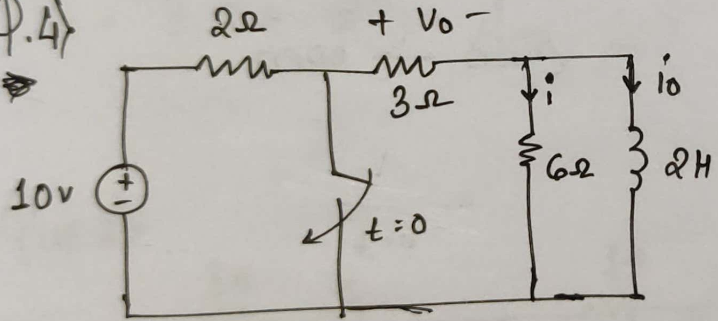
$\cancel{\tau = \frac{4}{2} = 2}$

$\tau = \frac{2}{4} = 0.5$

$\boxed{\cancel{i(t) = 2e^{-t/2}}}$ Ans

$\boxed{i(t) = 2e^{-2t}}$ Ans

Q.4)



⇒

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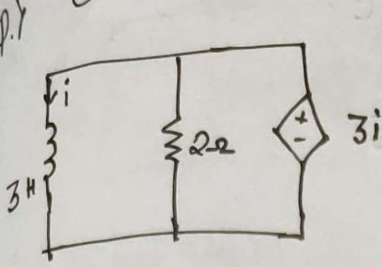
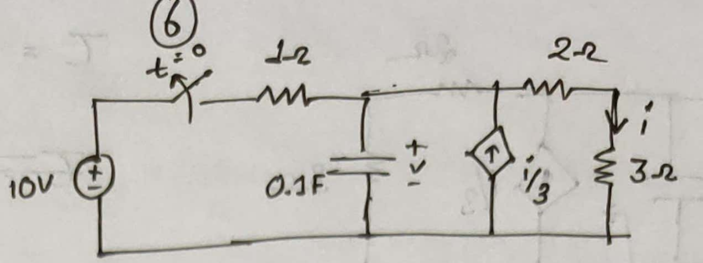
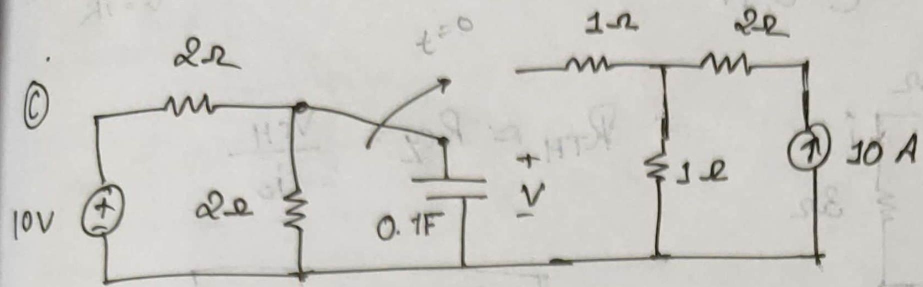
Q.) (a)



(b)



(c)



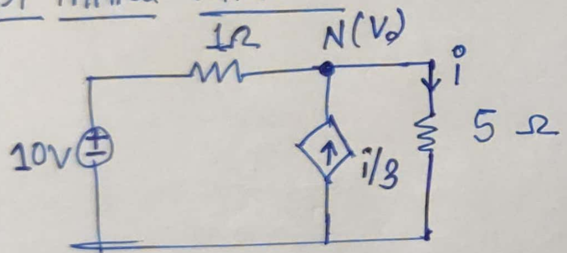
Source ckt

(b)

⇒ $t=0 \rightarrow$ Switch ~~close~~ open $\rightarrow$ T.S.

$t<0 \rightarrow$ " close $\rightarrow$ S.S.

For initial Value $\longrightarrow$



$$\frac{V_0-10}{1} + \left(-\frac{i}{3}\right) + \frac{V_0}{5} = 0$$

$$V-10 + \frac{-V_0}{15} + \frac{V_0}{5} = 0$$

$$\frac{17}{15} V_0 = 10$$

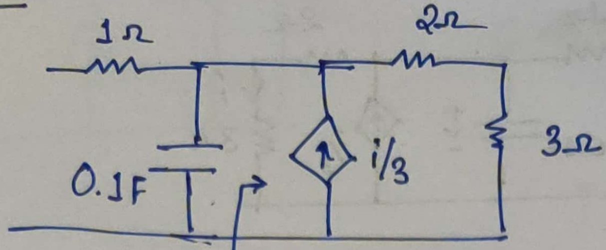
$$V_0 = \frac{150}{17}$$

$$\boxed{V_0 = 8.824}$$

$$i_0 = \frac{V_0}{5}$$

$$i_0 = \frac{150}{5 \times 17} = 1.765 \text{ Amp}$$

for $t \geq 0$



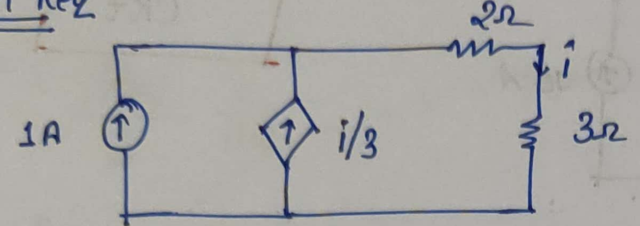
$\cancel{Req = 5\Omega}$ $\quad C = \cancel{0.1F}$

$\tau = R_{eq} C$

$\cancel{\tau = 0.5}$

$v = iR$

For Req



$R_{TH} \approx R_{eq} = \frac{V_{TH}}{i_0}$

$$\boxed{R_{eq} = 7.5\,\Omega}$$

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

$$i = \frac{1}{1 - \frac{1}{3}} = \frac{3}{2} = 1.5\,A$$

$$V_{TH} = 3 \times i$$

$$V_{TH} = 7.5\,\cancel{A}\,\Omega$$

$$\tau = R_{eq} C$$

$$\tau = 0.75$$

$$V(t) = V_0 e^{-t/\tau}$$

$$\boxed{\cancel{V(t) = 8.824\, e^{-t/0.75}}\ V}$$

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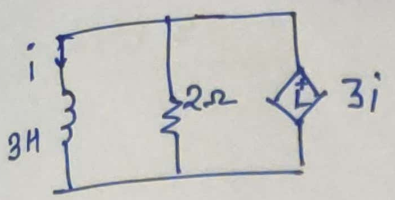
a) ⇒

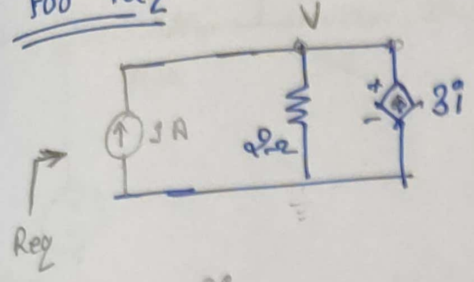


$i_0 = 10\ mA$ (Given)

$\tau = L/R_{eq}$

~~for initial Value~~ →

For Req



$R_{eq} = \frac{V}{i_0} = 2\,\Omega$

$i_0 = 1A$

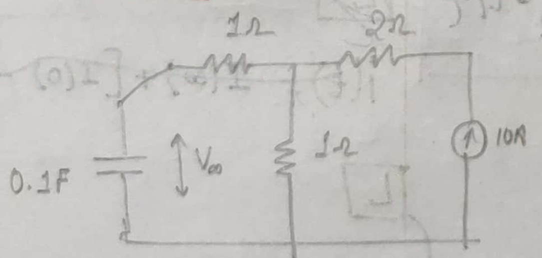
$\tau = \frac{3}{2}$

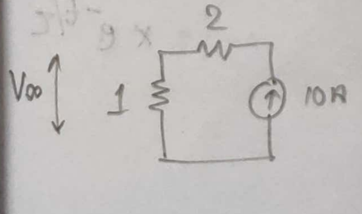
$-1 + \frac{3i}{2} = 0$

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

$V = 3i = 2$

c) ⇒ for $V(\infty)$ ⇒

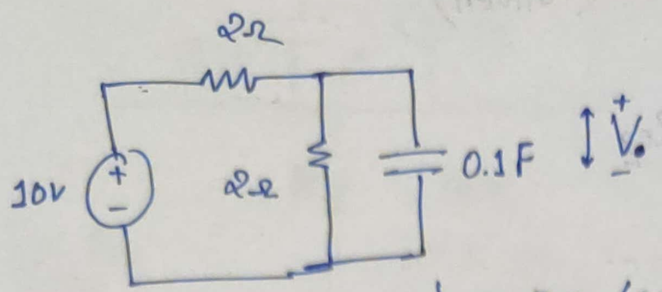




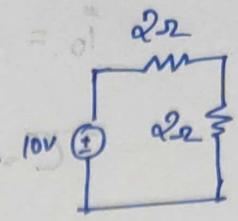
$\boxed{V_\infty = 10\ V}$

c) ⇒ for V_0 ⟶

for intial Value



⇒



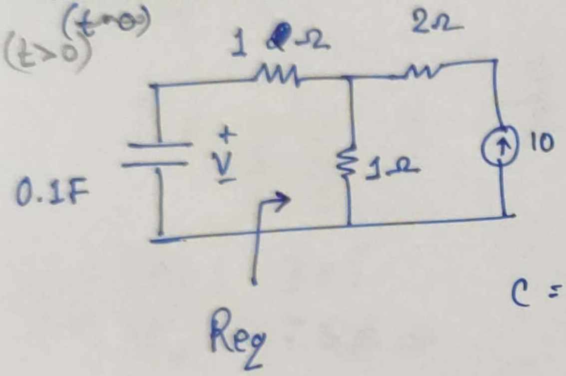
$$\boxed{V_0 = 5V}$$

↳ DC source

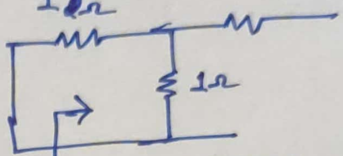
$X_C = \infty$

for Req ⟶

(t>0)



⟶ Re



$$\boxed{Req = 2\Omega}$$

$C = 0.1F$

$\tau = RC$

$$\boxed{\tau = 0.2}$$

$V(t) = \cancel{V_0 e^{-t/\tau}}$

$\cancel{V(t) = 5e^{-t/0.2}}$ V ⇒ $\cancel{V(t)} = \boxed{\cancel{V(t) = 5e^{-5t}} \text{ V}}$

C

$$\boxed{V(t) = V(\infty) + [V(0) - V(\infty)]e^{-t/\tau}}$$

After S.S. Before S.

$V(t) = 10 + (5 - 10)e^{-5t}$

$$\boxed{V(t) = 10 - 5e^{-5t} \text{ V}}$$

L

~~i(t) = I(∞) + [I(0) − I(∞)~~

L

$\cancel{i(t) = I(\infty) + [I(0) - I(\infty)]}$

$\times e^{-t/\tau}$

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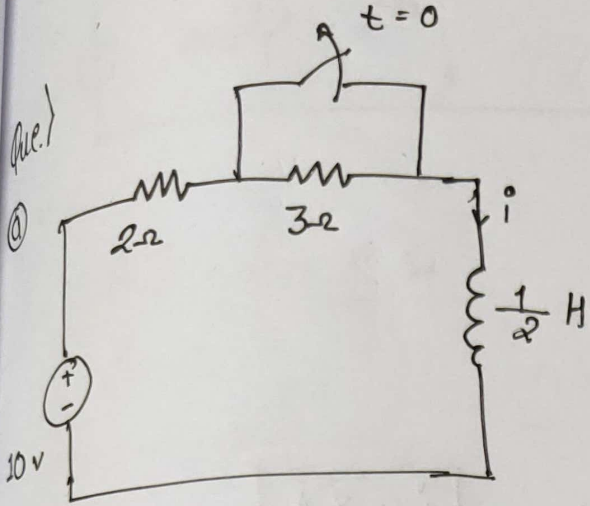
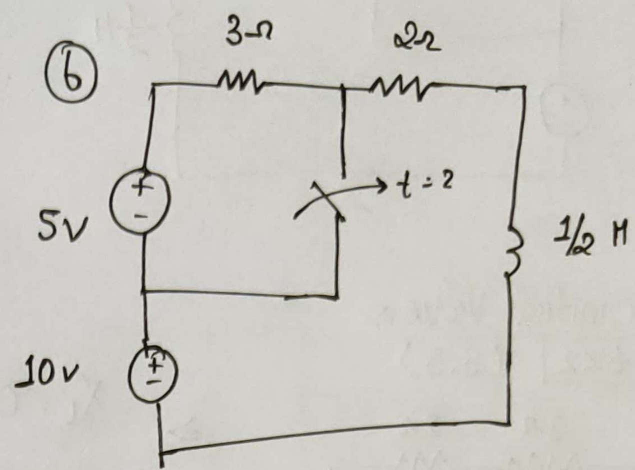
$$[L] \quad \boxed{i(t) = I(\infty) + [I(0) - I(\infty)]e^{-t/\tau}}$$

Que.)

