BEC304 - NETWORK ANALYSIS

MODULE-1 BASIC CONCEPTS

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→ classification of Networks.

1) Linear, n/w & non linear network

linear network : If the R, L, C offered by an element does not change linearly with the change in applied voltage or current in an element is called linear element

non Linear network : If the R, L, C offered by an element change non linearly with the change in applied voltage or current in an element is called non linear element.

2) unilateral / Bilateral network :

unilateral n/w : properties or characteristics changes with the direction of operation.

Ex : Diode, BJT, FET

Bilateral network : properties or characteristics remains same in either Direction.

3) Active & Passive network:

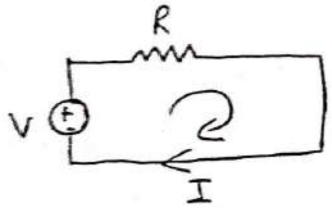
Active n/w : It is one which contains atleast one energy source either voltage or current.

Ex : BJT, Power supply, opamp.

Passive n/w : It is one which does not contain any source to drive the ckt

Ex : R, L, C

→ R in ohms (Resistor)

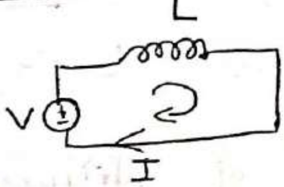


From ohm's law

$$V = IR$$

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

Inductor (L in henry)



From ohm's law

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

$$X_L = 2\pi f L$$

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

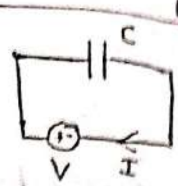
apply integration

$$\int V.dt = L\int \frac{dI}{\cancel{dt}}$$

$$\int V.dt = LI$$

$$\boxed{I = \frac{1}{L}\int V.dt}$$

capacitor (C in farad)



From ohm's law

$$V = I X_C$$

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

$$\boxed{V = \frac{1}{C}\int I\,dt}$$

Apply diff

$$\frac{dv}{dt} = \frac{1}{C}\int dt\,\frac{d}{dt}$$

$$\frac{dv}{dt} = \frac{1}{C} I$$

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

4. Lumped and distributed network.

circuit having elements R, L, C can be seperated physically is called Lumped network

Ex: simple electrical n/w

distributed network :

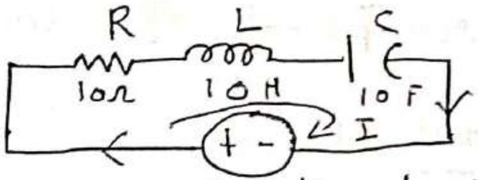
ckt's having elements R, L, C cannot be seperated physically is called distributed network :

Ex: Transmission line, where R-L-C are distributed along the length & cannot be shown as seperate element.

→ Impedance (Z) (Ω)

It is defined as the total opposition to the flow of electron

If a ckt consist of RLC



Voltage, $f = 100$ Hz
100V

$$\boxed{Z = R + jX_L - jX_C}$$

$$Z = R + j(X_L - X_C) \quad \ldots (1)$$

WKT

$X_L = 2\pi f L$

$X_L = 2 \times 3.14 \times 100 \times 10$

$X_L = 6283.18$

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

$X_C = \frac{1}{2 \times \pi \times 100 \times 10}$

$X_C = 1.591 \times 10^{-4}$

$$Z = 10 + j6283.18 - j1.591 \times 10^{-4}$$

$$Z = 10 + j(6283.179)$$

$$|Z| = \sqrt{a^2 + b^2}$$

$$|Z| = \sqrt{10^2 + 6283.179}$$

$$\boxed{|Z| = 6283.18}$$

$I = \frac{V}{R}$ $\quad I = \frac{100}{6283.18}$

$I = 0.0159$

$$\boxed{I = 15.9 \times 10^{-3} A}$$

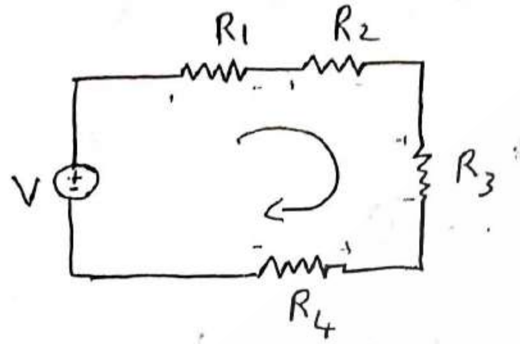
→ Admitance (Y)

unite is (℧) mho

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

Admitance is the reciprocal of impedence

→ Kirchoff's voltage law. (KVL)

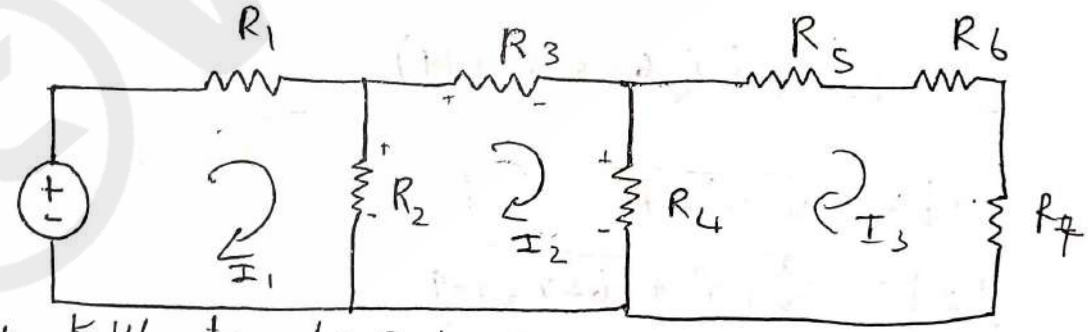


Applying KVL

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

$$V - I(R_1 + R_2 + R_3 + R_4) = 0$$

$$V = I(R_1 + R_2 + R_3 + R_4)$$



Apply KVL to loop-1

$$V - I_1R_1 - (I_1 - I_2)R_2 = 0$$

$$V - I_1R_1 - I_1R_2 + I_2R_2 = 0$$

$$V - I_1(R_1 + R_2) + I_2R_2$$

$$\boxed{V = I_1(R_1 + R_2) - I_2R_2}$$

$$-I_2 R_3 - I_2 R_4 + (I_2 - I_1) R_2 = 0$$

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$$-I_2 R_3 - I_2 R_4 - I_2 R_2 + I_1 R_2 = 0$$

$$-I_2 (R_3 + R_4 + R_2) + I_1 R_2 = 0$$

$$\boxed{I_1 R_2 = I_2 (R_3 + R_4 + R_2)}$$

Loop 3:

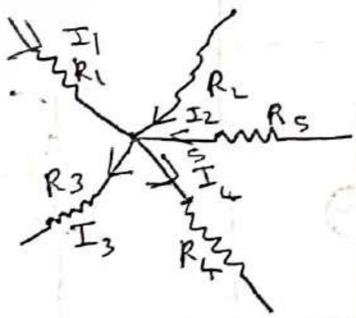
$$-I_3 R_5 - I_3 R_6 - I_3 R_7 - (I_3 - I_2) R_4 = 0$$

$$-I_3 (R_5 + R_6 + R_7 + R_4) + I_2 R_4$$

$$\boxed{I_2 R_4 = I_3 (R_5 + R_6 + R_7 + R_4)}$$

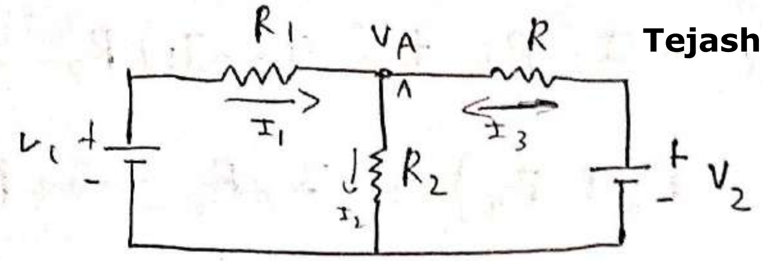
→ Kirchoff's current law (KCL)

The sum of current entering into the node is equal sum of current leaving the node.



$$\boxed{I_1 + I_2 + I_5 = I_3 + I_4}$$

• Eg :



$$I_1 + I_3 = I_2$$

$$I_1 - I_2 + I_3 = 0$$

from ohm's law.

$$\frac{V_1 - V_A}{R_1} - \frac{V_A}{R_2} + \frac{V_2 - V_A}{R_3} = 0$$

→ Energy Sources :-

There are two Basic energy Source

1) Voltage

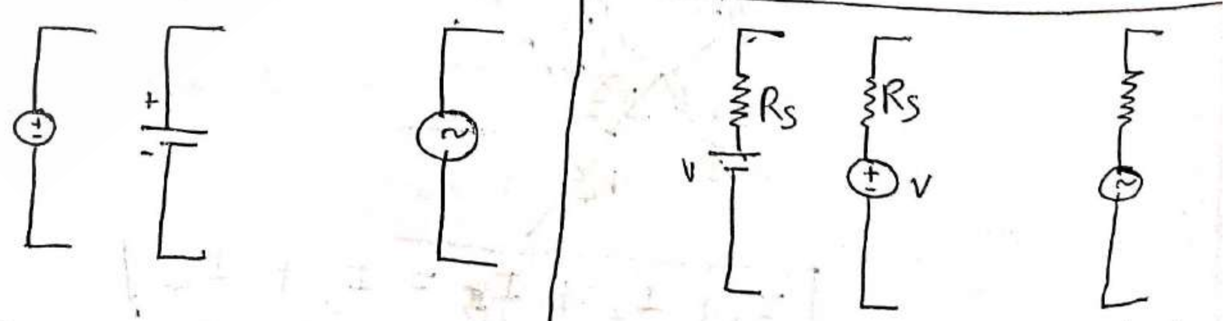
2) current

It is broadly classified into two types

→ Independent source

- voltage source can be ideal or practical
- Ideal voltage source is defined as the energy source which gives constant voltage with independent of current.

Ideal source	Practical source



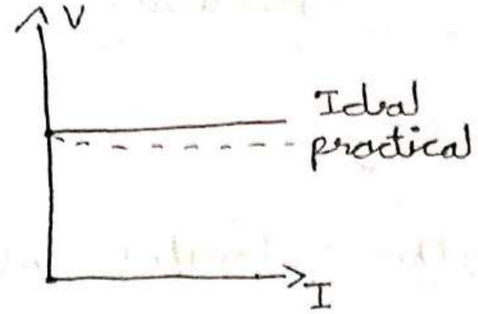
Ideal DC Voltage source

Ideal AC

Practical DC Voltage source

Practical AC Voltage source

- All practical voltage source will have internal resistance called Source Resistance (RS)

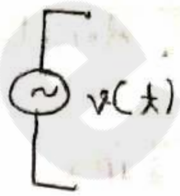


~~Time Variant~~.

* Voltage source are again classified into:

-> Time variant AC Voltage source:

- Voltage varies w.r.t time
- It is denoted by small letters



-> Time invariant DC Voltage source:

- Voltage does not vary w.r.t time
- It is denoted by capital letters

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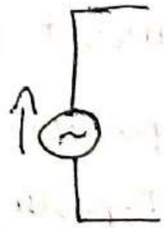
* current source:

- current source can be ideal or practical
- In ideal current source current remains constant with independent of voltage

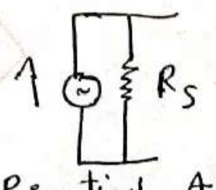
Ideal DC current Source



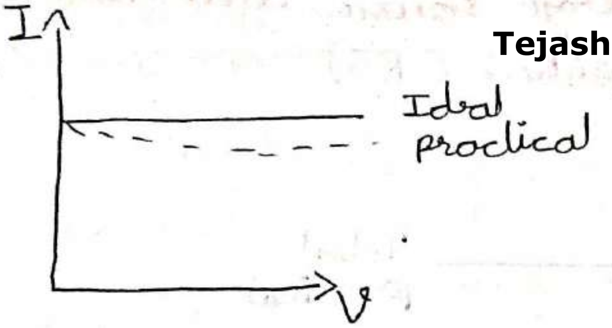
Ideal AC current Source

- In practical current source an internal resistance is present known as source resistance

Practical DC current source

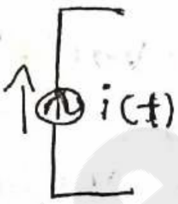


Practical AC current source

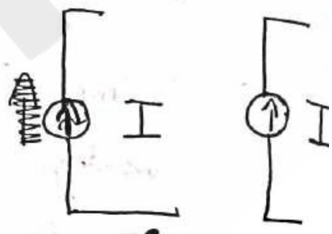


current sources are further classified into

* Time Varient AC current source.
  - current changes w r t time
  - denoted by small letter



* Time invarient AC current source.
  - current does not vary w r t time
  - denoted by capital letter's



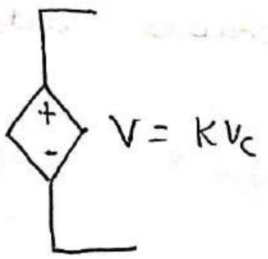
⟹ Dependent Sources

Denoted by this

- Voltage Dependent Voltage source.
- ~~Volt~~ ~~I~~ current Dependent Voltage source.
- Voltage Dependent current source.
- current Dependent current source.

1) Voltage Dependent Voltage source.