ⓐ

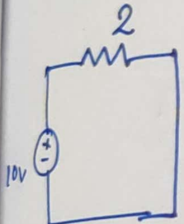


ⓑ



a)

$t < 0$

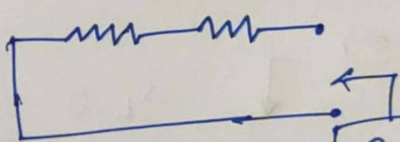


$X_L = 0$ (DC source)

$i_0 = \frac{10}{2} = 5A$

$$\boxed{i(0) = 5A}$$

for Req ($t \geq 0$) (T.S.)

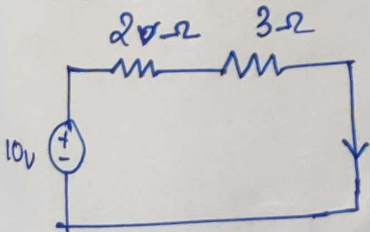


$$\boxed{R_{eq} = 5\Omega}$$

$\tau = \frac{L}{R_{eq}}$

$\tau = \frac{1}{2 \times 5} = \frac{1}{10}$

for $i(\infty)$



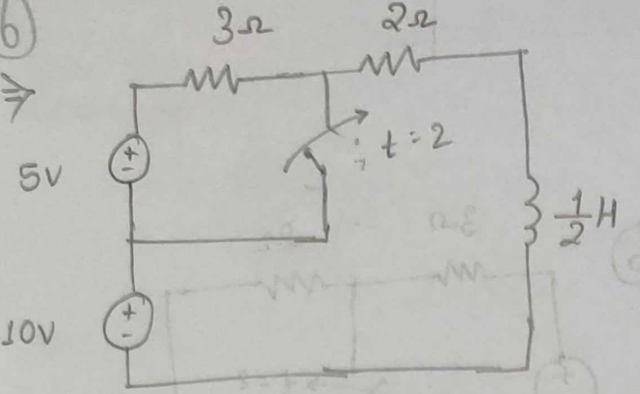
$i(\infty) = \frac{10}{5}$

$$\boxed{i(\infty) = 2A}$$

$i(t) = i(\infty) + [i(0) - i(\infty)]e^{-t/\tau}$

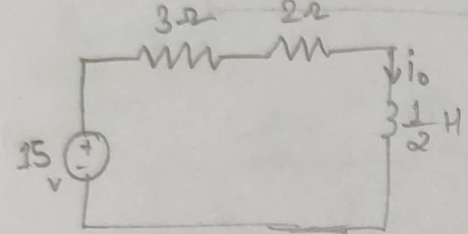
$i(t) = 2 + (5-2)e^{-t/\tau} \Rightarrow \boxed{i(t) = 2 + 3e^{-10t}}$ A

(b)

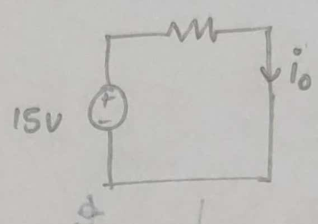


for initial value ⇒

$\boxed{t<2}$ (S.S)



$X_L = 0$



$\boxed{i_0 = 3A}$

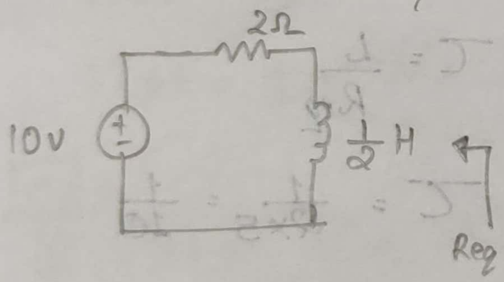
$\underline{t>2}$ (T.S.)

$X_L = 0$

$\boxed{\tau = \frac{L}{R_{eq}}}$

for Req

$R_{eq} = 2\Omega$

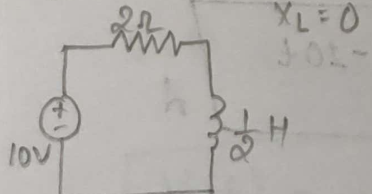


$$\tau = \frac{1}{2\times 2} = \frac{1}{4}$$

$\underline{t=\infty}$

$i(\infty)$ ⇒

$X_L = 0$



$i(\infty) = 5A$

$$i(t) = i(\infty) + [\, i(0) - i(\infty) \,] e^{-\frac{(t-2)}{\tau}}$$

$$= 5 + [3-5]\, e^{-4(t-2)}$$

$$\boxed{i(t) = 5 - 2e^{-4(t-2)} \quad A}$$

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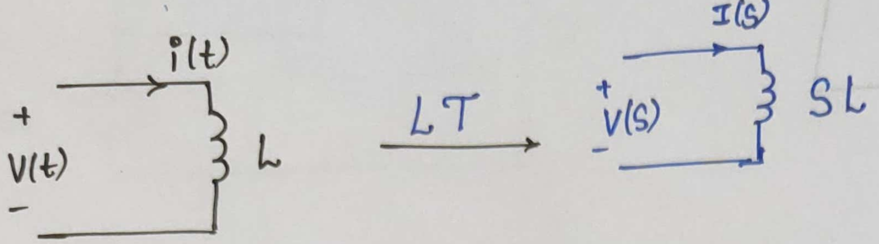
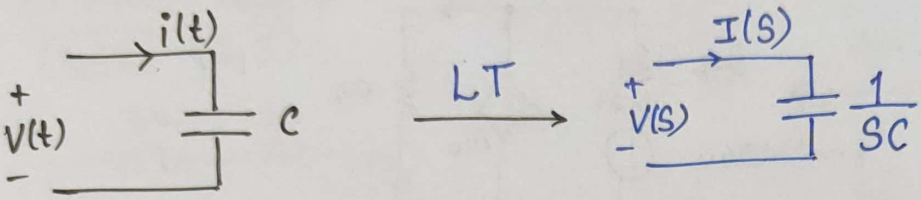
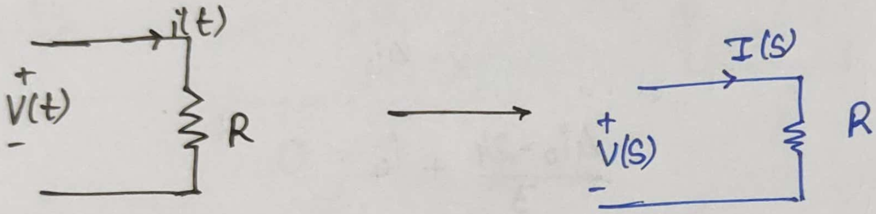
No initial Value →

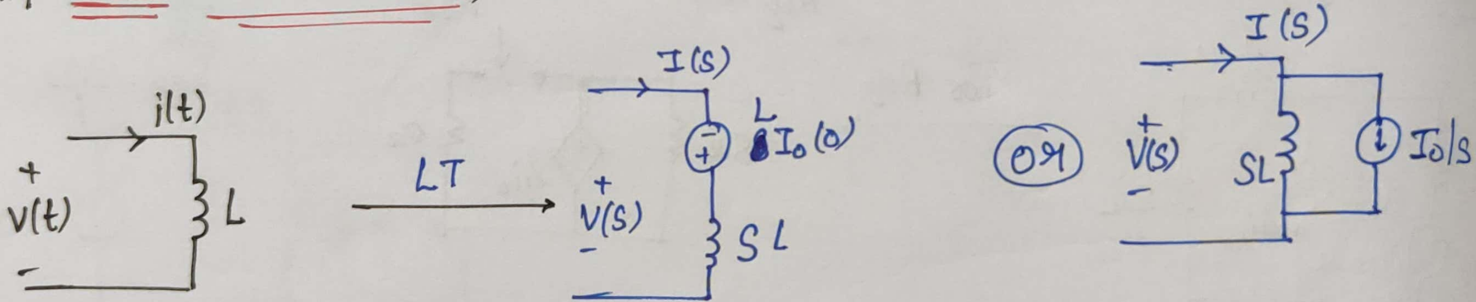
$I_o(0)$ or $V_o(0)$

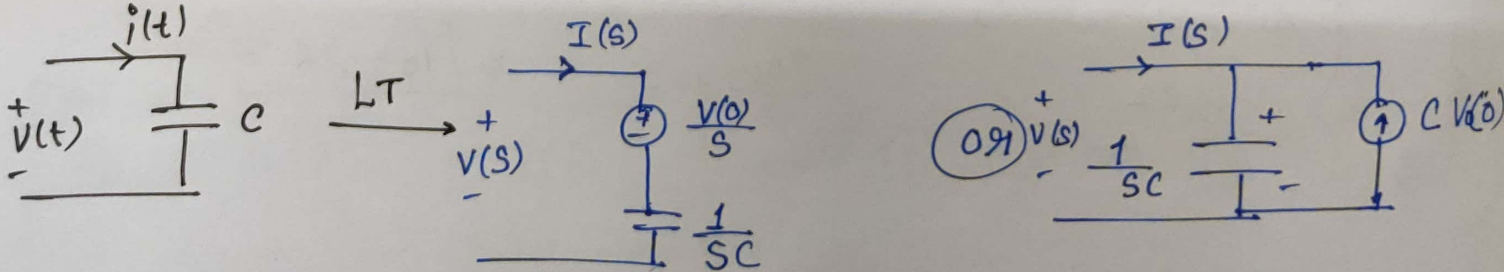




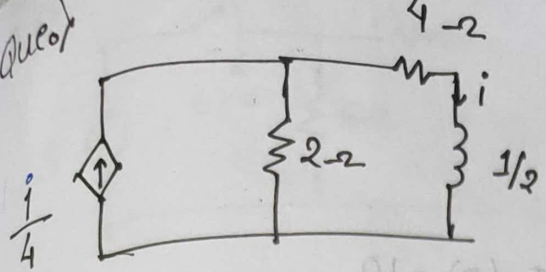


#) With $I_o(0)$ or $V_o(0)$ →



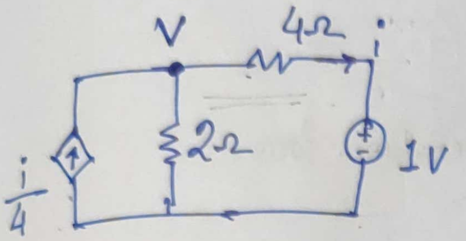


Que) $I(0) = 10$, find $i(t) = ?$ 15/oct/24



→

$$\tau = \frac{L}{R_{eq}}$$



Nodal Analysis →

$$-\frac{i}{4} + \frac{V}{2} + \frac{V-1}{4} = 0$$

$$i = \frac{V-1}{4}$$

$$V = 4i+1$$

$$-\frac{i}{4} + \frac{4i+1}{2} + \frac{\cancel{4}i}{\cancel{4}} = 0$$

$$\cancel{-\frac{i}{4} + i + i + \frac{1}{4} = 0}$$

$$\cancel{\frac{7}{4} i = -\frac{1}{4}}$$

$$\cancel{i = -1/7}$$

$$-i + 8i + 2 + 4i = 0$$

$$i = \frac{-2}{11}$$

$$R_{eq} = \frac{11}{2\Omega}$$

$$R_{eq} = \frac{1}{i_{in}}$$

$$\cancel{R_{eq} = 7\ \Omega}$$

$$\cancel{\tau = \frac{1}{14}}$$

$$\cancel{i(t) = i(\infty) + [i(0) - i(\infty)]e^{-t/\tau}}$$

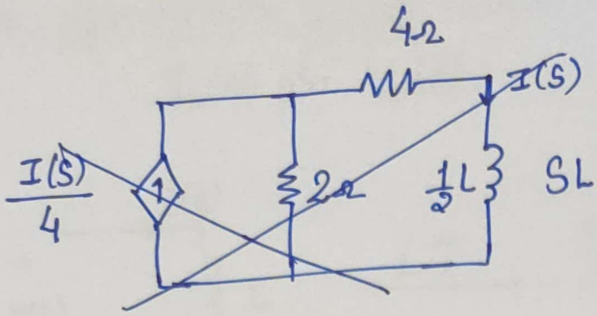
$$\cancel{i(t) = 10e^{-14t}}$$

~~t = ∞~~

$$\tau = \frac{L}{R} = \frac{1}{11}$$

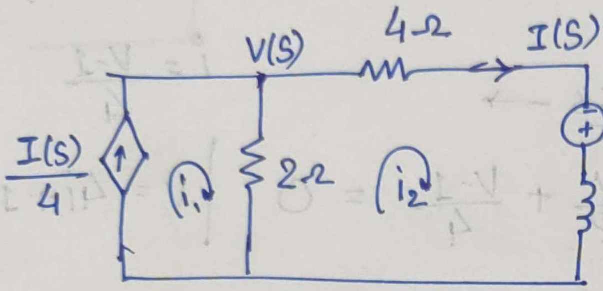
$$\boxed{i(t) = 10e^{-11t}}$$

By frequency domain →



$SL = \frac{s}{2}$

$I_0(0) = 10$



$L I_0(0) = 5\,V$

$SL = \frac{s}{2}\,\Omega$ → Resistance form

$i_1 = \frac{I(s)}{4}$, $-2(\cancel{I(s)}\, i_2 - i_1) - 4(i_2) + 5 - \frac{s}{2} i_2 = 0$

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

$$-2 \times \frac{3I}{4} - 4I + 5 - \frac{s}{2} I = 0$$

$$\left(\frac{s}{2} + 4 + \frac{3}{2}\right) I = 5$$

$$I = \frac{5 \times 2}{11 + s} = \frac{10}{11+s}$$

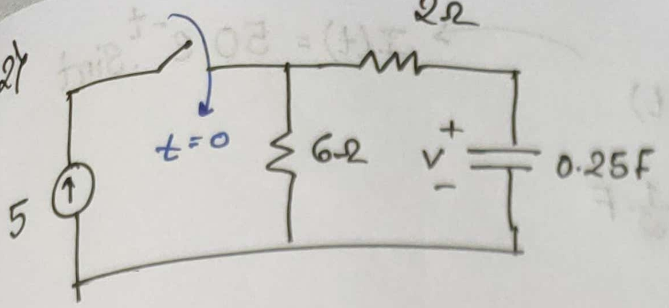
$\cancel{\frac{1}{a+s} \to e^{-at}}$

$\frac{1}{s-a} = e^{at}$

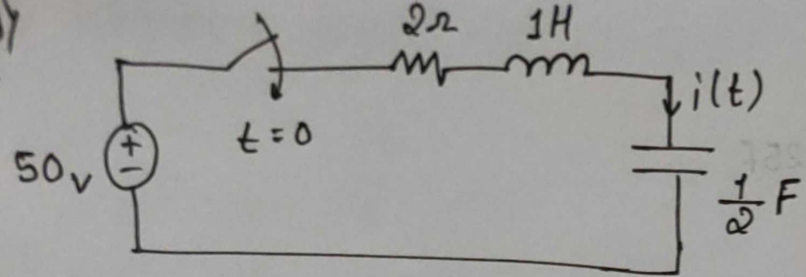
$$I = 10 \cdot \times \frac{1}{s-(-11)}$$

$$\boxed{I(t) = 10e^{-11t}}$$

Q.2)

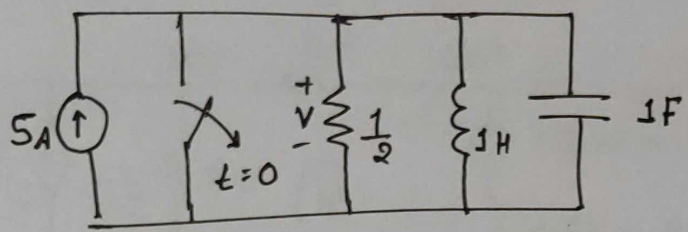


Q.1)



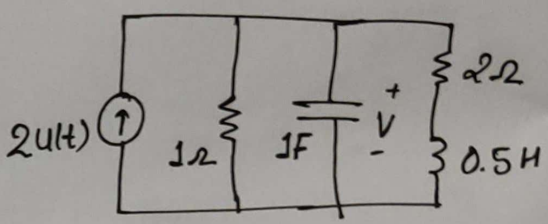
$\rightarrow I(t) = 50\, e^{-t} . \sin t$

Q.2)



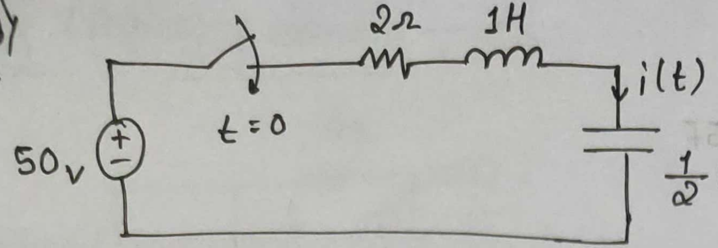
$V(t) = 5 t e^{-t} u(t)$

Q.3)



$v(t) = \frac{4}{3} u(t) - 2e^{-2t} + \frac{2}{3} e^{-3t}$

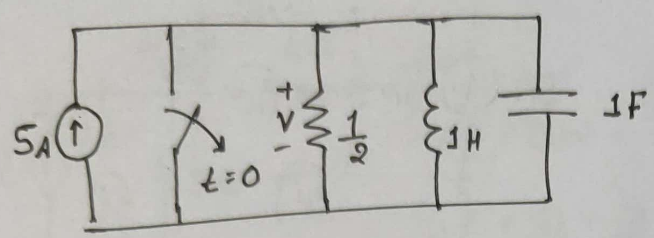
Q.1)



$\rightarrow$ $I(t) = 50\, e^{-t} \sin t$

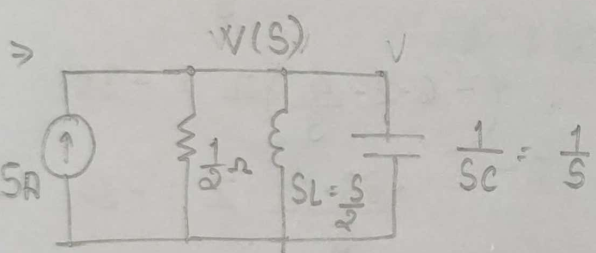
$\Rightarrow$

Q.2)



$V(t) = 5t\,e^{-t}u(t)$

$\Downarrow$



$\frac{1}{SC} = \frac{1}{S}$

Nodal Analysis

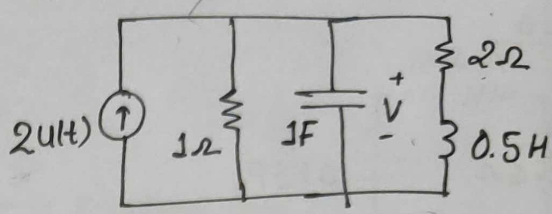
$$-5 + 2V(S) + \frac{2V(S)}{S} + SV(S) = 0$$

$$\left(2 + \frac{2}{S} + S\right)V(S) = 5$$

$$V(S) = \frac{5}{(S+2) + \frac{2}{S}}$$

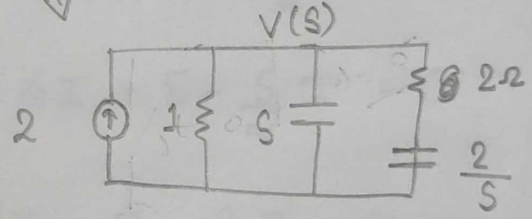
$$V(S) = \frac{5S}{S^2 + 2S + 2}$$

Q.3)



$$v(t) = \frac{4}{3}u(t) - 2e^{-2t} + \frac{2}{3}e^{-3t}$$

$\Downarrow$

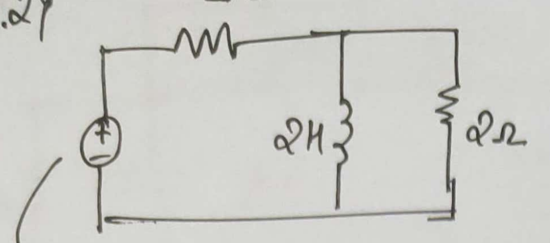


$\frac{1}{SC}$

$$-2 + V(S) + \frac{V(S)}{S} + \frac{V(S)}{2 + \frac{2}{S}} = 0$$

$$\left(1 + \frac{1}{S} + \frac{S}{2S+2}\right)V(S) = 2$$

(Q.2)

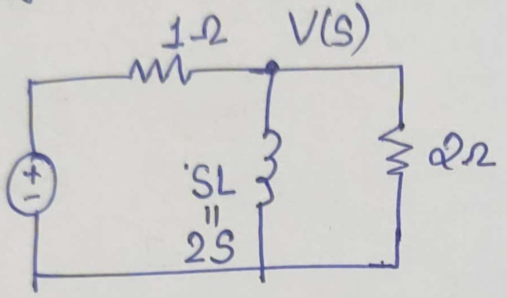


$30e^{-2t}u(t)$

$v_o(t) = ?$

$i_{2H}(0) = 0$

⇒ frequency domain →



$\frac{30}{S+2}$

Nodal Analysis

$$\frac{V(S) - \frac{30}{S+2}}{1} + \frac{V(S)}{2S} + \frac{V(S)}{2} = 0$$

$$\left(1 + \frac{1}{2S} + \frac{1}{2}\right) V(S) = \frac{30}{S+2}$$

$$\cancel{\frac{V(S)}{2(S+1)} = \frac{30}{S+2}}$$

$$\left(\frac{3}{2} + \frac{1}{2S}\right) V(S) = \frac{30}{S+2}$$

Don't transform u(t) ↓ Here it work as a switch

$$V(S) = \frac{60\,S}{(S+2)(3S+1)}$$

$$V(S) = \frac{20\,S}{(S+2)(S+1/3)}$$

$$\frac{S}{(S+2)(S+1/3)} = \frac{A}{S+2} + \frac{B}{S+1/3}$$

$$S = A\left(S+\frac{1}{3}\right) + B(S+2)$$

$$S = (A+B)S + \frac{A}{3} + 2B$$

$A + B = 1$, $\frac{A}{3} + 2B = 0$ ⇒ $B = -\frac{A}{6}$

$$A - \frac{A}{6} = 1$$

$$A = \frac{6}{5}$$

$$B = -\frac{1}{5}$$

$$\frac{S}{(S+2)(S+1/3)} = \frac{6}{5(S+2)} + \frac{-1}{5(S+1/3)}$$

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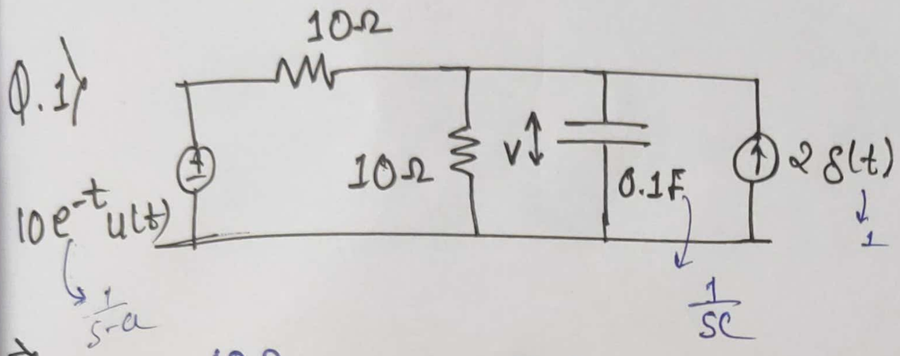
$$V(t) = 20\left[\frac{6}{5}e^{-2t} - \frac{1}{5}e^{-t/3}\right]$$

$$v(t) = \left(24e^{-2t} - 4e^{-t/3}\right)u(t) \quad \underline{Ans}$$

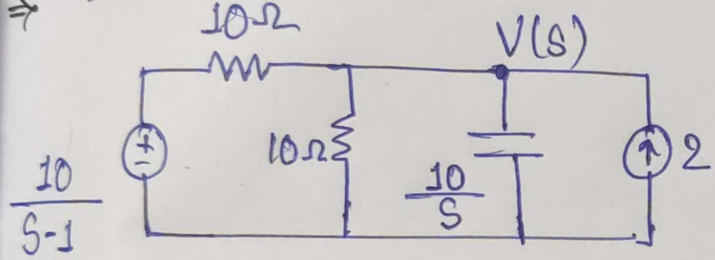
Q.1)



$V_o(0) = 5v$

find $v(t) = ?$

⇒



$$\frac{V(S) - \frac{10}{S-1}}{10} + \frac{V(S)}{10} + \frac{S\,V(S)}{10} - 2 = 0$$

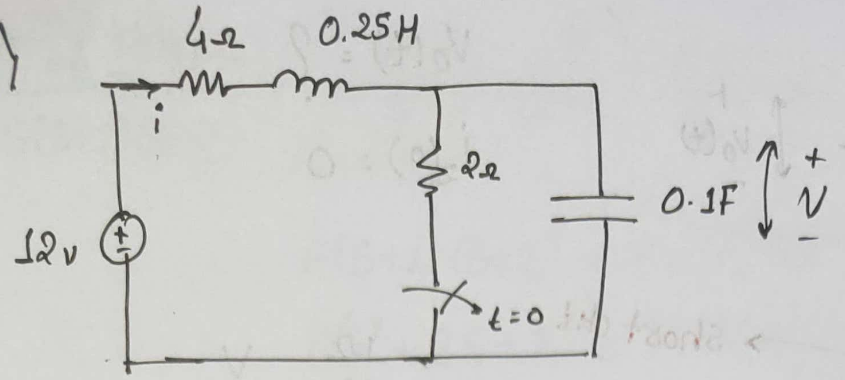
$$(1+1+S)V(S) - \frac{10}{S-1} = 20$$

$$(2+S)V(S) = 20 + \frac{10}{S-1}$$

$$V(S) = \frac{20S-10}{(S-1)(S+2)} = \frac{10(2S-1)}{(S-1)(S+2)}$$

$$V(t) = \frac{10}{3}e^{t} + \frac{50}{3}e^{-2t} \quad \underline{Ans}$$

Q.)