It produces voltage as a function of Voltage



K = scaling factor

V_c = circuit voltage

2) current Dependent Voltage Source:

It produces Voltage as a function of current

$V = K I_c$

K = scaling factor

I_c = ckt current

3) Voltage Dependent current source :-

It produces current as a function of ~~voltage~~ voltage

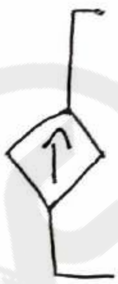
$I = K V_c$

K = scaling factor

V_c = ckt Voltage

4) current Dependent current source :-

It produces current as a function of current



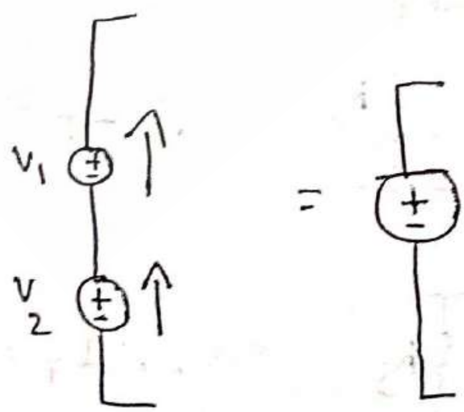
$I = K I_c$

K = scaling factor

I_c = ckt current

→ Addition & subtraction of Voltage sources:-

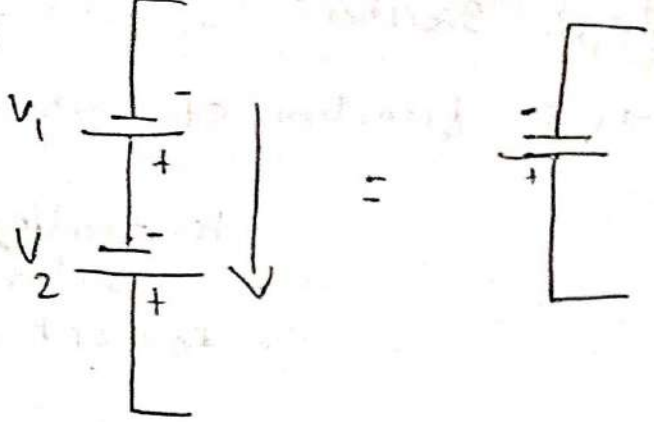
1)



$V_T = V_1 + V_2$

Voltage can be added or subtracted in series
current can be added or subtracted in parallel

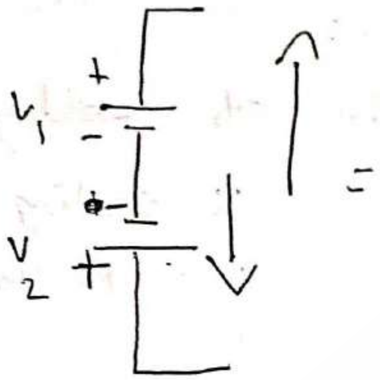
2)



$V_T = -V_1 - V_2$

$V_T = -(V_1 + V_2)$

3)



Case 1

$V_1 > V_2$

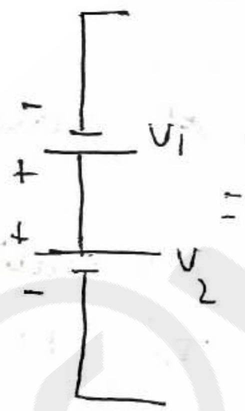
$V_T = V_1 - V_2$

Case 2

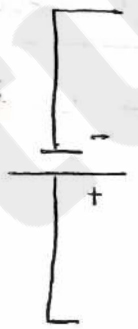
$V_2 > V_1$

$V_T = $

4)



$V_1 > V_2$



$V_T = -V_1 + V_2$

$V_T = V_2 - V_1$

$V_2 > V_1$

$V_T =$

$-V_1 +$

$V_T = V_2$

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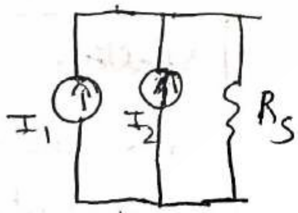
→ Addition & subtraction of current sources.

1)



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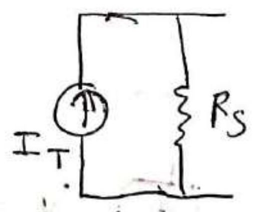
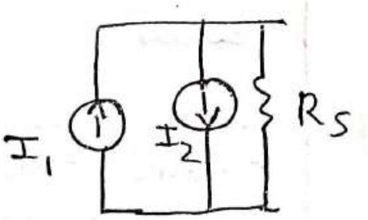


$\therefore I_T = I_1 + I_2$

2)



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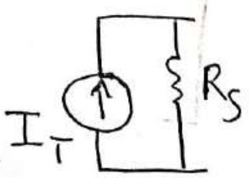
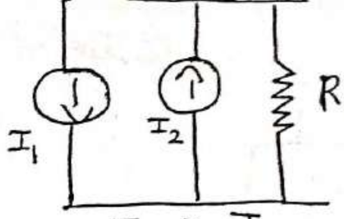


$\therefore I_T = I_1 - I_2$

$I_1 > I_2$

3)



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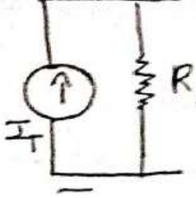
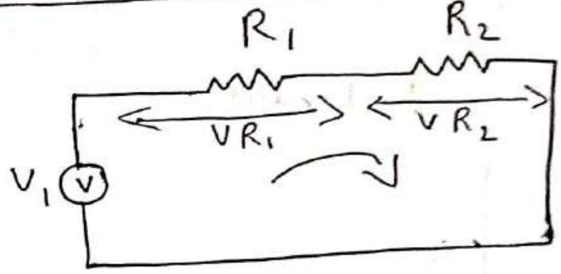


$I_T = I_2 - I_1$

$I_2 > I_1$

→ Voltage Divider Rule:

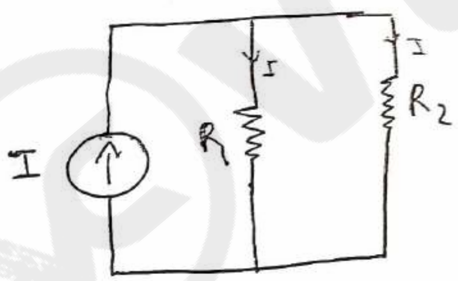


$$\boxed{V_{R_1} = \frac{V \times R_2}{R_1 + R_2}}$$

V_2

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

→ Current Divider Rule

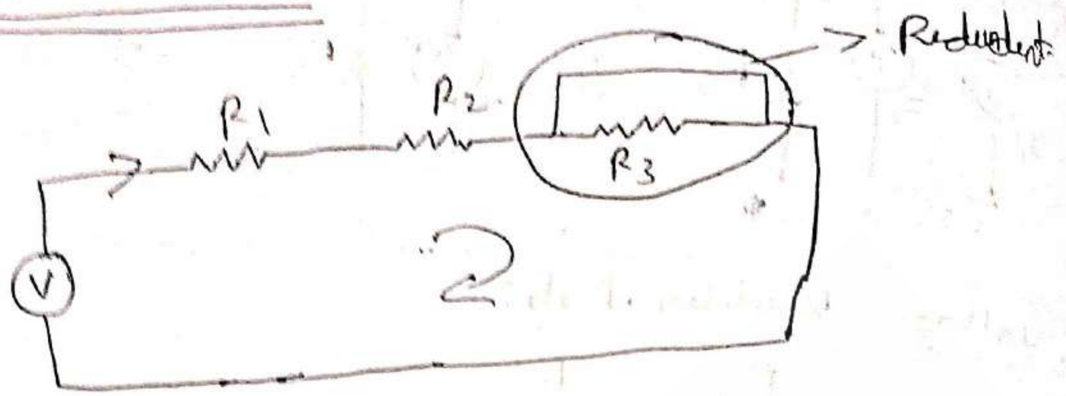


$$\boxed{I_{R_1} = \frac{I \times R_2}{R_1 + R_2}}$$

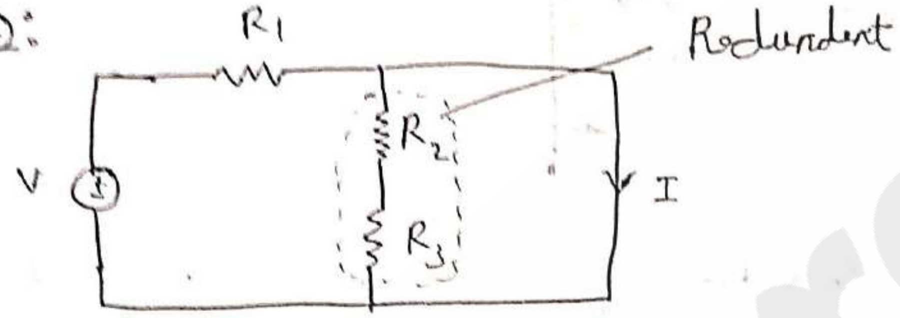
$$\boxed{I R_2 = \frac{I \times R_1}{R_1 + R_2}}$$

→ Redundant Branches :-

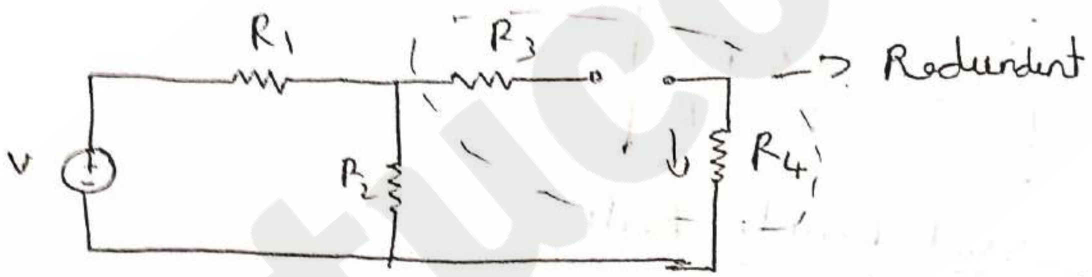
Case ① :



Case ② :

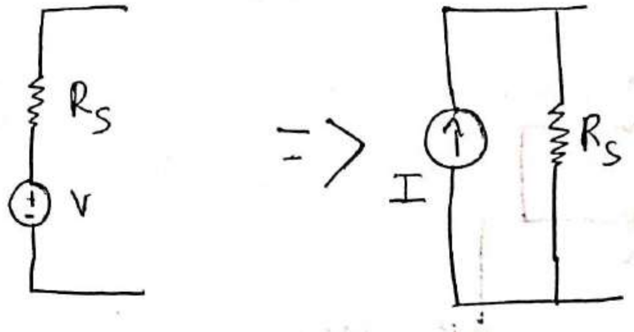


Case ③ :



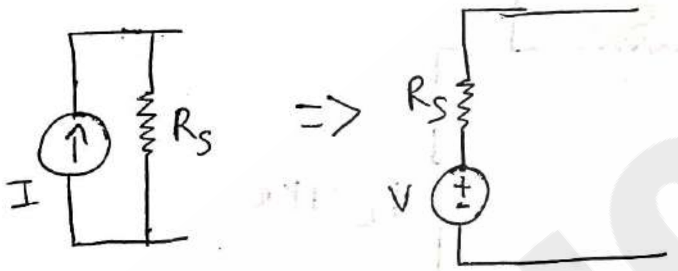
→ Source transformation :

i) voltage - current transformation (V - I)



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

ii) current - voltage transformation (I - V)



$\boxed{V = IR}$

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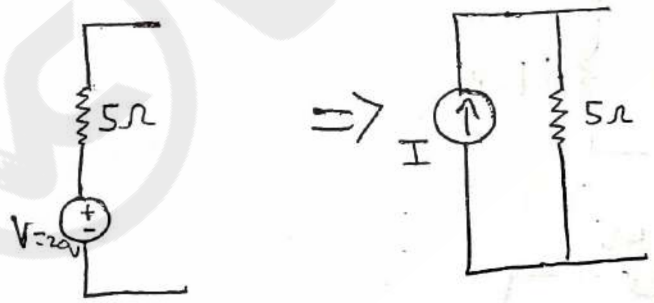
1) → Transform a voltage source of 20V with an Internal resistance of 5Ω to a current source



$$I = \frac{V}{R} = \frac{20}{5} = 4A$$

$\boxed{I = 4A}$

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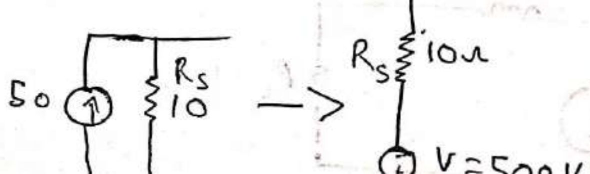
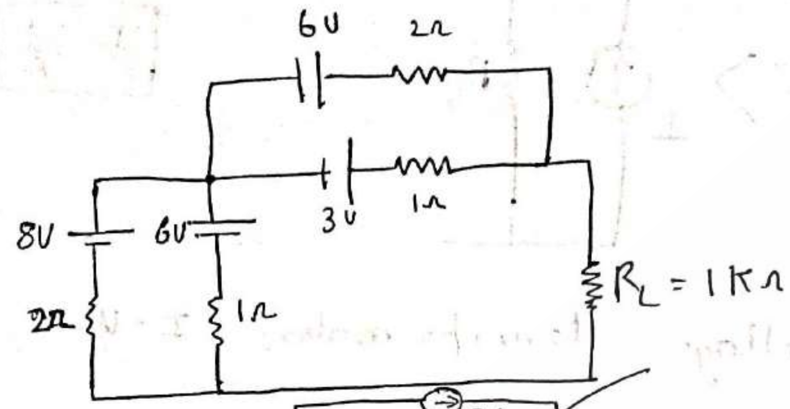
2) convert the given I source of 50A with internal resistance of 10Ω.

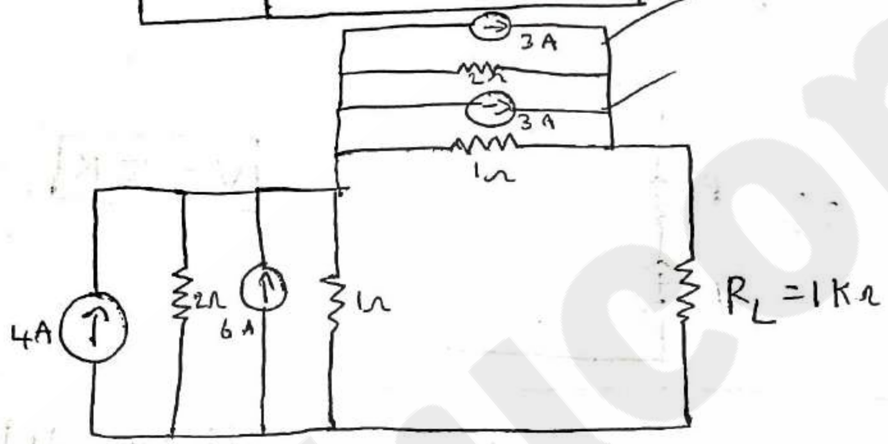


$V = IR$
$= 50 \times 10$
$\boxed{V = 500V}$

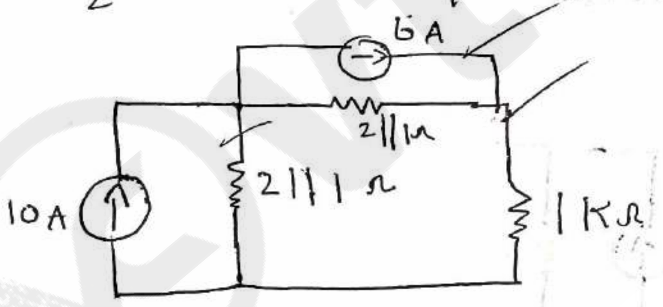
3) Using current transformation technique simplify the given network and find the current through $R_L = 1K\Omega$

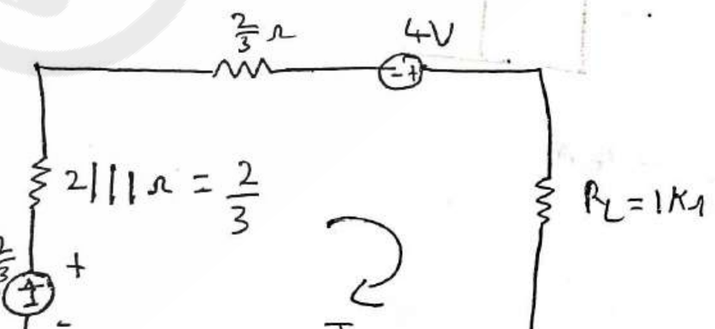
Soln:





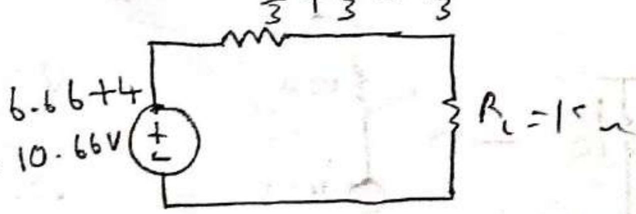
$I = \frac{8}{2} = 4A$ $\quad I = \frac{6}{1} = 6A$ $\quad I = \frac{6}{2} = 3A$ $\quad I = \frac{3}{1} = 3A$





$V = IR$
$= 10 \times \frac{2}{3}$
6.66V

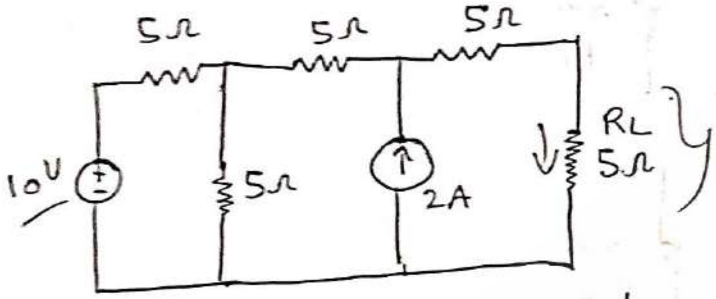
$\frac{2}{3} + \frac{2}{3} = \frac{4}{3}\ \Omega$



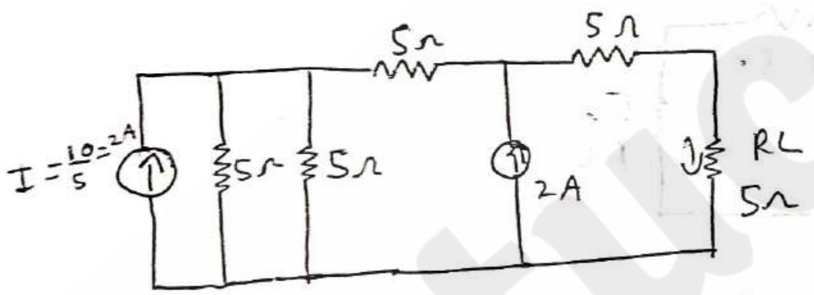
$$I = \frac{V}{R} = \frac{10.66}{4/3 + 1\times10^{3}}$$

$\boxed{I = 10.65 \times 10^{-3}}$ or $\boxed{I = 10.65\ mA}$

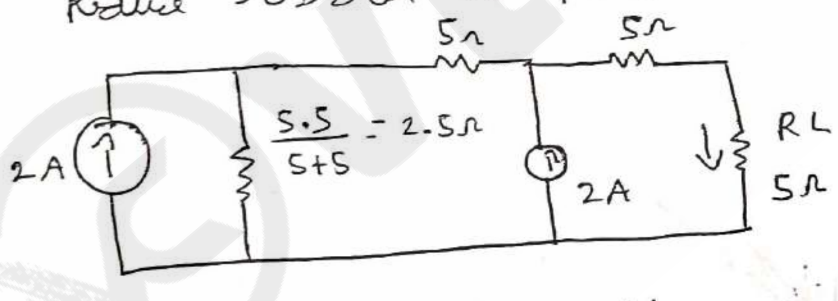
4) Using source transformation find the load current I_L in the following ckt shown below.



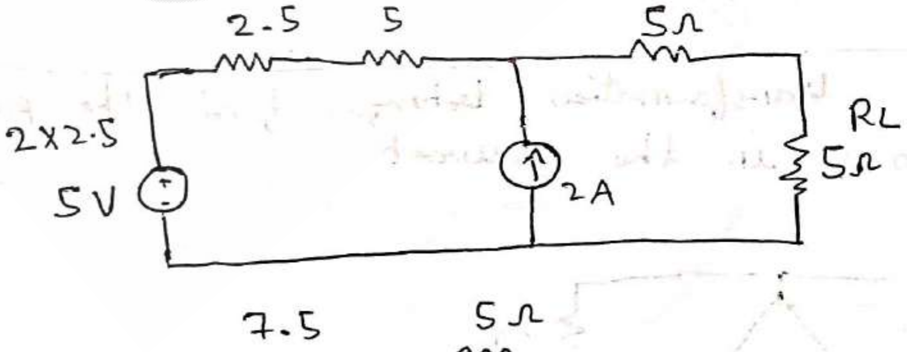
soln: convert 10V 5Ω to current source.

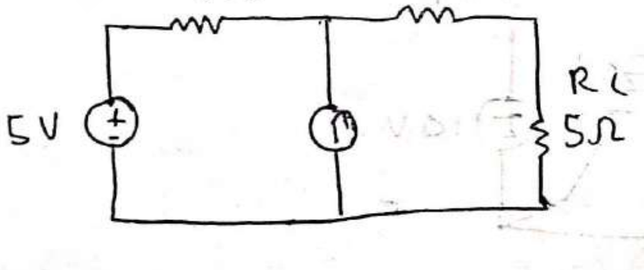


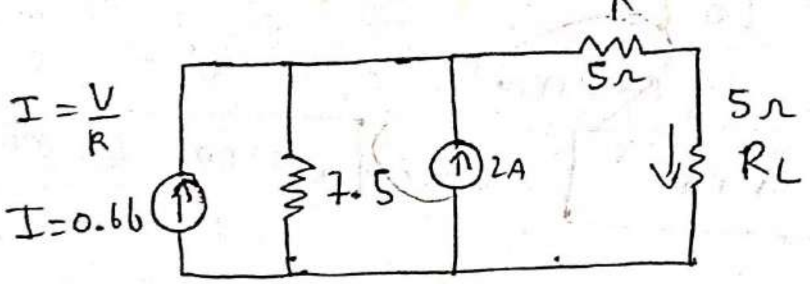
Reduce resistor in parallel.

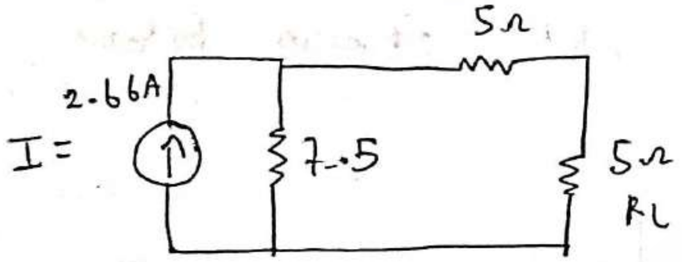


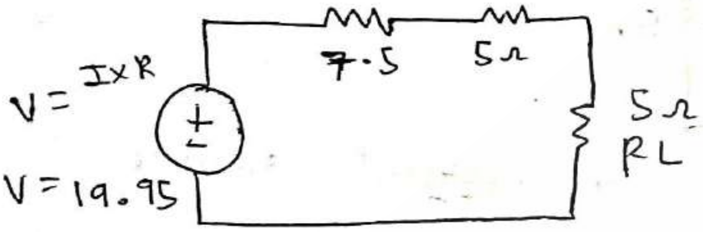
convert 2A & 2.5 to voltage source.

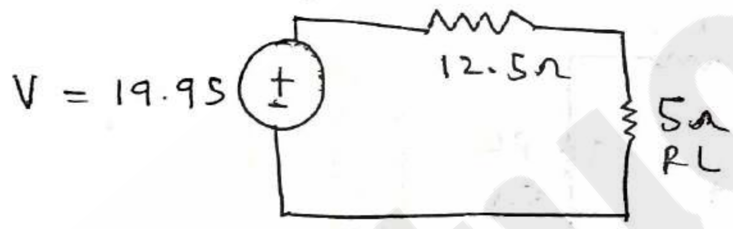










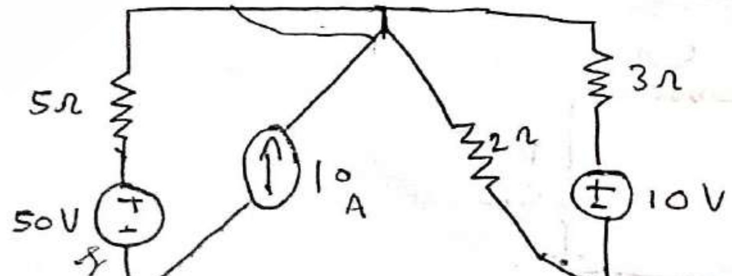


$$I = \frac{V}{R}$$

$$I = \frac{19.95}{12.5+5}$$

$$\boxed{I_L = 1.14\,A}$$

5) Using source transformation technique find the power delivered by 50 V in the network



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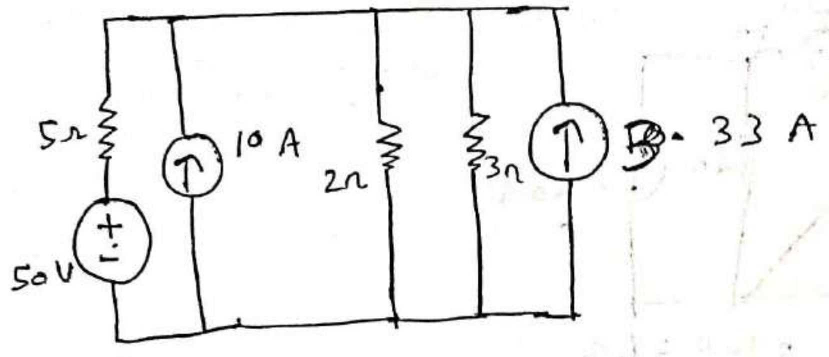
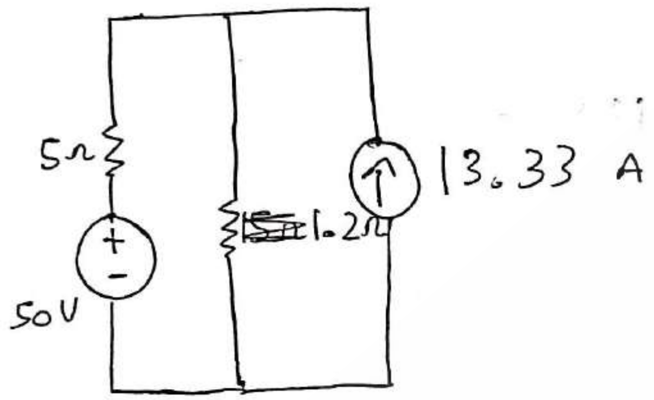
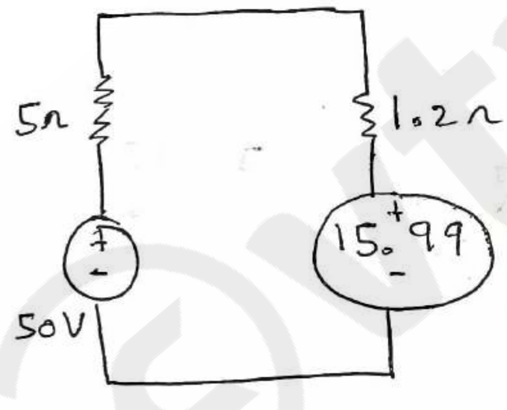
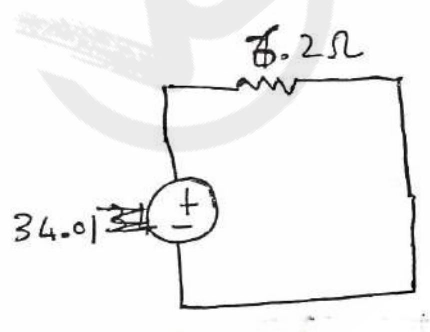
$P = V I$