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

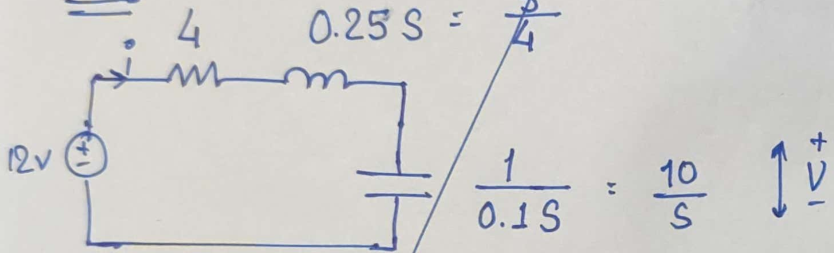
$i = C\dfrac{dv}{dt}$

S.S. { ⓐ $i(0^+)$, $v(0^+)$
ⓑ $i(\infty)$, $v(\infty)$ }

T.S ⓒ $\dfrac{d\,i(0^+)}{dt}$, $\dfrac{dv(0^+)}{dt}$

⇒

$\underline{\underline{t > 0}}$



$0.25\,S = \dfrac{S}{4}$

$\dfrac{1}{0.1S} = \dfrac{10}{S}$

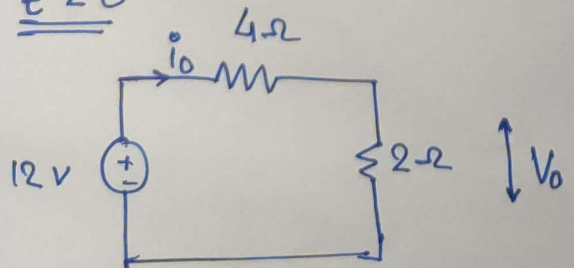
$12 - 4I - \dfrac{S}{4}I - \dfrac{10}{S}I = 0$

$\left(4 + \dfrac{S}{4} + \dfrac{10}{S}\right) I = 12$

$I = \dfrac{12\,(4S)}{16S + S^2 + 40} = \dfrac{48\,S}{S^2 + 16S + 40}$

ⓐ

$\underline{\underline{t < 0}}$



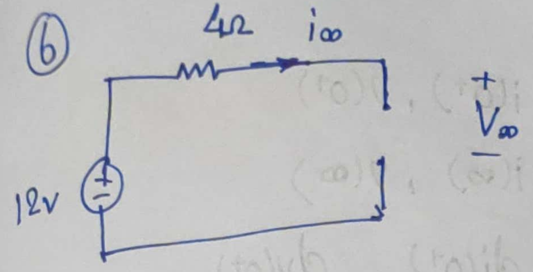
$V_0 = 12 \times \dfrac{2}{6}$

$\boxed{V_0 = 4v}$

$i_0 = \dfrac{12}{6} \Rightarrow \boxed{i_0 = 2v}$

$i_L(0^+) = 2v$, $V_c(0^+) = 4v$

(b)

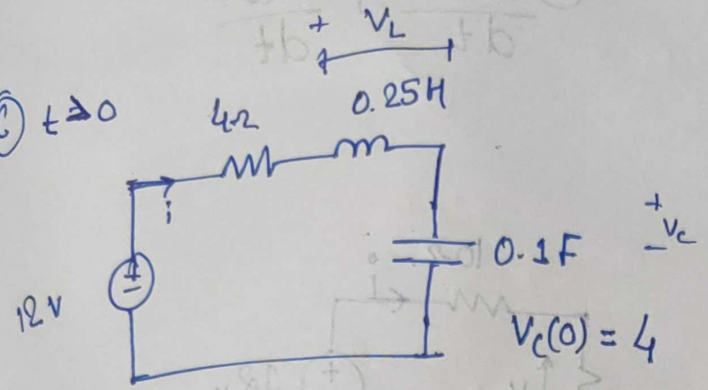


$i_L(\infty) = 0\ A$

$V_c(\infty) = 12\ V$

$i_c(0^+) = i_L(0^+)$

(c) $t \geq 0$



$V_c(0) = 4$

$i_L(0) = 2$

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

$\frac{di(0^+)}{dt} = \frac{V_L(0)}{L}$

$\frac{di(0^+)}{dt} = 0\ A$

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

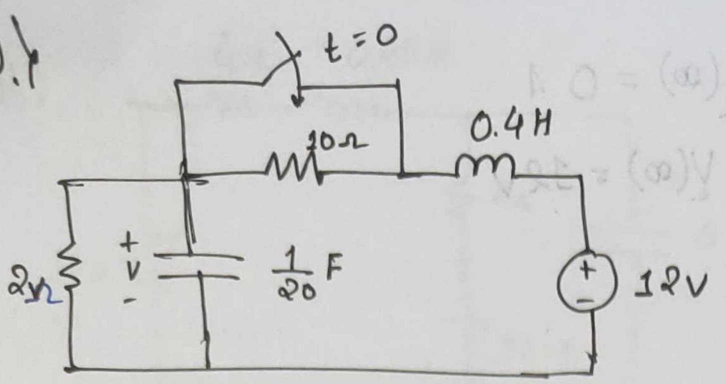
$\frac{dv(0^+)}{dt} = \frac{i_c(0)}{C} = \frac{2}{0.1}$

$\frac{dv(0^+)}{dt} = 20\ v/sec$

$12 - 4i_L(0) - V_L - 4 = 0$

$V_L = 0$

Q.1



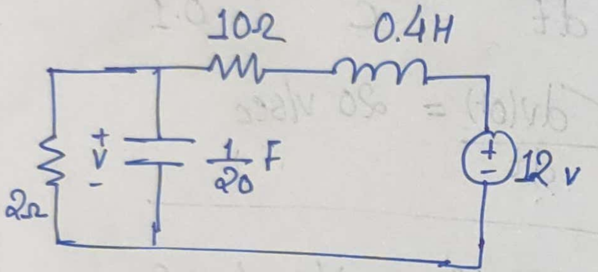
ⓐ $i(0^+)$, $V(0^+)$

ⓑ $i(\infty)$, $V(\infty)$

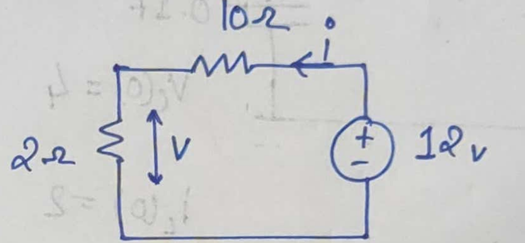
ⓒ $\frac{di(0^+)}{dt}$, $\frac{dv(0^+)}{dt}$

⇒

ⓐ at $t < 0$



⇒



$i_L(0^-) = i_L(0^+) \frac{12}{12} = 1A$

$V_c(0^+) = 12 \times \frac{2}{12} = 2V$

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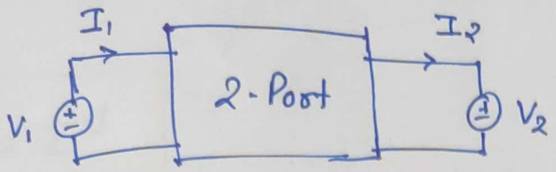
Two Port



${}^4C_2 = 6 \rightarrow$ Z, Y, h, g ~~A, B, C, D or a, b, c, d~~
ABCD abcd

V_1 I_1

Dependent ← V_2 I_2

Z parameter (Impedance)

$$V_1 = Z_{11} I_1 + Z_{12} I_2$$

$$V_2 = Z_{21} I_1 + Z_{22} I_2$$

Y Parameter (Admittance)

$$I_1 = Y_{11} V_1 + Y_{12} V_2$$

$$I_2 = Y_{21} V_1 + Y_{22} V_2$$

V_1 I_1

V_2 I_2

h-Parameter (Hybrid Parameters)

$$V_1 = h_{11} I_1 + h_{12} V_2$$

$$I_2 = h_{21} I_1 + h_{22} V_2$$

Dependent

V_1 I_1

V_2 I_2

~~$V_1(I_1$~~

$V_1 = f(I_1, V_2)$

$I_2 = f(I_1, V_2)$

g-Parameter (inverse hybrid Parameters)

$$I_1 = g_{11} V_1 + g_{12} I_2$$

$$V_2 = g_{21} V_1 + g_{22} I_2$$

V_1 I_1

V_2 I_2

$V_1 \xrightarrow{ABCD} I_1$

$V_2 \xrightarrow{abcd} I_2$

$$V_1 = Z_{11} I_1 + Z_{12} I_2$$

$$V_2 = Z_{21} I_1 + Z_{22} I_2$$

$I_2 = 0$
↓

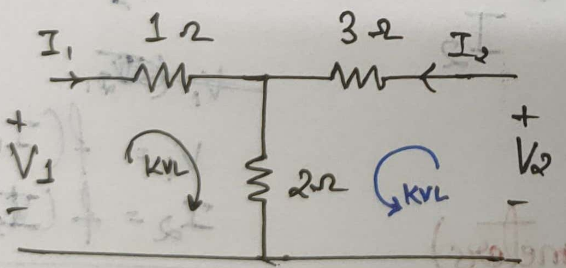
$Z_{11} = \dfrac{V_1}{I_1}$ (i/p impedance)

$Z_{21} = \dfrac{V_2}{I_1}$, $Z_{12} = \dfrac{V_1}{I_2}$ → Transfer impedance , $Z_{22} = \dfrac{V_2}{I_2}$ → o/p impedance

→ $Z_{11} = Z_{22} \longrightarrow$ Symmetrical Parameter

→ $Z_{12} = Z_{21} \longrightarrow$ Reciprocal

Que.)



$$Z = \begin{bmatrix} 3 & 2 \\ 2 & 5 \end{bmatrix}$$

⇒

$V_1 - I_1 - 2(I_1 + I_2) = 0$

$V_1 = 3I_1 + 2I_2$

On Comparing,

$V_1 = Z_{11} I_1 + Z_{12} I_2$

$Z_{11} = 3$, $Z_{12} = 2$

$V_2 - 3I_2 - 2(I_1 + I_2) = 0$

$V_2 = 2I_1 + 5I_2$

On Comparing,

$Z_{21} = 2$, $Z_{22} = 5$

⇒ System is reciprocal

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Que.) ⇒ If dependent source is present, then we can not find Symmetrical / Reciprocal Parameter.

• $\boxed{Y = Z^{-1}}$

$Y_{11} = \frac{1}{3}$, $Y_{21} = \frac{1}{2}$

$Y_{12} = \frac{1}{2}$, $Y_{22} = \frac{1}{5}$

Y_{11} = Short-ckt i/p admittance

Y_{12} = Short-ckt transfer admittance from port 2 to 1.

Y_{21} = — , ——— from port 1 to 2.

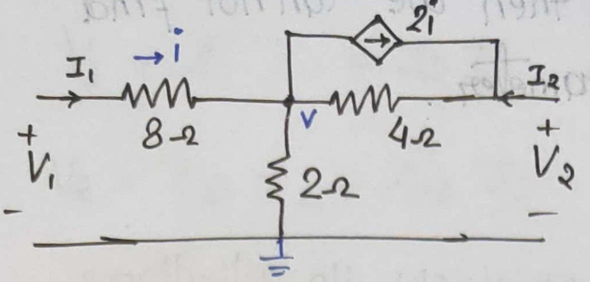
Y_{22} = Short-ckt o/p admittance

•

$$\left.\begin{aligned} V_1 &= AV_2 + BI_2 \\ I_1 &= CV_2 + DI_2 \end{aligned}\right\} \longrightarrow T(ABCD)$$

(Transmission Parameters)

Que.1) Calculate Z - parameters → for Z parameter apply KVL



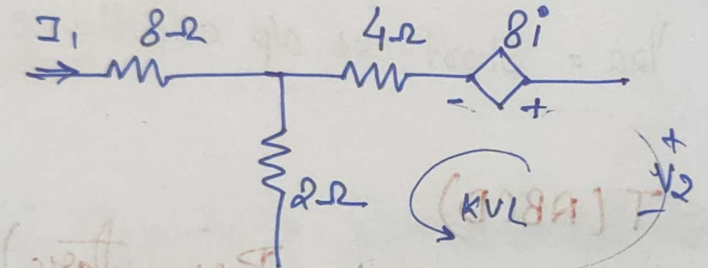
⇒ $8I_1 + 2(I_1 + I_2) = V_1$

$$V_1 = 10I_1 + 2I_2$$

I_1

4I

~~v = iR~~



$i = I_1$

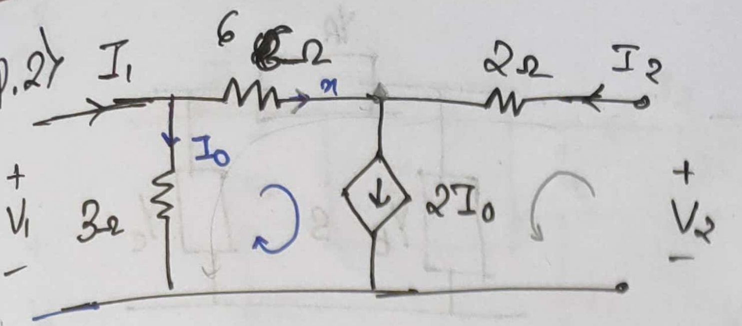
$4I_2 + 8I_1 + 2(I_1 + I_2) = V_2$

$$V_2 = 10I_1 + 6I_2$$

$$Z = \begin{bmatrix} 10 & 2 \\ 10 & 6 \end{bmatrix}$$

$$Y = \begin{bmatrix} 6 & -2 \\ -10 & 10 \end{bmatrix}$$

Q.2)



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Y Parameters ?

X

$\Rightarrow \quad I_1 = x + I_0$

$x = I_1 - I_0$

$\cancel{-6x + 2I_0 + 3I_0}$

$V_1 = +3I_0$

$x + I_2 = 2I_0$

$I_1 - I_0 + I_2 = 2I_0$

$I_1 + I_2 = 3I_0$

$I_0 = \dfrac{I_1 + I_2}{3}$

$V_1 = -3I_0 - 3x$

$V_1 = -I_1 - I_2$ —(1)

$V_2 - 2I_2 + 6x - 3I_0 = 0$

$V_2 = 2I_2 - 6x + 3I_0 = 0$

$V_2 = 2I_2 - 6(I_1 - I_0) + 3I_0$

$V_2 = -6I_1 + 2I_2 + 9I_0$

$V_2 = -6I_1 + 2I_2 + 3I_1 + 3I_2$

$V_2 = -3I_1 + 5I_2$

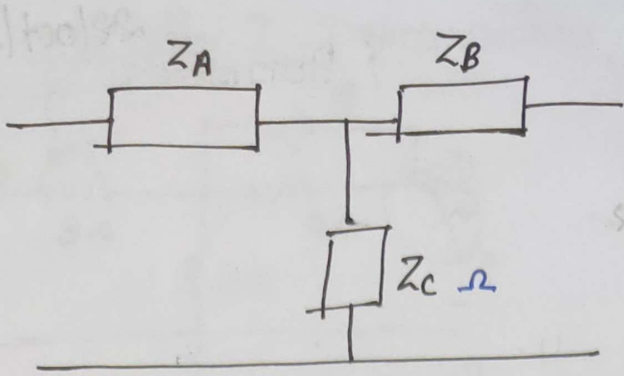
$Z_{11} = -1$

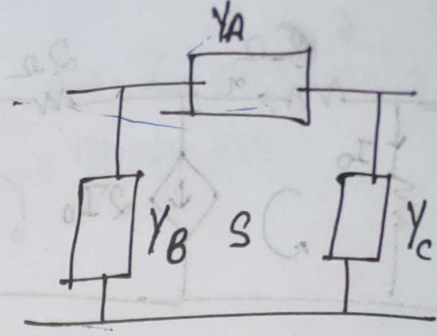
$Z_{12} = -1$

$Z_{21} = -3$

$Z_{22} = 5$

#)





$$Z = \begin{bmatrix} Z_A + Z_C & Z_C \\ Z_C & Z_B + Z_C \end{bmatrix}$$

$$Y = \begin{bmatrix} Y_A + Y_B & -Y_A \\ -Y_A & Y_A + Y_C \end{bmatrix}$$

when there is no dependent Source is present

$Z = Y^{-1}$

$h = g^{-1}$

$Z_A = Z_{11} - Z_{12}$

$Z_B = Z_{22} - Z_{21}$

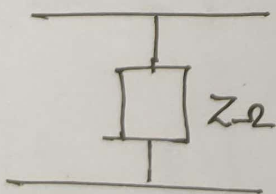
$Z_C = Z_{12} = Z_{21}$

$Y_A = -Y_{12} = -Y_{21}$

$Y_B = Y_{11} + Y_{12}$

$Y_C = Y_{22} + Y_{21}$

Q.1)

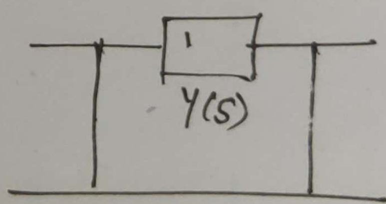


$Y = ?$

$$\Rightarrow Z = \begin{bmatrix} Z & Z \\ Z & Z \end{bmatrix}$$

$Y = Z^{-1}$

$Y =$ Not Exist



$Z = ?$

$$Y = \begin{bmatrix} Y & -Y \\ -Y & Y \end{bmatrix}$$

$Z = Y^{-1}$

Do not exist

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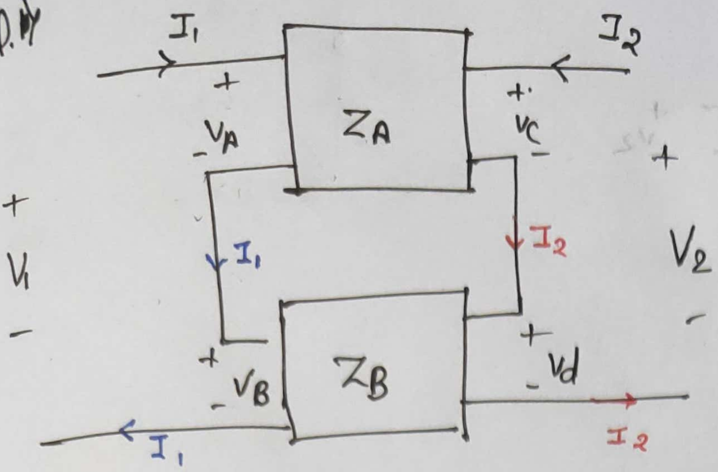
Series

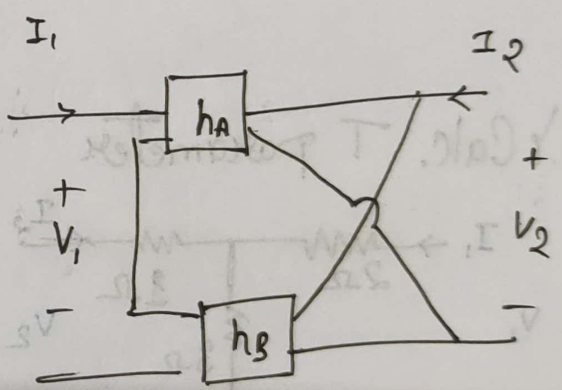
Q.2



$$[Z] = [Z_A] + [Z_B]$$

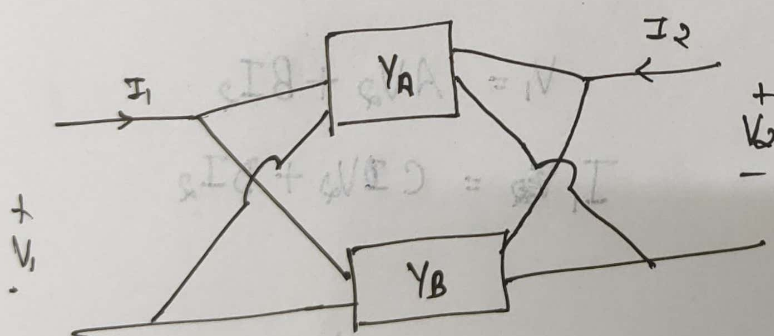
⇒

Series - Parallel



⇒ $[h] = [h_A] + [h_B]$

Q.3) Parallel

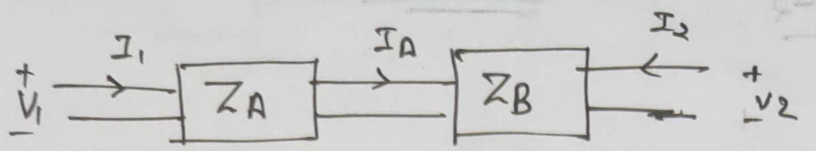


⇒ $Y = [Y_A] + [Y_B]$

Parallel Series

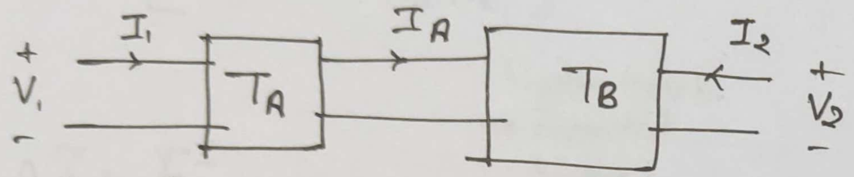
$$[g] = [g_A] + [g_B]$$

Cascaded ⇒



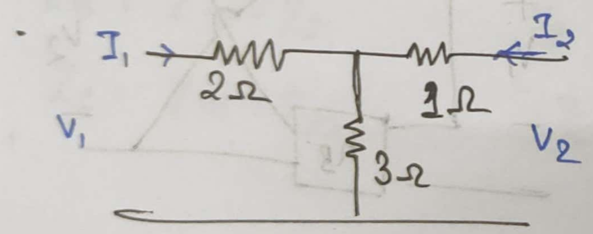
$\Rightarrow [Z] = [Z_A] \times [Z_B]$

(T) ⟶ ABCD



$\Rightarrow [T] = [T_A][T_B]$

Q.) Calc. T parameter



$V_1 = AV_2 + BI_2$

$I_1 = CV_2 + DI_2$

⇒

$$[Z] = \begin{bmatrix} 5 & 3 \\ 3 & 4 \end{bmatrix}$$

$V_1 = Z_{11} I_1 + Z_{12} I_2$

$V_2 = Z_{21} I_1 + Z_{22} I_2$

Put $I_2 = 0 \Rightarrow Z_{11}$ ✓

Put $I_1 = 0 \Rightarrow Z_{12}$ ✓

$V_1 = 5I_1 + 3I_2$

$V_2 = 3I_1 + 4I_2$

$V_1 = AV_2 + BI_2$

$= A(3I_1 + 4I_2) + BI_2 = 5I_1 + 3I_2$

$3AI_1 + (4A+B)I_2 = 5I_1 + 3I_2$

On Comparing

$A = 5/3$

$B = -11/3$

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$$Y = \begin{bmatrix} 4 & -3 \\ -3 & 5 \end{bmatrix}$$

$I_1 = 4V_1 - 3V_2$ — (1)

$I_2 = -3V_1 + 5V_2$

$I_1 = CV_2 + DI_2$

$I_1 = CV_2 + D(-3V_1 + 5V_2)$

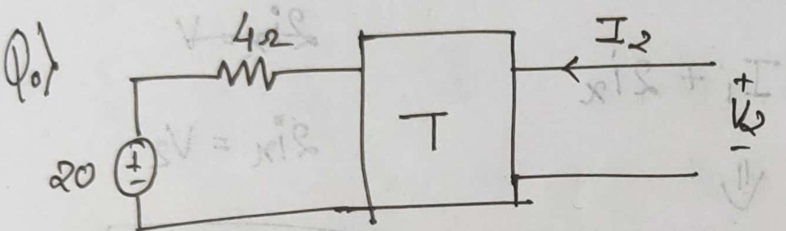
$I_1 = -3DV_1 + (C + 5D)V_2$

On comparing with (1)

$-3D = 4$, $C + 5D = 5$

$D = \frac{-4}{3}$, $C = \frac{35}{3}$

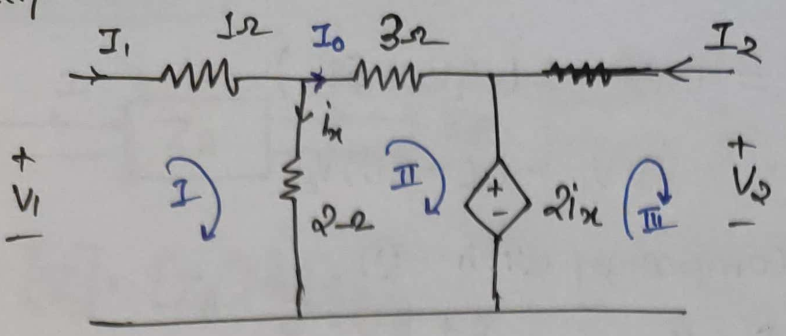
Q.)