$6.2 \overline{)\,34.01}$

$I = \frac{34.01}{6.2}$

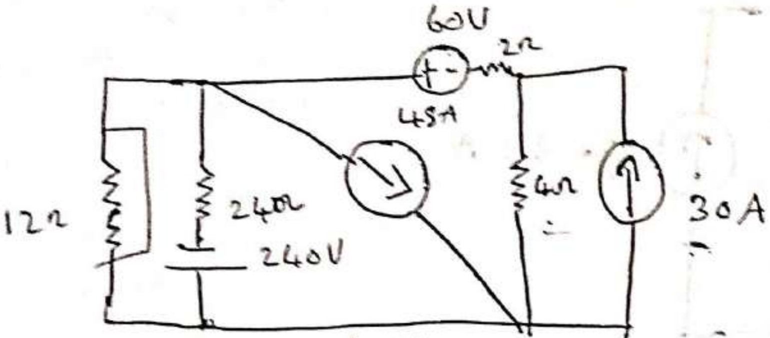
$I = 5.48\,\Omega$

Power $= V \times I$

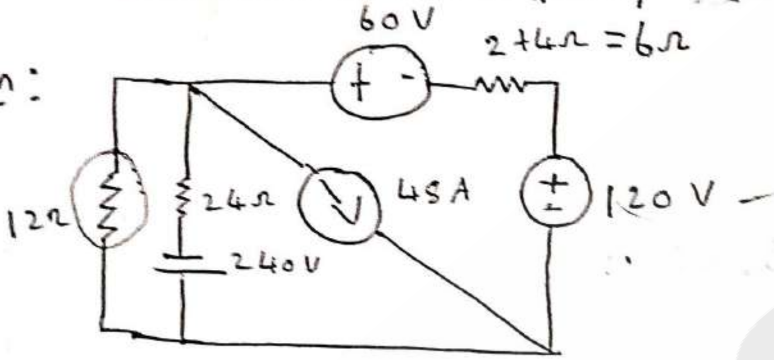
$= 50 \times 5.48$

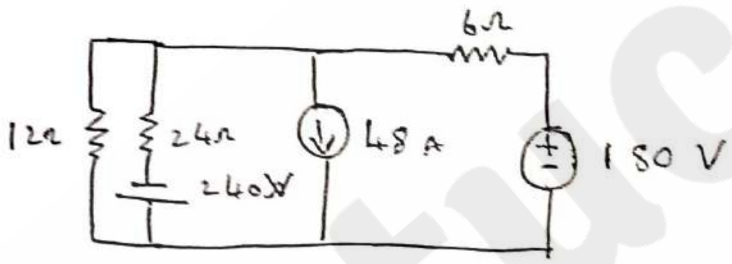
$\boxed{P_{... } = 274.89 \text{ Watts}}$

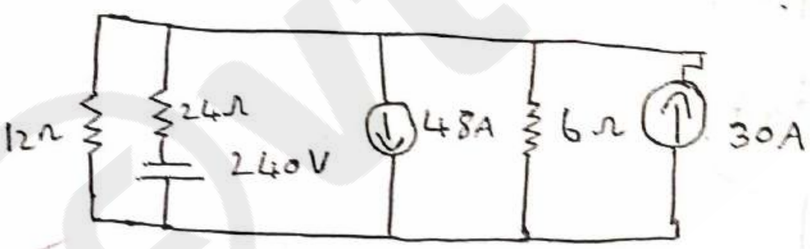
6) Find the current through 12 Ω resistor in a network shown using source transformation



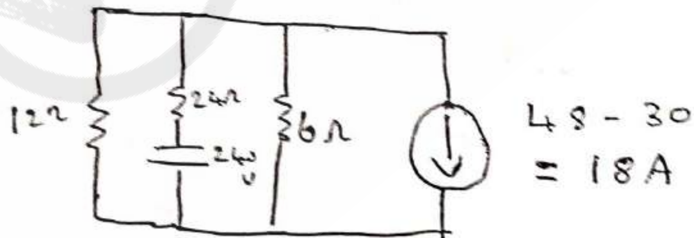
Soln:

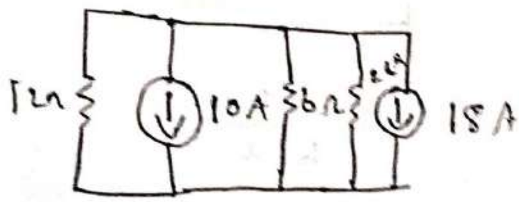






$I = \frac{180}{6}$





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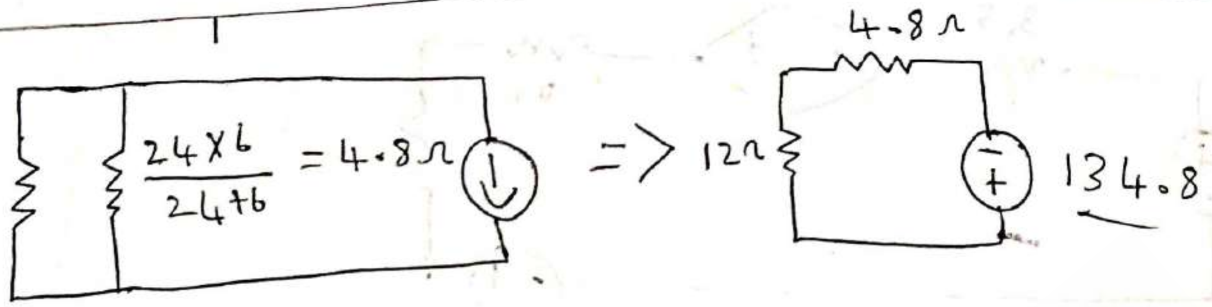
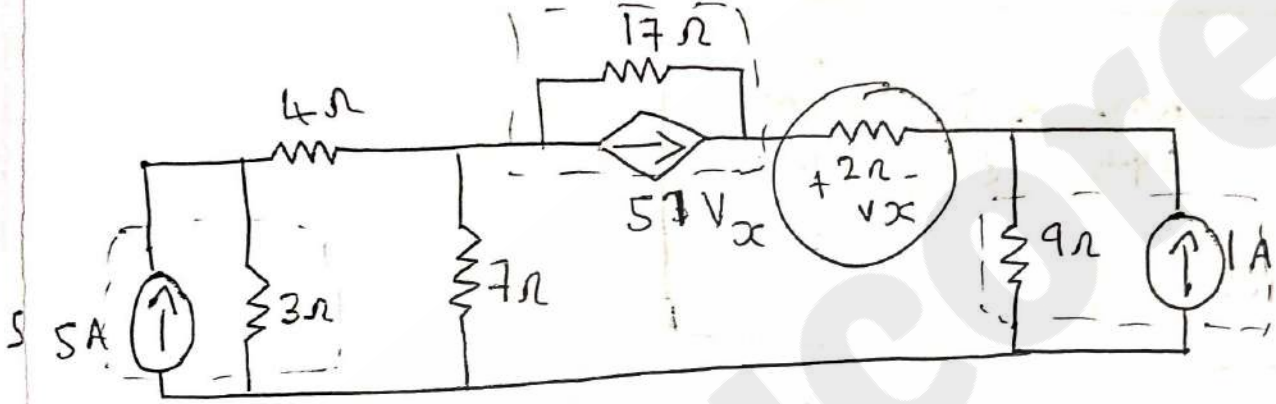
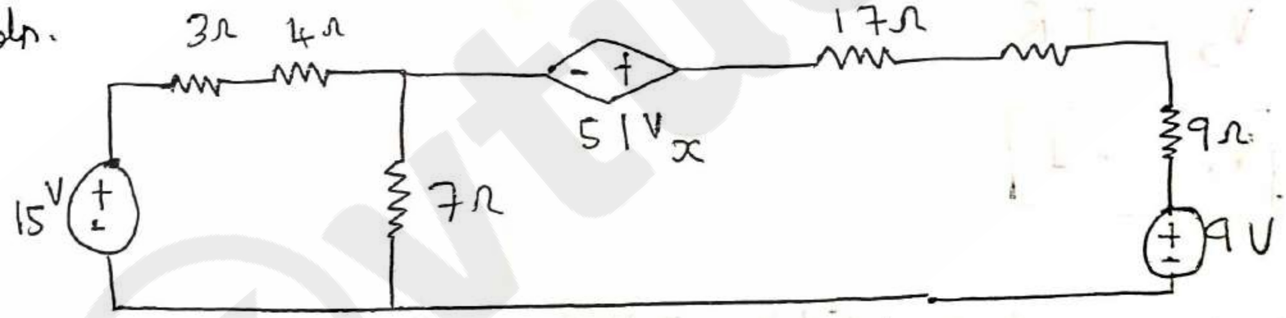


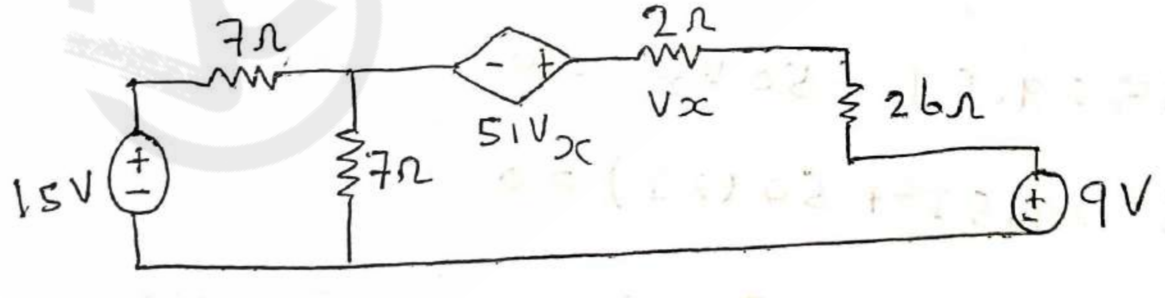
$\boxed{I = 8A}$

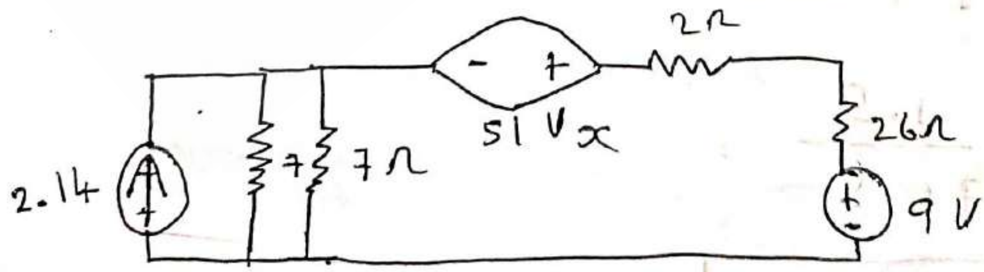
7) Using source transformation find the current I in the following ckt shown across 2Ω

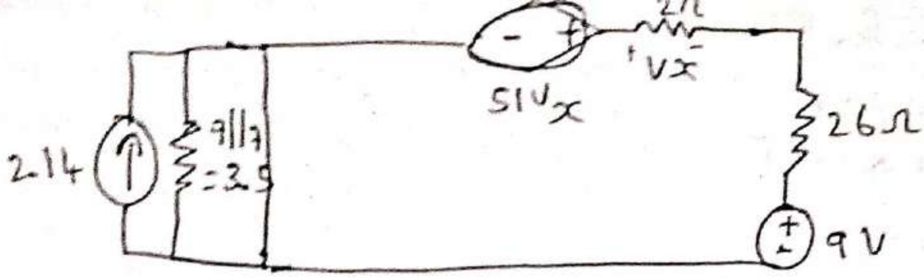


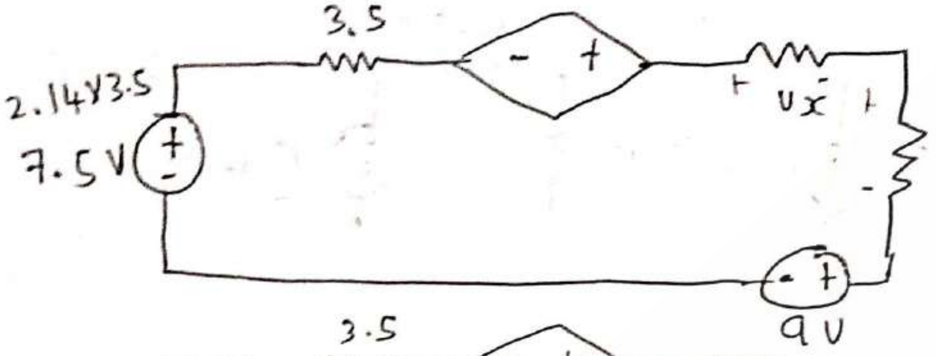
soln.