⇒

$$T = \begin{bmatrix} 5/3 & -11/3 \\ 1/3 & -4/3 \end{bmatrix}$$

Que.)



⇒

$I_1 = i_x + i_0$

$i_0 = I_1 - i_x$

I

$V_1 - I_1 - 2i_x = 0$

$V_1 = I_1 + 2i_x$

⇓

$\boxed{V_1 = 3I_1}$

II

$-3i_0 - 2i_x + 2i_x = 0$

$\boxed{i_0 = 0}$

$\boxed{I_1 = i_x}$

III

$\cancel{2i_x = V}$

$2i_x = V_2$

$\boxed{V_2 = 2I_1}$

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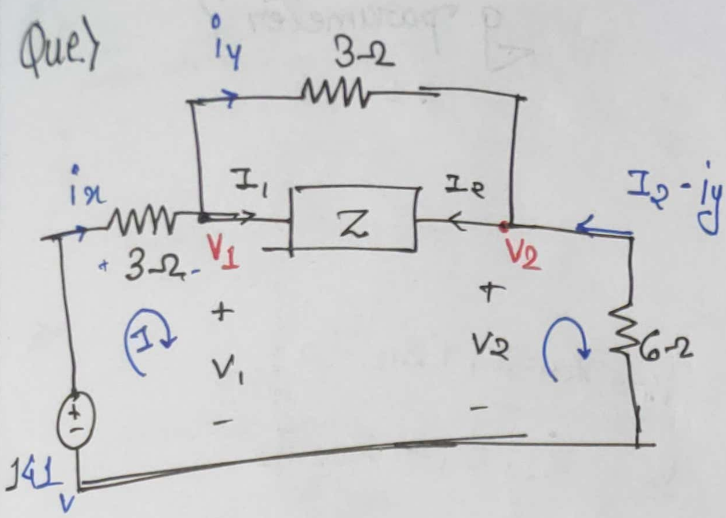
Que.)



$$Z = \begin{bmatrix} 2 & 1 \\ 1 & 4 \end{bmatrix}$$

find I_1 & I_2

$\Rightarrow$ $i_x = i_y + I_1$ —(3)

$V_1 = 2I_1 + 1I_2$ —(1)

$V_2 = I_1 + 4I_2$ —(2)

$$i_y = \frac{+V_1 - V_2}{3}$$

$$i_y = \frac{+I_1 - 3I_2}{3} \quad \text{—(5)}$$

from ~~(3), (4),~~ (5)

~~$141 - 2I_1 - I_2 = \frac{I_1 - 3I_2}{3} + I_1$~~

KVL - I

$141 - 3i_x = V_1$ ← (Substitute V_1 from (1))

$$i_x = \frac{141 - 2I_1 - I_2}{3} \quad \text{—(4)}$$

from (3), (5)

$$i_x = \frac{4I_1 - 3I_2}{3} \quad \text{—(6)}$$

KVL - II

$V_2 + 6(I_2 - i_y) = 0$

$i_y = \frac{1}{6}(V_2 + 6I_2)$

$i_y = \frac{1}{6}(I_1 + 10I_2)$ —(7)

from (4) & (6)

$6I_1 - 2I_2 = 141$

from (5) & (7)

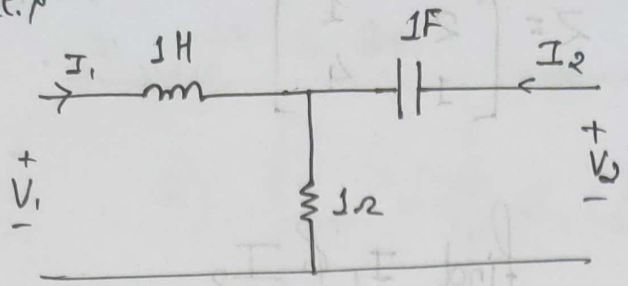
$I_1 - 16I_2 = 0$

$I_1 = 24$ $\quad$ $I_2 = 1.5$

Ans

Que.)

g parameter?



→

$1H \longrightarrow SL = S\,\Omega$

$1F \longrightarrow \frac{1}{SC} = \frac{1}{S}\,\Omega$

$$Z = \begin{bmatrix} S+1 & 1 \\ 1 & \frac{1}{S}+1 \end{bmatrix}$$

$\downarrow$

(V_1, V_2)

$I_1 = g_{11}V_1 + g_{12}I_2$ —①

~~I_2~~ $V_2 = g_{21}V_1 + g_{22}I_2$ —②

$V_1 = (S+1)I_1 + I_2 \longrightarrow I_1 = \left(\frac{1}{S+1}\right)V_1 + \left(\frac{-1}{S+1}\right)I_2$ —③

$V_2 = I_1 + \left(\frac{S+1}{S}\right)I_2$

$\downarrow$

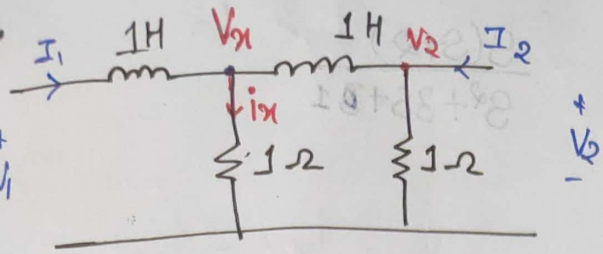
$V_2 = \left(\frac{1}{S+1}\right)V_1 + \left(\frac{-1}{S+1}\right)I_2 + \left(\frac{S+1}{S}\right)I_2$

$V_2 = \left(\frac{1}{S+1}\right)V_1 + \left(\frac{S^2+S+1}{S(S+1)}\right)I_2$ —④

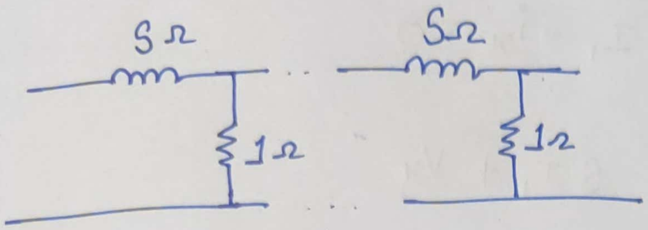
~~for~~ On Comparing ①&③ , ②&④

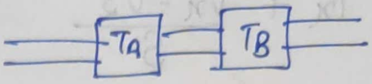
$$g = \begin{bmatrix} \frac{1}{S+1} & \frac{-1}{S+1} \\ \frac{1}{S+1} & \frac{S^2+S+1}{S(S+1)} \end{bmatrix}$$

Q.) g ? 23/oct/24



★ Apply Nodal / Mesh





$[T] = [T_A].[T_B]$

Nodal

$$\frac{V_x - V_1}{S} + \frac{V_x}{1} + \frac{V_x - V_2}{S} = 0$$

$$\left(\frac{1}{S} + 1 + \frac{1}{S}\right) V_x = \frac{V_1}{S} + \frac{V_2}{S}$$

$$\left(\frac{S+2}{\cancel{S}}\right) V_x = \frac{V_1 + V_2}{\cancel{S}}$$

$$V_x = \frac{V_1 + V_2}{S+2}$$

Nodal

$$\frac{V_2 - V_x}{S} + \frac{V_2}{1} + (-I_2) = 0$$

$$\boxed{\begin{aligned} I_1 &= g_{11} V_1 + g_{12} I_2 \\ V_2 &= g_{21} V_1 + g_{22} I_2 \end{aligned}}$$

$$I_2 = \frac{V_2 - V_x}{S} + \frac{V_2}{1} = \frac{V_2}{S} - \frac{V_1 + V_2}{S(S+2)} + V_2$$

$$I_2 = \left(\frac{1}{S} - \frac{1}{S(S+2)} + 1\right) V_2 - \frac{V_1}{S(S+2)}$$

$$\frac{S+2 - 1 + S(S+2)}{S(S+2)}$$

$$\frac{S^2+3S+1}{S(S+2)}$$

$$V_2 = \left(I_2 + \frac{V_1}{S(S+2)}\right) \times \frac{1}{\left(\frac{1}{S} - \frac{1}{S(S+2)} + 1\right)}$$

$$V_2 = \cancel{\left(\frac{S^2+3S+3}{S(S+2)}\right) I_2} \qquad V_2 = \left(\frac{S(S+2)}{S^2+3S+1}\right) I_2 + \left(\frac{1}{S^2+3S+1}\right) V_1$$

$$g_{21} = \frac{1}{S^2+3S+1} \quad , \quad g_{22} = \frac{S(S+2)}{S^2+3S+1}$$

$$i_x = \frac{V_x}{1}$$

$$I_1 = i_x + \frac{V_x - V_2}{S}$$

$$I_1 = \frac{V_x}{1} + \frac{V_x - V_2}{S}$$

$$I_1 = V_x + V_2 - I_2$$

$$V_1 - S I_1 - i_x = 0$$

$$V_1 = S I_1 + V_x$$

$$V_1 = S I_1 + \frac{V_1 + V_2}{S+2}$$

$$S I_1 = V_1 - \frac{V_1 + V_2}{S+2}$$

$$S I_1 = \frac{(S+1)V_1 - V_2}{S+2}$$

$$I_1 = \frac{S+1}{S(S+2)} V_1 - \frac{1}{S(S+2)} V_2$$

$$I_1 = \frac{S+1}{S(S+2)} V_1 - \frac{1}{S(S+2)} \times \left[\frac{S(S+2)}{S^2+3S+1} I_2 + \frac{1}{S^2+3S+1} V_1 \right]$$

$$I_1 = \left(\frac{S+1}{S(S+2)} - \frac{1}{S(S+2)(S^2+3S+1)} \right) V_1 + \left(\frac{-1}{S^2+3S+1} \right) I_2$$

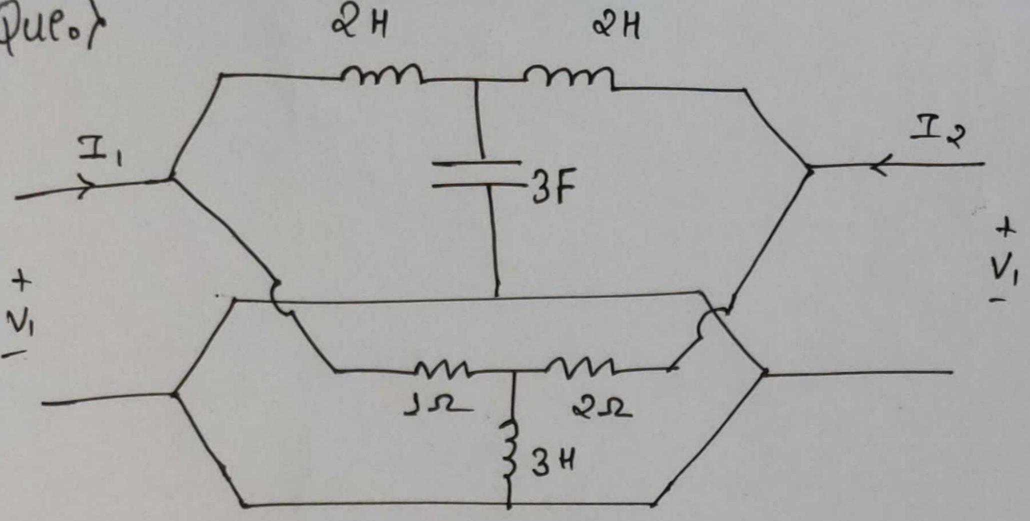
$$I_1 = \frac{S(S+2)^2}{S(S+2)(S^2+3S+1)} V_1 + \left(\frac{-1}{S^2+3S+1} \right) I_2$$

$$I_1 = \left(\frac{S+2}{S^2+3S+1} \right) V_1 + \left(\frac{-1}{S^2+3S+1} \right) I_2$$

$$g_{11} = \frac{S+2}{S^2+3S+1} \qquad g_{12} = \frac{-1}{S^2+3S+1}$$

Ans

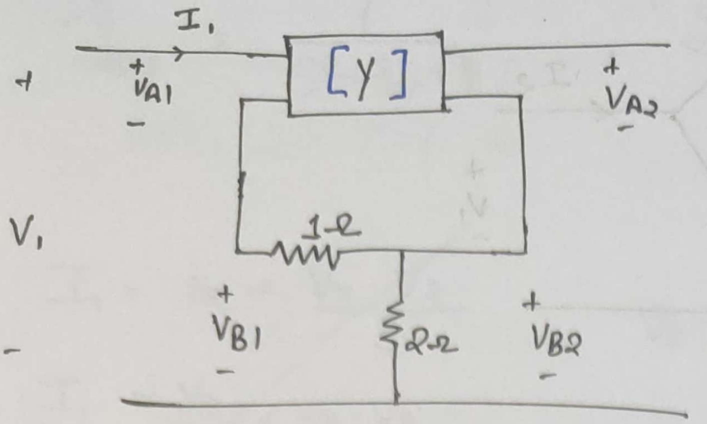
Que.)