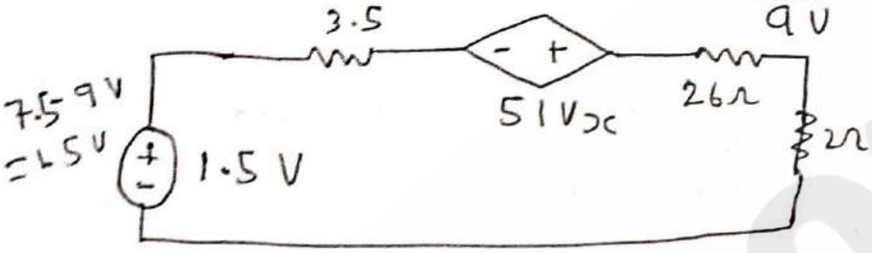


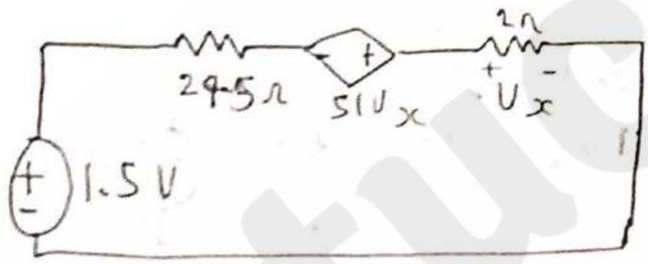












$V_x = I R$

$\boxed{V_x = 2I}$

$1.5 - 29.5I + 51V_x - V_x = 0$

$1.5 - 29.5I + 50V_x = 0$

$1.5 - 29.5I + 50(2I) = 0$

$1.5 - 29.5I + 100I = 0$

$I = \frac{1.5}{70.5}$

$\boxed{I = 21.27 \text{ mA}}$ //

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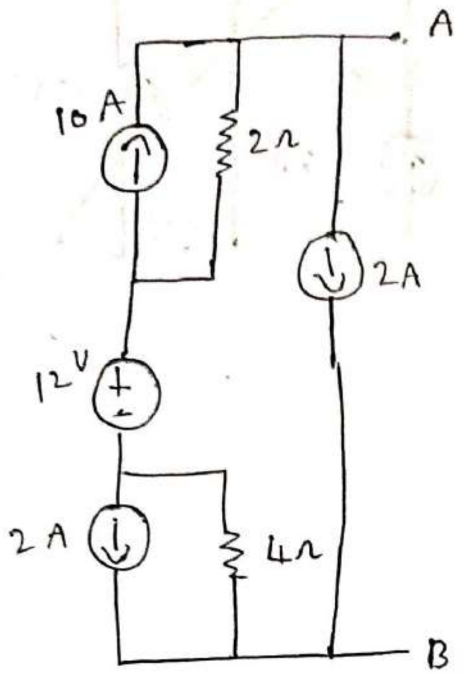
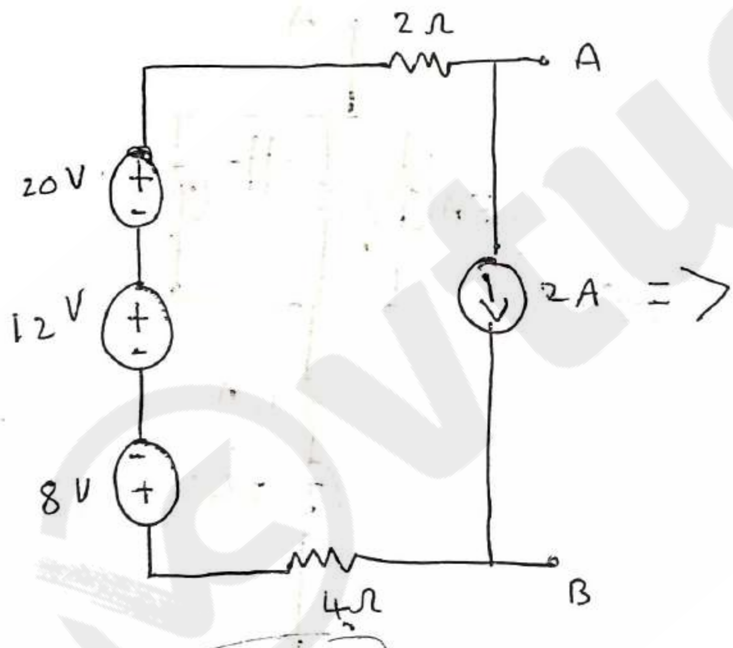
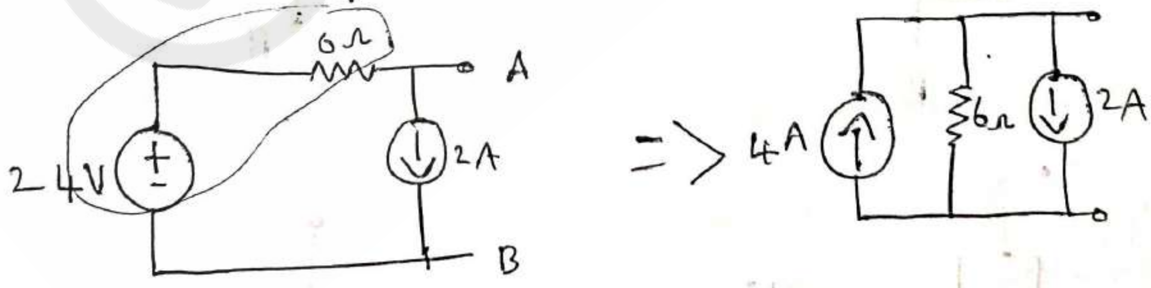
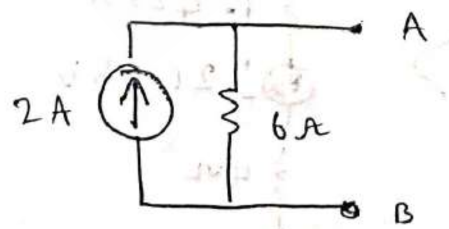
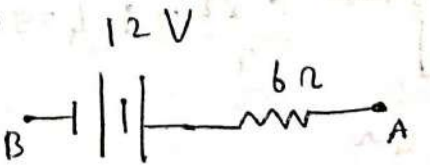
8) Reduce the Network shown in fig below into a voltage source between A B



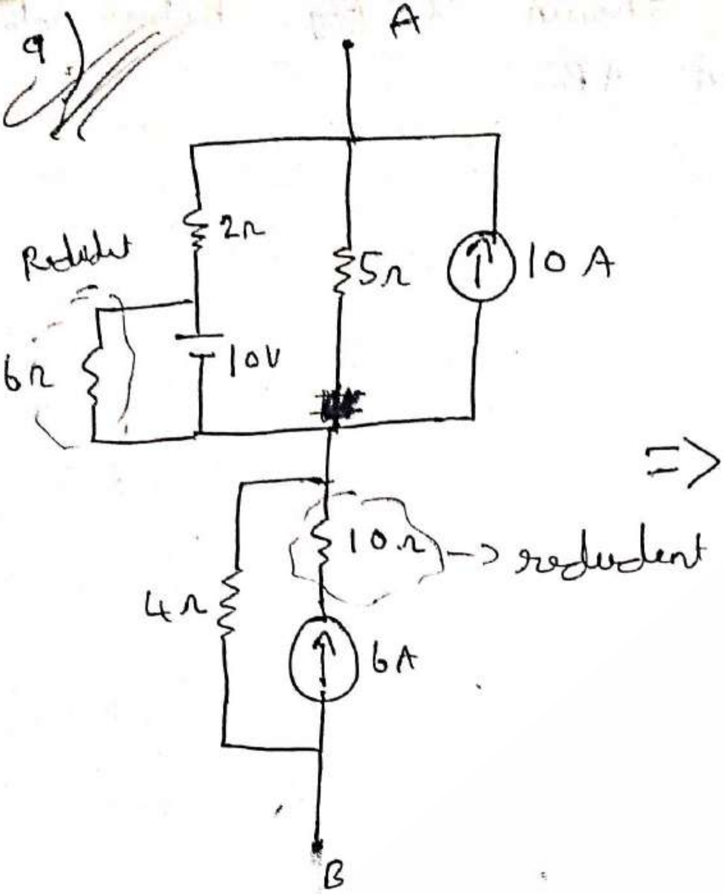






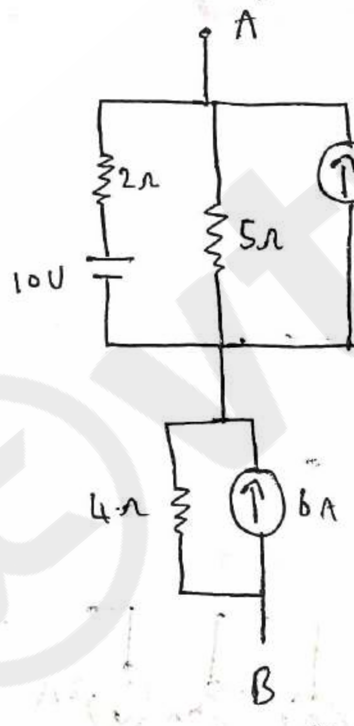


9)

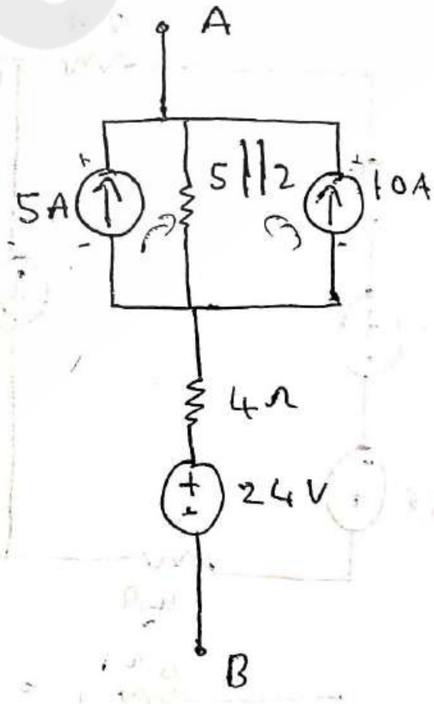


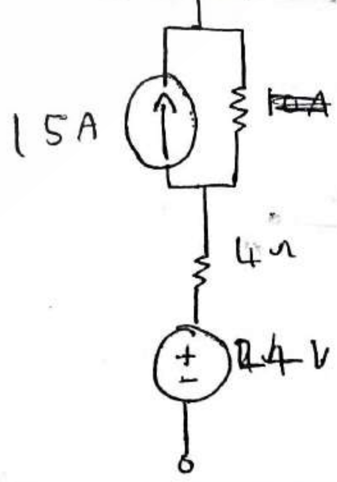
⇒

sol:



⇒

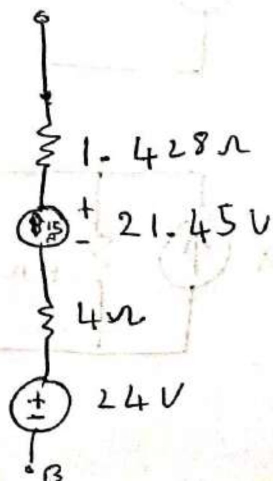


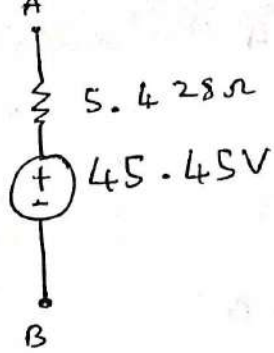


5||2

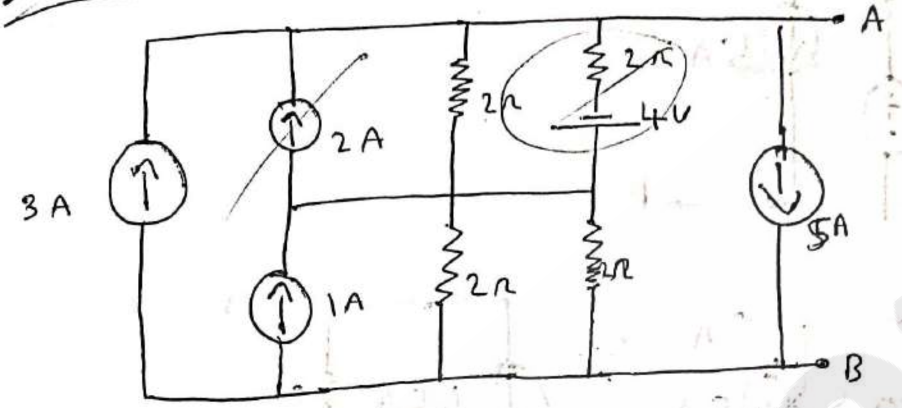
$$\frac{5\times 2}{7} = 1.428\Omega$$

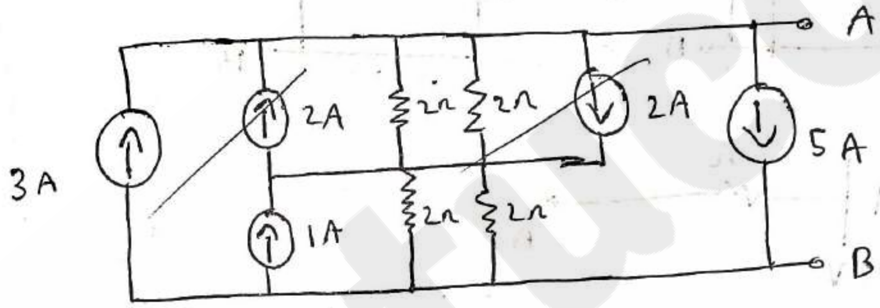
⇒

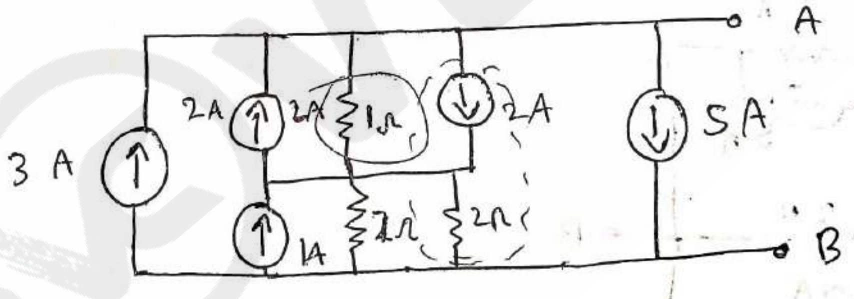


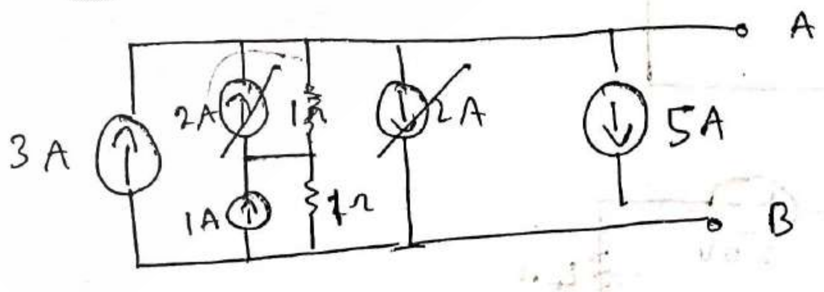

A
5.428Ω
45.45V
B

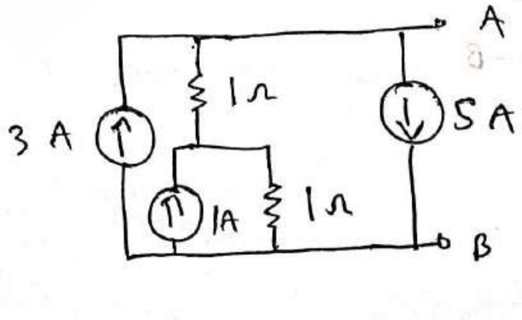
10)

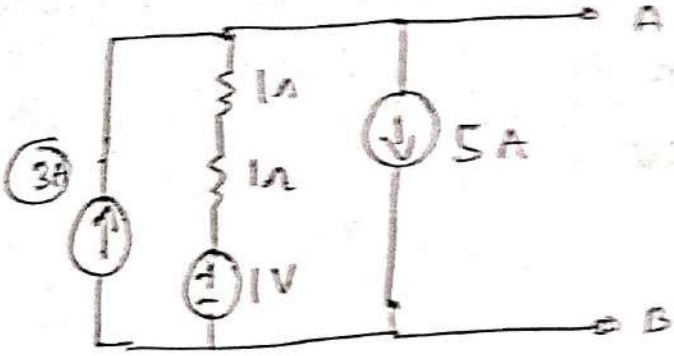

A
3A
2A
2Ω
2Ω
4V
5A
1A
2Ω
2Ω
B

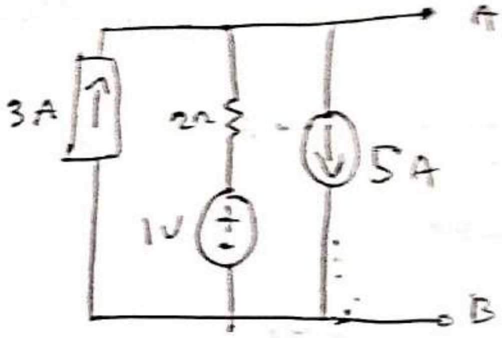

A
3A
2A
2Ω
2Ω
2A
5A
1A
2Ω
2Ω
B

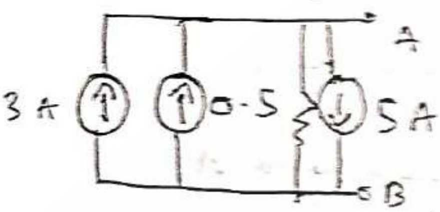

A
3A
2A
2A
1Ω
2A
5A
1A
1Ω
2Ω
B

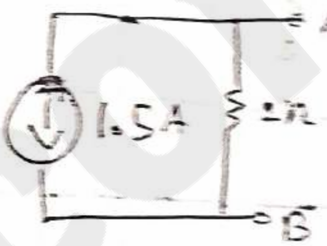

A
3A
2A
1Ω
2A
5A
1A
1Ω
B


A
3A
1Ω
5A
1A
1Ω
B


A
1Ω
1Ω
3A
5A
1V
B

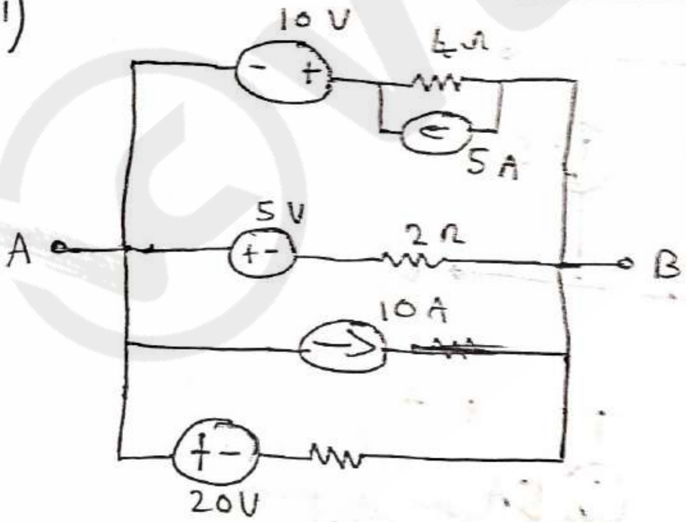

A
3A
2Ω
5A
1V
B


A
3A
0.5
5A
B

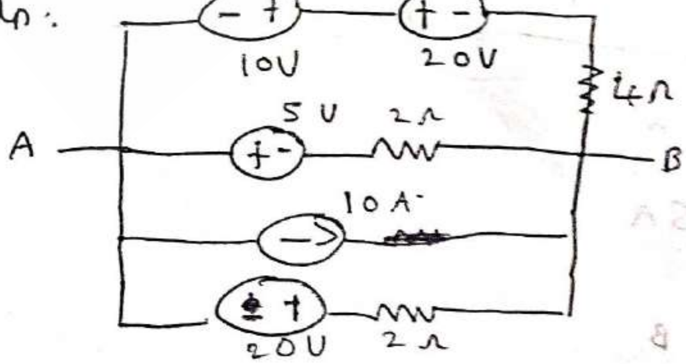

A
1.5A
2Ω
B


2Ω
A
B
3V

11)

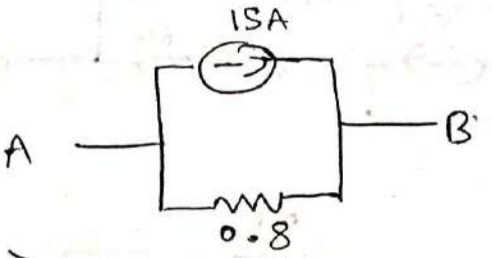

10V
4Ω
5A
5V
2Ω
A
B
10A
20V

soln:

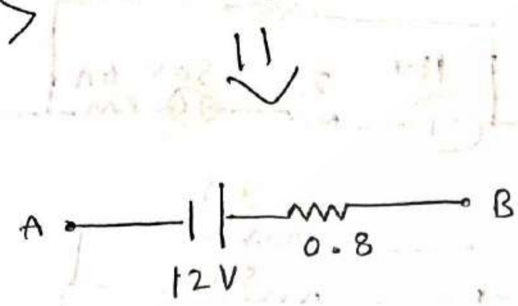

10V
20V
4Ω
5V
2Ω
A
B
10A
20V
2Ω

=>

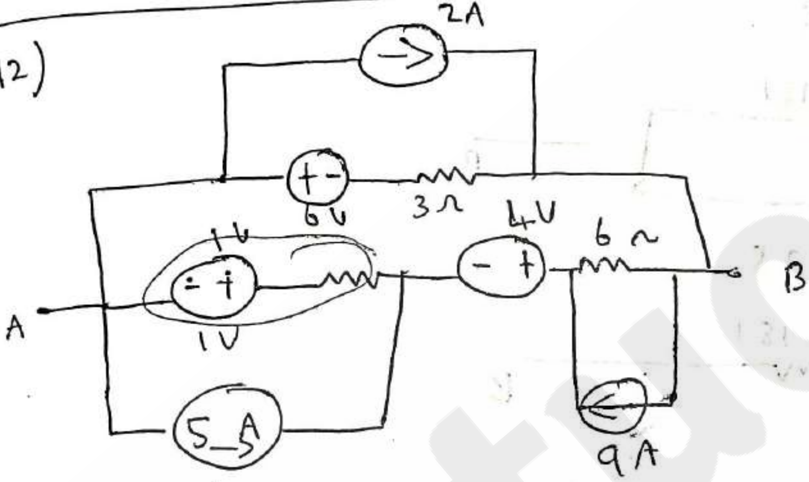

2.5
4
2.5
2Ω
10A
10A
2Ω

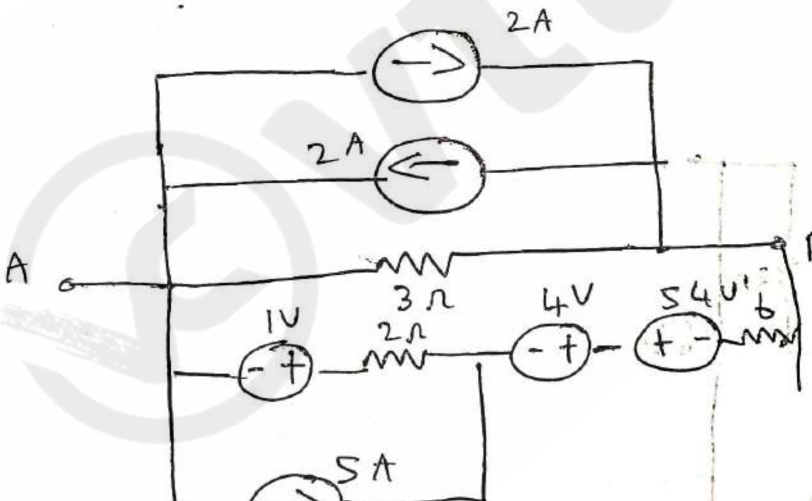

15A
A
B
0.8

=>

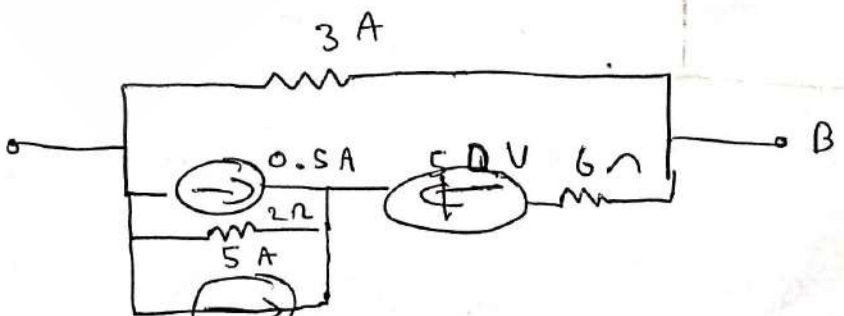

A
B
12V
0.8

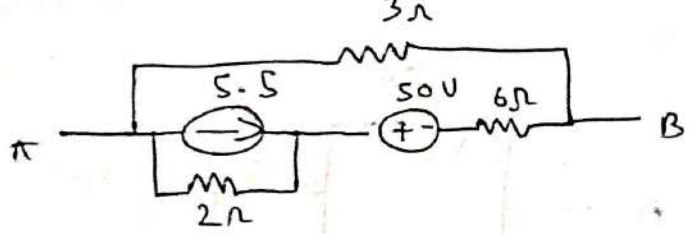
12)