⇒

Que 1)

05/NOV/24



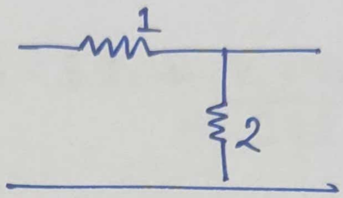
Calc. ~~φ~~ Z parameter

$$[Y] = \begin{bmatrix} 2 & 1 \\ 2 & 4 \end{bmatrix}$$

⇒

$$[Z_1] = [Y]^{-1}$$

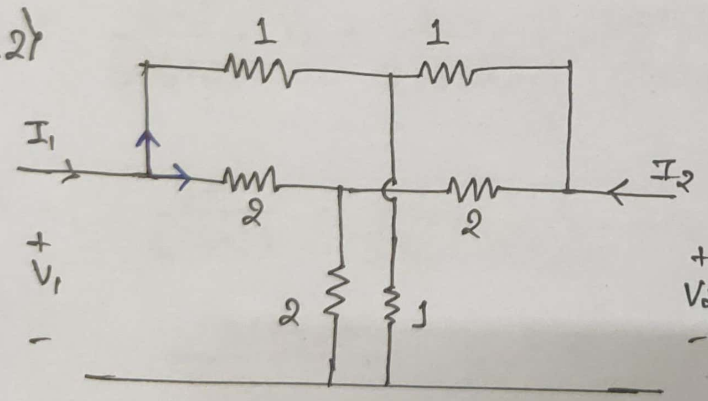
$$[Z_1] = \begin{bmatrix} 4 & -1 \\ -2 & 2 \end{bmatrix}$$



$$[Z_2] = \begin{bmatrix} 3 & 2 \\ 2 & 2 \end{bmatrix}$$

$$Z = Z_1 + Z_2 = \begin{bmatrix} 7 & -1 \\ 0 & 4 \end{bmatrix}$$ Ans

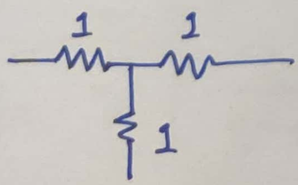
Que.2)



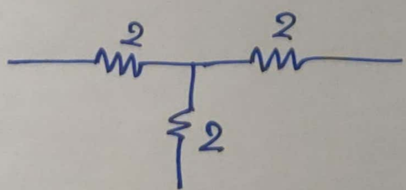
find [Y] ?

→ Parallel

⇒



$$Z_1 = \begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix}$$



$$Z_2 = \begin{bmatrix} 4 & 2 \\ 2 & 4 \end{bmatrix}$$

⇒ $Y = Y_1 + Y_2$

$$Y = \begin{bmatrix} 2 & -1 \\ -1 & 2 \end{bmatrix} + \begin{bmatrix} 4 & -2 \\ -2 & 4 \end{bmatrix}$$

$$Y = \begin{bmatrix} 6 & -3 \\ -3 & 6 \end{bmatrix}$$ Ans

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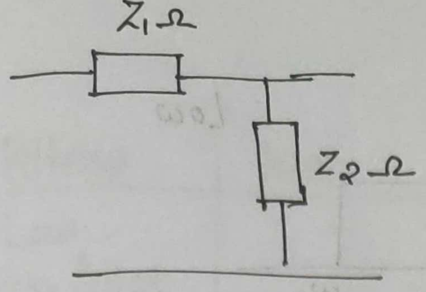
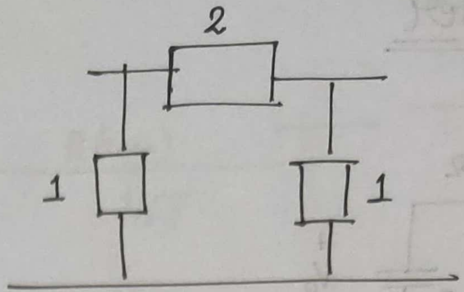
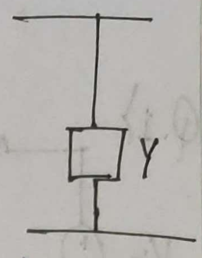
Que.3)



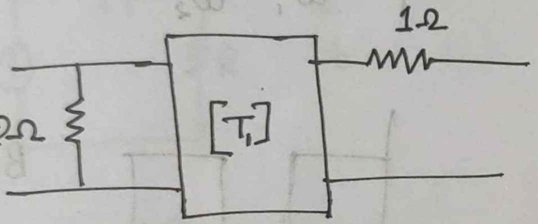
[T] ?





$$[T] = \begin{bmatrix} 1 & 0 \\ Y & 1 \end{bmatrix}$$

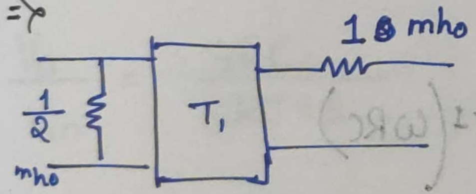
Que.4)



$$[T_1] = \begin{bmatrix} 3 & 4 \\ 2 & 3 \end{bmatrix}$$

T ?

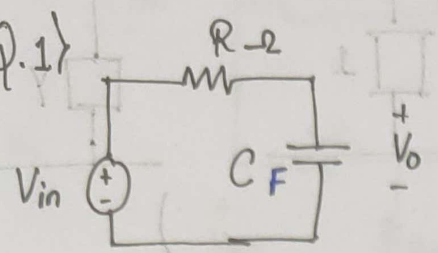
=>

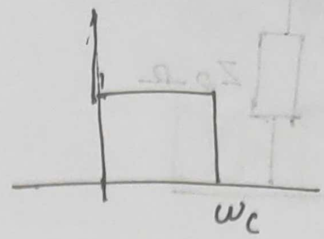


$$[T] = \begin{bmatrix} 1 & 0 \\ 1/2 & 1 \end{bmatrix} \begin{bmatrix} 3 & 4 \\ 2 & 3 \end{bmatrix} \begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix}$$

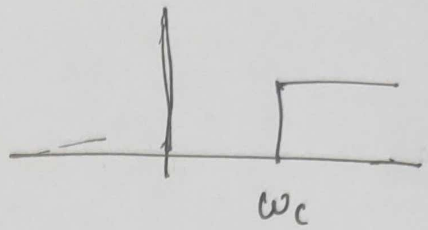
~~Que.~~ # Filter

Q.1)

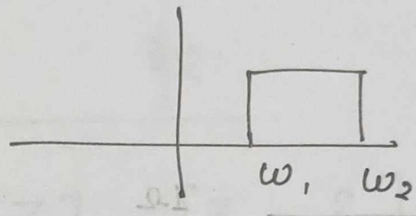




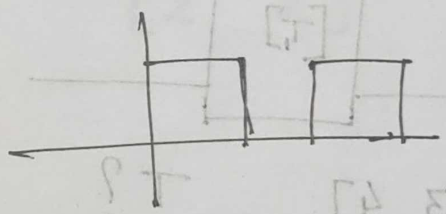
Low



High



Band Pass



Band Stop

$\Rightarrow$

$$T.F. = \frac{O/P}{I/P} = \frac{V_o}{V_{in}}$$

~~Vin~~ =

$$V_o = V_{in} \times \frac{\frac{1}{SC}}{\frac{1}{SC} + R}$$

$$\frac{V_o}{V_{in}} = \frac{1}{1 + SRC}$$

$$\frac{V_o}{V_{in}} = \frac{1}{1 + j\omega RC} = H(\omega)$$

$$|TF| = \frac{1 - j\omega RC}{1 + (\omega RC)^2}$$

$$\theta = -\tan^{-1}(\omega RC)$$

$$|TF| = \frac{\sqrt{1 + (\omega RC)^2}}{1 + (\omega RC)^2}$$

$$\left.\begin{aligned} H(0) &= 1 \\ H(\infty) &= 0 \end{aligned}\right\} \text{Low Pass filter}$$

$$|TF| = \frac{1}{\sqrt{1 + (\omega RC)^2}}$$

$$\rightarrow |H(\omega_c)| = \frac{1}{\sqrt{2}}$$

$$1 + (\omega_c RC)^2 = 2$$

$$\boxed{\omega_c = \pm\frac{1}{RC}}$$

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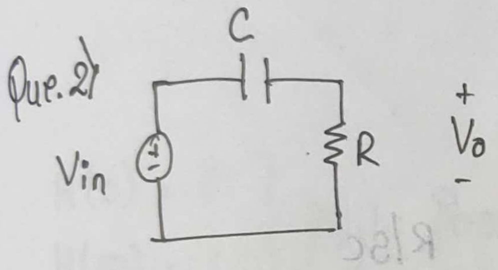
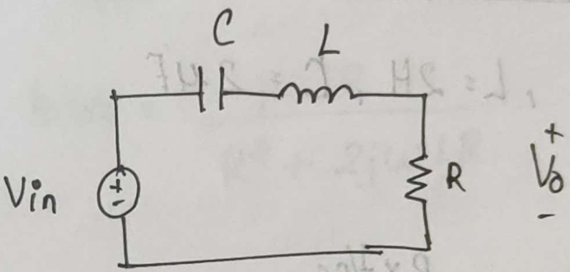
Filters	H(0)	H(∞)	H(ω_c)
Low Pass filter	1	0	$1/\sqrt{2}$
High	0	1	$1/\sqrt{2}$
Band Pass	0	0	1
Band Stop	1	1	0

Que. 2)





⇒

$$V_o = V_{in} \times \frac{R}{R + \frac{1}{SC}}$$

$$\frac{V_o}{V_{in}} = \frac{SRC}{SRC + 1}$$

$$H(\omega) = \frac{j\omega RC}{1 + j\omega RC}$$

$$|H(\omega)| = \frac{\omega RC}{\sqrt{1 + (\omega RC)^2}}$$

$$\left.\begin{aligned} H(0) &= 0 \\ H(\infty) &= 1 \end{aligned}\right\} \text{High Pass}$$

⇒

$$V_o = V_{in} \times \frac{R}{R + \frac{1}{SC} + SL}$$

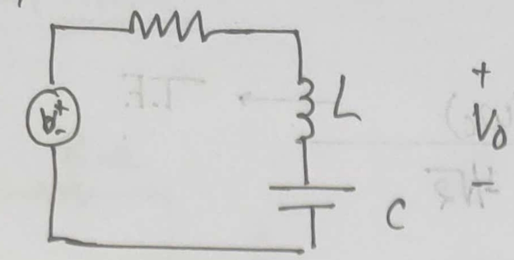
$$\frac{V_o}{V_{in}} = \frac{SRC}{SRC + 1 + S^2CL}$$

$$H(\omega) = \frac{j\omega RC}{1 - \omega^2 CL + j\omega RC}$$

$$|H(\omega)| = \frac{\omega RC}{\sqrt{(1 - \omega^2 CL)^2 + (\omega RC)^2}}$$

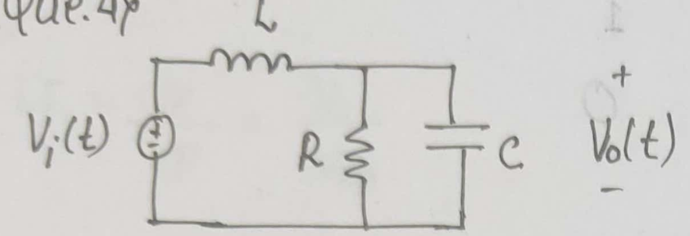
$$\left.\begin{aligned} H(0) &= 0 \\ H(\infty) &= 0 \end{aligned}\right\} \text{Band Pass}$$

Que. 3)



Q

Que. 4)



Find Type of filter & Cut off freq.

$R = 2K\Omega$, $L = 2H$, $C = 2\mu F$

$\Rightarrow$

$$V_0 = V_i \times \frac{\frac{R \times 1/SC}{R + \frac{1}{SC}}}{SL + \frac{R \times \frac{1}{SC}}{R + \frac{1}{SC}}}$$

$$\Rightarrow \frac{V_0}{V_i} = \frac{R/SC}{SRL + R/SC + \frac{L}{C}}$$

$$\frac{V_0}{V_i} = \frac{R}{S^2RLC + R + SL}$$

$$H(\omega) = \frac{R}{R - \omega^2 RLC + j\omega L}$$

$$\left.\begin{array}{l} H(0) = 1 \\ H(\infty) = 0 \end{array}\right\} \text{Low Pass}$$

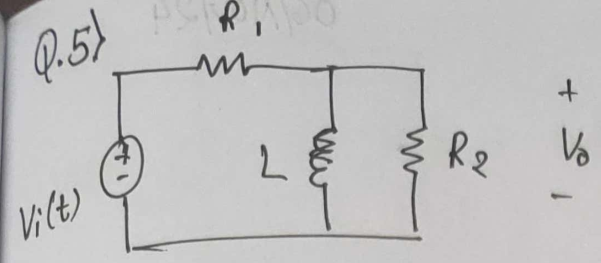
$$|H(\omega_c)| = \frac{1}{\sqrt{2}}$$

$$\frac{R}{\sqrt{(R - \omega^2 RLC)^2 + (\omega L)^2}} = \frac{1}{\sqrt{2}}$$

$$2R^2 = R^2 + \omega^4 R^2 L^2 C^2 - 2\omega^2 R^2 LC + \omega^2 L^2$$

$$\Rightarrow (R^2L^2C^2)\omega_c^4 + (L^2 - 2R^2LC)\omega_c^2 - R^2 = 0$$

Q.5)



$\omega_c = ?$

$R_1 = R_2 = 100 \;, \; L = 2mH$

$\Rightarrow$

$$V_0 = V_{in} \times \left[\frac{\frac{SLR}{SL+R}}{\frac{SLR}{SL+R} + R} \right] \Rightarrow \frac{V_0}{V_{in}} = \frac{SLR}{SLR + SLR + R^2}$$

$$= \frac{SLR}{R^2 + 2SLR}$$

$\cancel{H(.}$

$$H(\omega) = \frac{j\omega LR}{R^2 + 2j\omega LR}$$

$\left.\begin{array}{l} H(0) = 0 \\ H(\infty) = 1/2 \end{array}\right\}$ High Pass

$$|H(\omega)| = \frac{\omega LR}{\sqrt{R^4 + (2\omega LR)^2}}$$

$$|H(\omega_c)| = \frac{1}{\sqrt{2}}$$

$$2\omega_c^2 L^2 R^2 = R^4 + 4\omega_c^2 L^2 R^2$$

$$2\omega_c^2 L^2 \cancel{R^2} = R^{\cancel{4}2}$$

$$\omega_c = \frac{R}{L\sqrt{2}} = \frac{100}{2 \times 10^{-3} \times \sqrt{2}}$$

$$\omega_c = 35.35 \cancel{k} \times 10^3 \; \cancel{s^{-1}} \; rad/sec$$

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Fourier Series →

$$f(t) = a_0 + \sum_{n=1}^{\infty} A_n \cos(n\omega_0 t + \phi_n)$$

$$\cos(A+B) = \cos A . \cos B - \sin A . \sin B$$

$$= [A_n \cos(n\omega_0 t)]\cos\phi_n - [A_n \sin(n\omega_0 t)]\sin\phi_n$$

$$= \cancel{a_n \cos\phi_n + b_n \sin B}$$

$$\cancel{a_n = A_n \cos(n\omega_0 t)}$$

$$\cancel{b_n = -A_n \sin(n\omega_0 t)}$$

$$\cancel{f(t) = a_0 + \sum_{n=0}^{\infty} (a_n \cos\phi_n + b_n \sin \overset{\phi_n}{B})}$$

$$|A_n| = \sqrt{a_n^2 + b_n^2}$$

$$\phi_n = -\tan^{-1}\left(\frac{b_n}{a_n}\right)$$

$$f(t) = a_0 + \sum_{n=1}^{\infty} \left(a_n \cos(n\omega_0 t) + b_n \sin(n\omega_0 t)\right)$$

$$|A_n| \angle \phi_n = \sqrt{a_n^2 + b_n^2} \;\angle -\tan^{-1}\left(\frac{b_n}{a_n}\right)$$

$$a_n = A_n \cos(\phi_n)$$

$$b_n = -A_n \sin(\phi_n)$$

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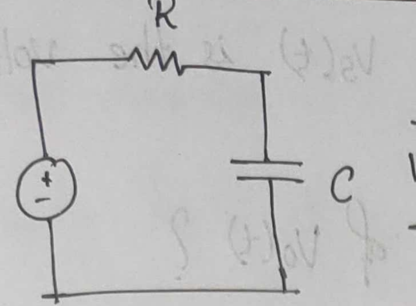
Que.)



find $V_o(t)$?

$$V_i(t) = 3 + \sum_{n\neq 0}^{\infty} 4\cos(5nt)$$

$\Rightarrow$

$$V_o(S) = \frac{1/SC}{R + 1/SC} \times V_i(S)$$

$S = j\omega$

$$V_o(j\omega) = \frac{1}{1+SRC} \times V_i(S)$$

$$V_o(j\omega) = \frac{1}{1+j\omega RC} \times V_i(j\omega)$$

$\boxed{a_0 = 3}$

$|A_n| = 4 = \sqrt{a_n^2 + b_n^2}$

$a_n^2 + b_n^2 = 16$ —(1)

$\phi_n = 0 = -\tan^{-1}\left(\frac{b_n}{a_n}\right)$

$\frac{b_n}{a_n} = 0 \Rightarrow \boxed{b_n = 0}$

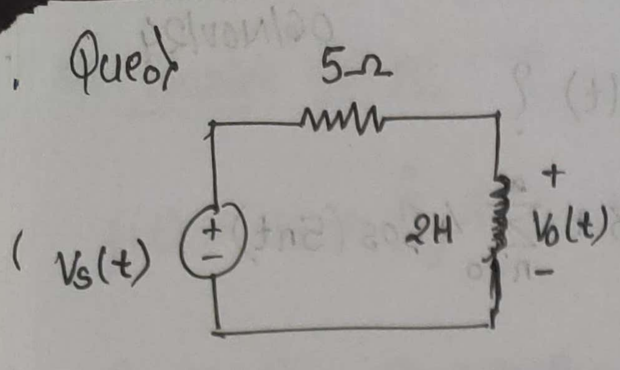
$\boxed{a_n = 4}$

$\omega = 5n$

$|A_n| = 4$ $\qquad \phi_n = 0$

$$v(t) = 3 + \sum_{n=1}^{\infty} 4\cos(5nt)$$

Ques)



Let the funct^n $V_s(t)$ is the voltage source in ckt.

find Response of $V_o(t)$?

$$V_s(t) = \underbrace{\frac{1}{2}}_{DC} + \underbrace{\frac{2}{\pi} \sum_{K=1}^{\infty} \frac{1}{n} \sin(n\pi t)}_{AC}$$

$n = 2K-1$

⇒ $\omega_n = 0$

$s = j\omega$

$\omega_n = n\pi$

for DC $\longrightarrow \omega_n = 0$

$$V_o = V_S \times \frac{2S}{2S+5}$$

$$S = j\omega$$
$$S = 0$$

$$V_o = \frac{1}{2} \times \frac{0}{0+5}$$

$$V_o = 0$$

For AC $\longrightarrow \omega_n = n\pi$

$$n = 2K-1$$

$$V_o = V_S \times \frac{2S}{2S+5}$$

$$V_S = \frac{2}{\pi} \underbrace{\sum_{K=1}^{\infty} \frac{1}{n} \sin(n\pi t)}_{\cancel{\angle -90^\circ}}$$

$$\cancel{\cos(-90^\circ) + j\sin(-90^\circ)}$$

$$\Downarrow$$

$$-j$$

Conversion to phasor domain

$$= r\angle\phi$$

$$\frac{1}{n}\sin(n\pi t)$$

$$\frac{1}{n}\cos(n\pi t - 90)$$

$$\cancel{r = 1/n}$$

$$\phi = -90^\circ$$

$$= -j$$

$$S = j\omega$$

$$S = j\pi n$$

$$V_S = -\frac{2j}{\pi n}$$

$$V_o = \frac{-2j}{\cancel{\pi n}} \times \frac{2j\cancel{\pi n}}{2j\pi n + 5} = \frac{+4}{(2\pi n)j + 5}$$

$$|V_o| = \frac{4}{\sqrt{4\pi^2 n^2 + 25}} \angle \tan^{-1}\left(\frac{2\pi n}{5}\right)$$

$$= \frac{4 \angle -\tan^{-1}\left(\frac{2\pi n}{5}\right)}{\sqrt{4\pi^2 n^2 + 25}}$$

$\hookrightarrow$ phase domain

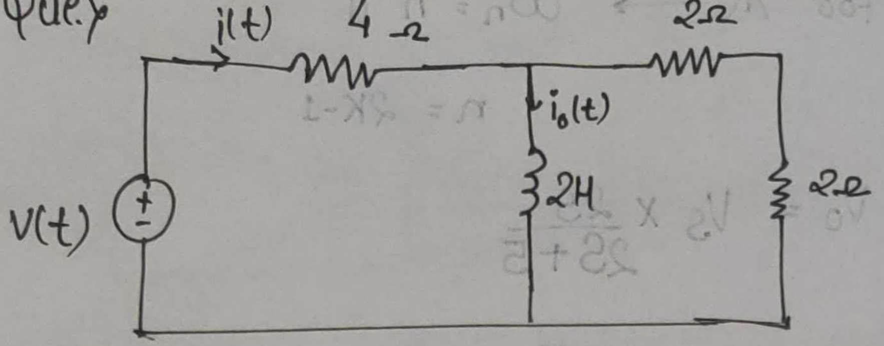
$$r\angle\phi$$

$$|V_o| = \frac{4}{\sqrt{4\pi^2 n^2 + 25}} \cos\left(n\pi t - \tan^{-1}\left(\frac{2\pi n}{5}\right)\right)$$

$\hookrightarrow$ Time domain

$$V_o(t) = 0 + \sum_{K=1}^{\infty} \frac{4}{\sqrt{4\pi^2 n^2 + 25}} \cos\left(n\pi t - \tan^{-1}\left(\frac{2\pi n}{5}\right)\right)$$

Que.)



find Response of $i_0(t)$

$$v(t) = \underset{\downarrow \text{ DC}}{1} + \underset{\downarrow \text{ AC}}{\sum_{n=1}^{\infty} \frac{2(-1)^n}{1+n^2}\left(\cos nt - n\sin(nt)\right)} \quad \text{--- (1)}$$

⇒

$$i_o(s) = i(s) \times \frac{4}{4+2S}$$

$$Z = 4 + (4 \| 2S) = 4 + \frac{8S}{4+2S}$$

$$Z = \frac{16+16S}{4+2S}$$

$$Z = \frac{8(S+1)}{S+2}$$

$$i(s) = \frac{V}{Z} = \frac{(S+2)\,V}{8(S+1)}$$

$$i_o(s) = \frac{V(S+\cancel{2})}{8(S+1)} \cdot \frac{2}{(\cancel{S+2})}$$

$$i_o(s) = \frac{V}{4(S+1)}$$

$$\omega = n$$

$$i_o = \frac{V}{4(1+j\omega_n)} \Rightarrow |i_o| = \frac{V}{4\sqrt{1+n^2}} \angle \tan^{-1}(n)$$

~~i_o = 1~~ for dc ($\omega_n = 0$ or $n = 0$)

$V = 1 \Rightarrow i_o = \frac{1}{4}$

Date ___/___/___

Saathi

17.7

$$V(t) = 1 + \sum_{n=1}^{\infty} \frac{2(-1)^n}{1+n^2}(\cos nt - n\sin nt)$$

$$v(t) = 1 + \sum_{n=1} \frac{2(-1)^n}{1+n^2} \qquad A_n \cos(-+)$$

$a_n = 1$ $\qquad A_n = \sqrt{1+n^2}$

$b_n = -n$

$$\phi = -\tan^{-1}(-n) = \tan^{-1}(n)$$

$$v(t) = 1 + \sum_{n=1} \frac{2(-1)^n}{\sqrt{1+n^2}} \cos(nt + \tan^{-1} n)$$

$$i_0 = \frac{V}{4\sqrt{1+n^2} \angle \tan^{-1}(n)}$$

$r < 0$

$\omega_n = n$

DC $\Rightarrow$ ~~ω_n~~ $\omega_n = 0 \Rightarrow n = 0$

$V = 1$

$$i_0 = \frac{1}{4}$$

Ac $\Rightarrow$

$$V = \frac{2(-1)^n}{\sqrt{1+n^2}} \angle \phi \qquad r = 1$$

$$\phi = \tan^{-1} n$$

$$V = \frac{2(-1)^n}{\sqrt{1+n^2}} \angle \tan^{-1}(n)$$

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for n^{th} harmonic,

$$V = \frac{2(-1)^n}{\sqrt{1+n^2}} \angle \tan^{-1}(n)$$

V_s

$$i_o = \frac{1}{4\sqrt{1+n^2} \angle \tan^{-1}(n)} \times \frac{2(-1)^n}{\sqrt{1+n^2}} \angle \tan^{-1}(n)$$

$$i_o = \frac{(-1)^n}{2(1+n^2)}$$

$$i_o(t) = \frac{1}{4} + \sum_{n=1}^{\infty} \frac{(-1)^n}{2(1+n^2)} \cos(nt)$$