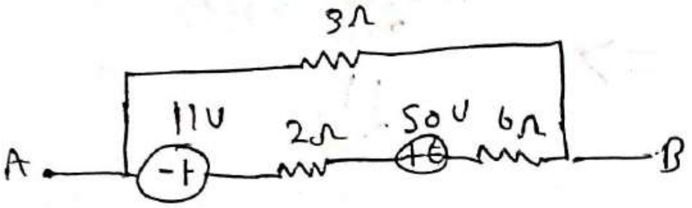

2A
6V
3Ω
4V
6Ω
1V
1V
A
B
5A
9A


2A
2A
A
B
3Ω
1V
2Ω
4V
54V
6
5A

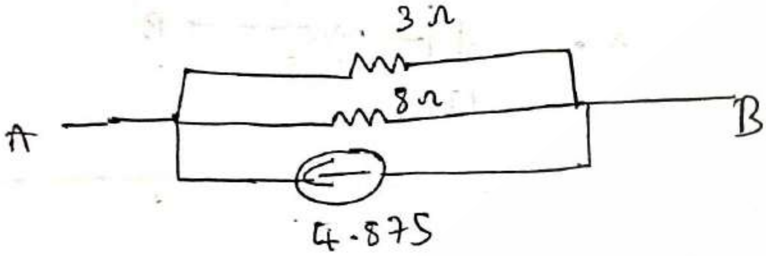
9 x 6

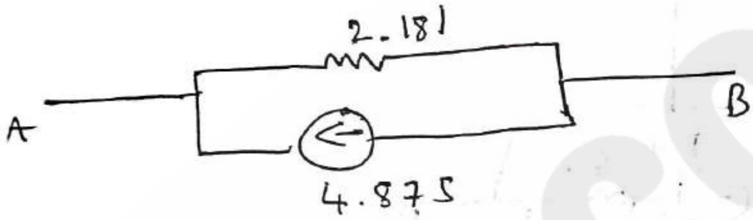

3A
B
0.5A
2Ω
50V
6Ω
5A

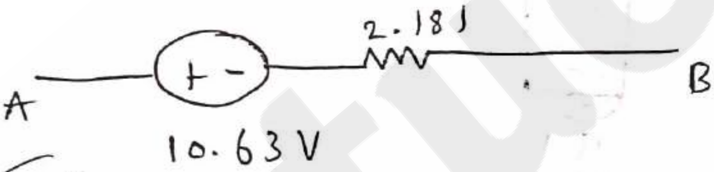

3Ω
5.5
50V
6Ω
A
B
2Ω


3Ω
11V
2Ω
50V
6Ω
A
B

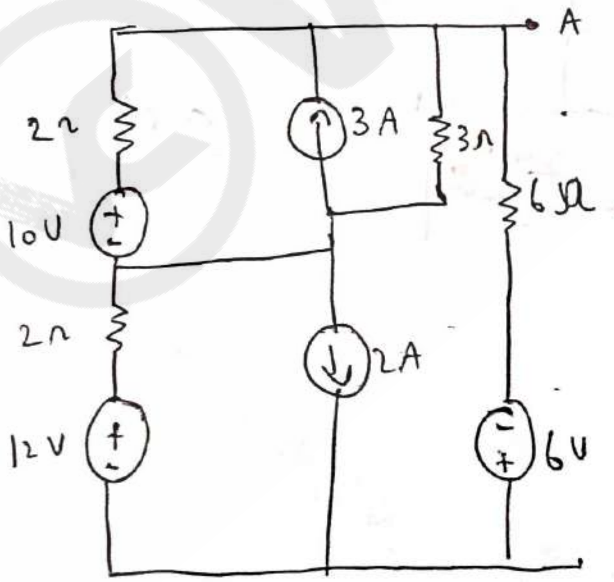
$50-11$
$= 39V$

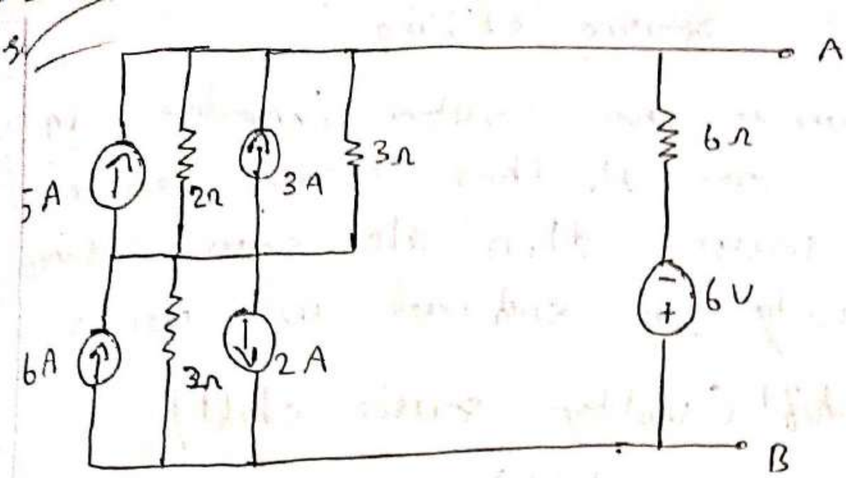

3Ω
8Ω
A
B
4.875


2.181
A
B
4.875

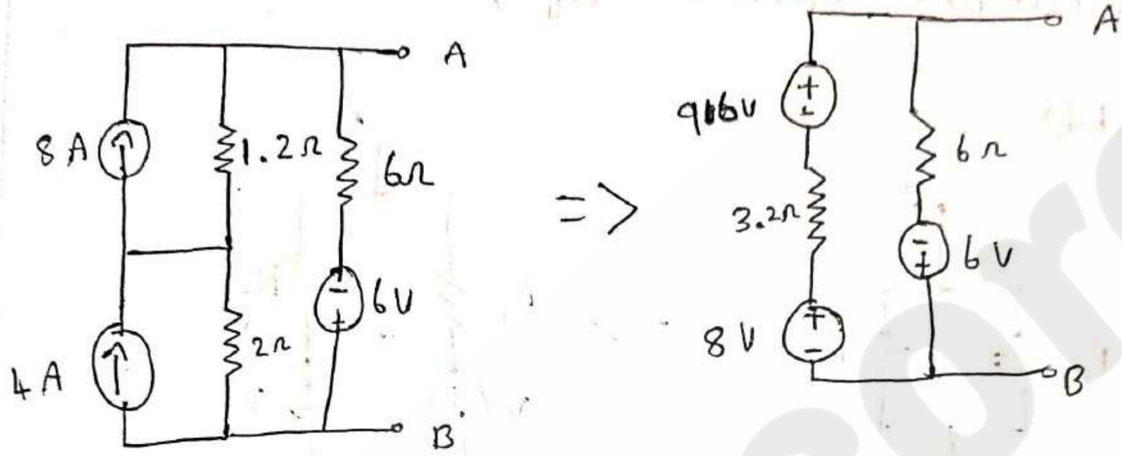

2.181
A
B
10.63V

13)

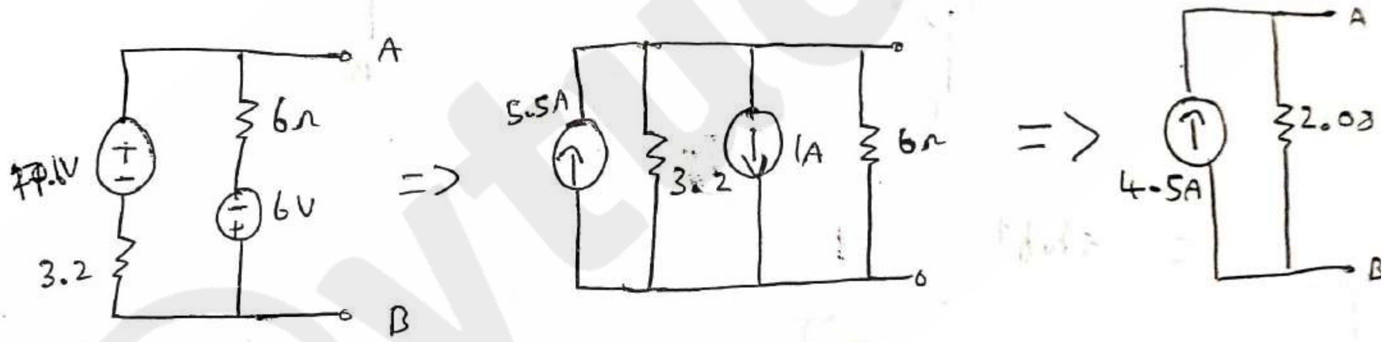

A
2Ω
10V
2Ω
12V
3A
3Ω
2A
6Ω
6V



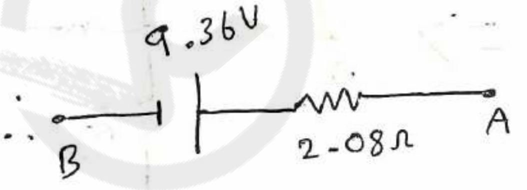
5A
2Ω
3A
3Ω
6Ω
6V
6A
3Ω
2A
A
B



8A
1.2Ω
6Ω
6V
4A
2Ω
A
B
=>
9.6V
3.2Ω
6Ω
6V
8V
A
B



6Ω
6V
3.2
A
B
=>
5.5A
3.2
1A
6Ω
=>
4.5A
2.08
A
B



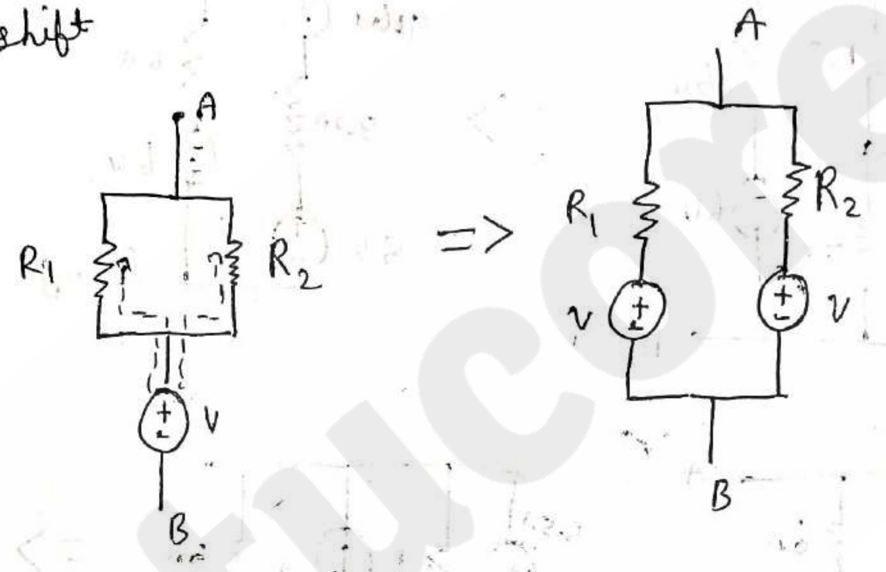
9.36V
2.08Ω
A
B

Source shifting:

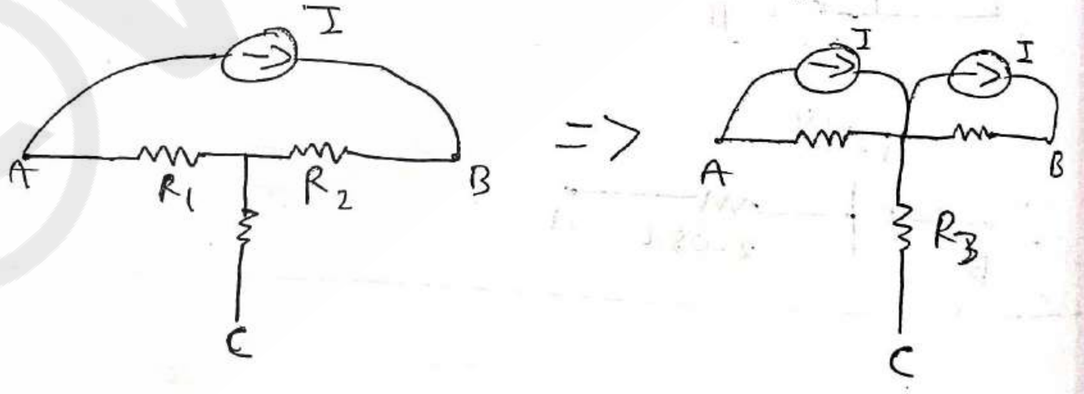
If in a network, there is no resistance / impedance in series with V source or if there is no resistan in parallel with I source then the source transf cannot be applied directly in such cases we use sou shifting V-shift / E-shift (voltage source shift)

I shift (current source shift)

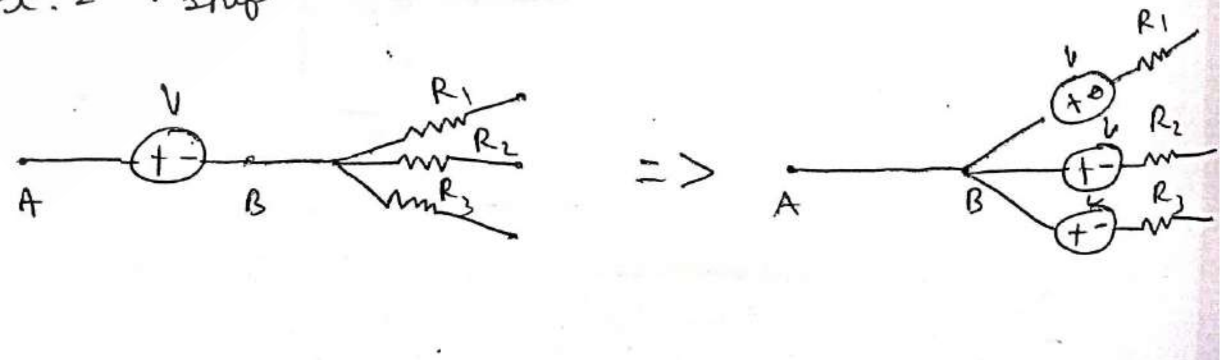
Ex: 1) V-shift



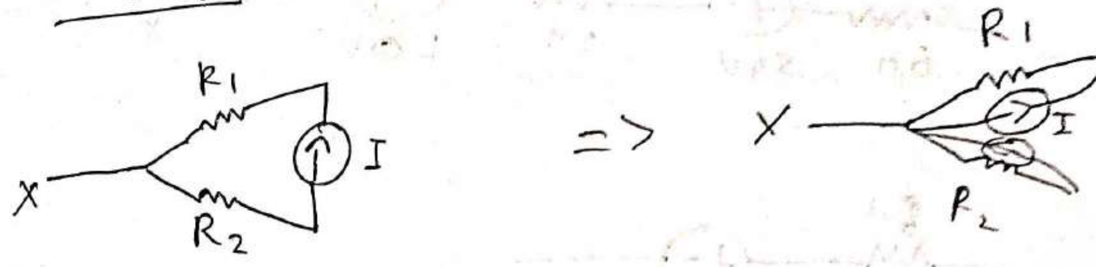
I - shift



Ex: 2 V shift

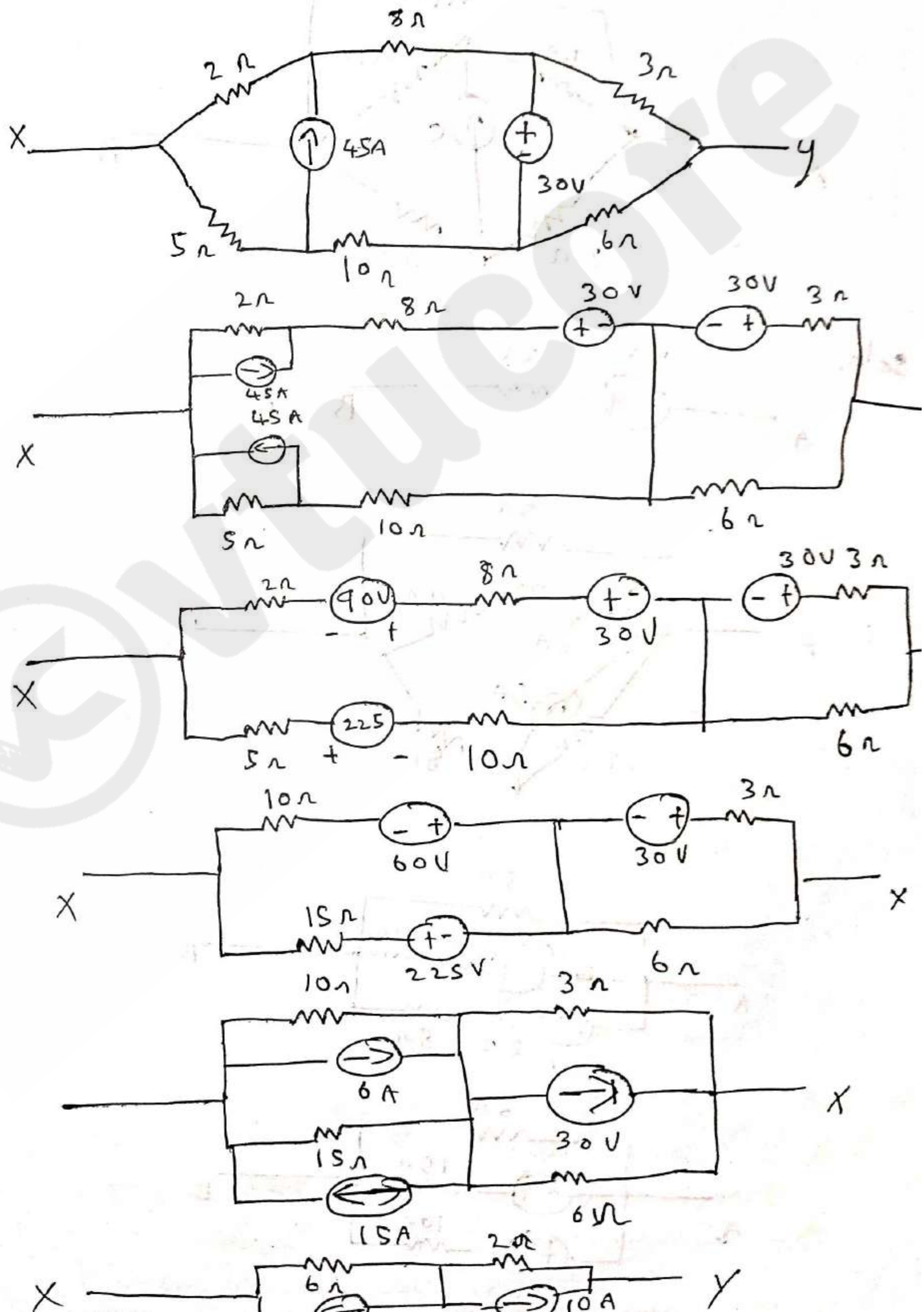


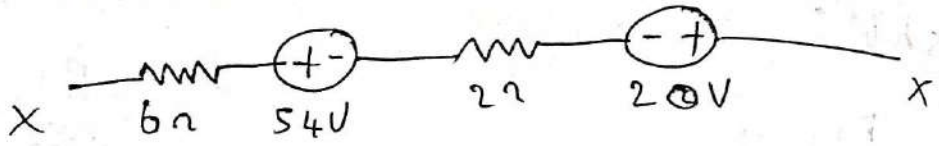
I shift:

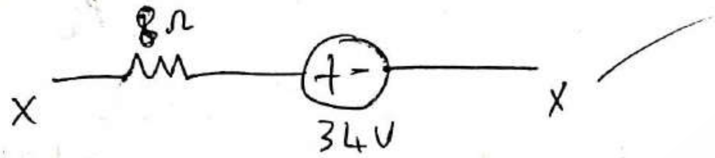


(1) using source transformation and source shifting reduce the network into a single source across x & y:

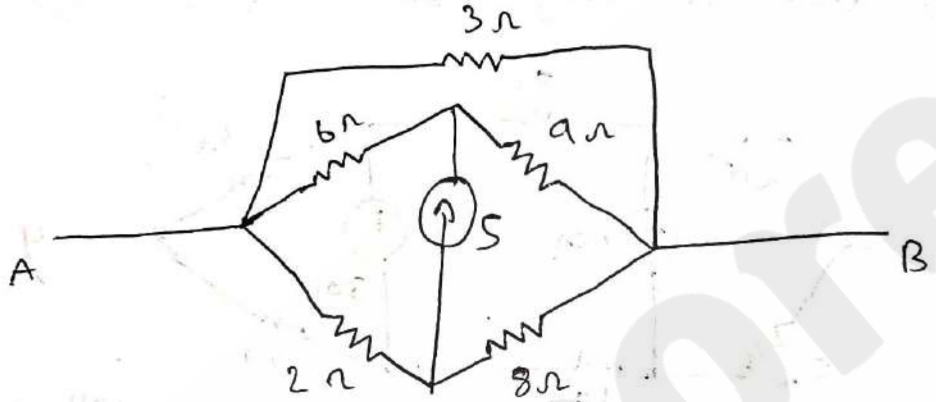
soln.



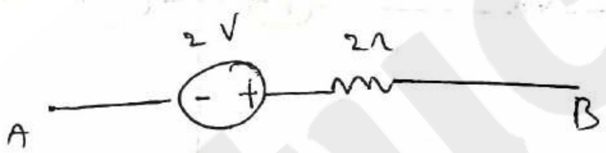

X
6Ω
54V
2Ω
20V
X

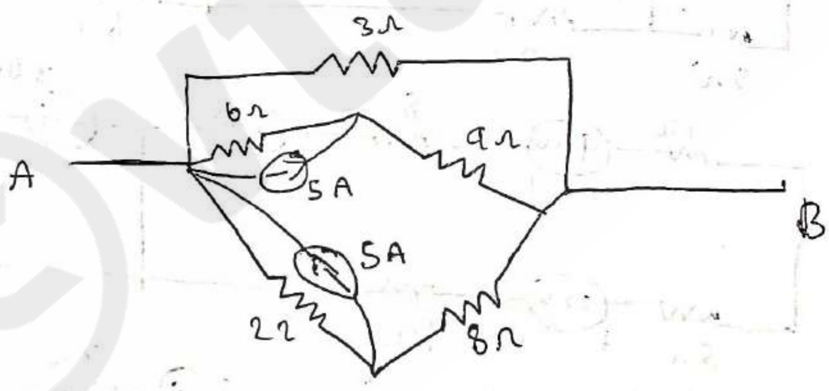

8Ω
X
34V
X

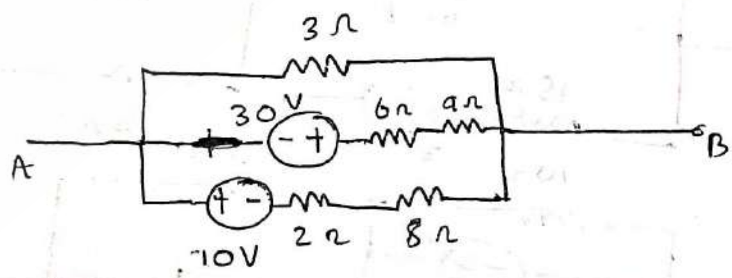
2)

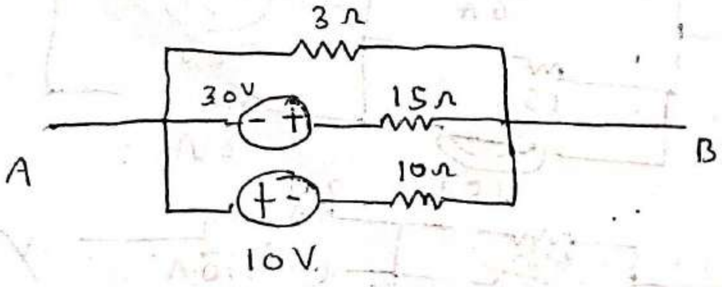

3Ω
6Ω
9Ω
5
A
B
2Ω
8Ω

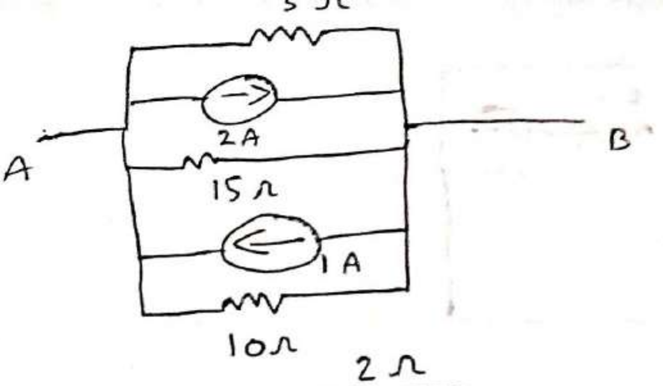
soln:

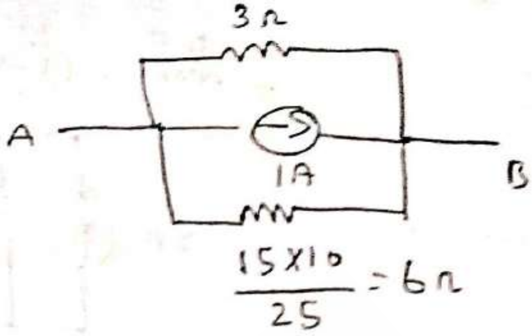

2V
2Ω
A
B

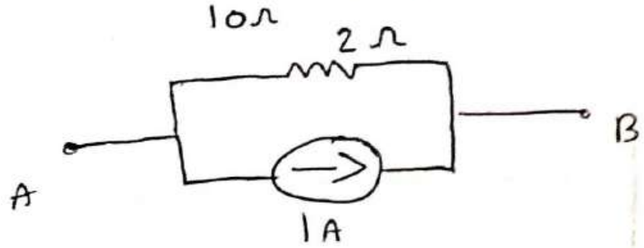

3Ω
6Ω
9Ω
A
5A
B
5A
2Ω
8Ω

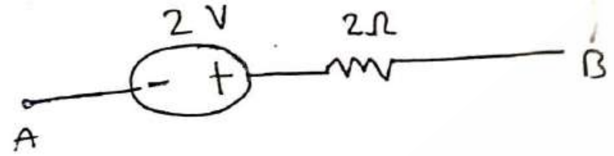

3Ω
30V
6Ω
9Ω
A
B
10V
2Ω
8Ω


3Ω
30V
15Ω
A
B
10Ω
10V

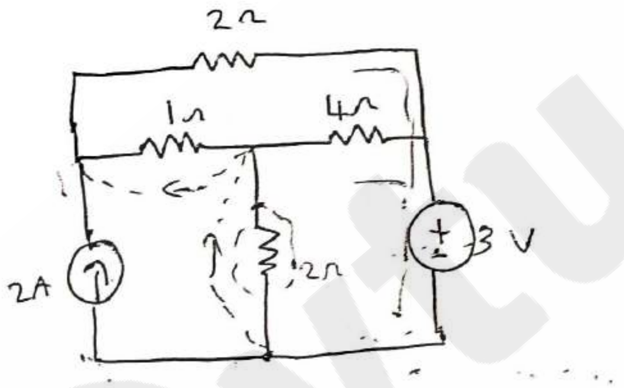






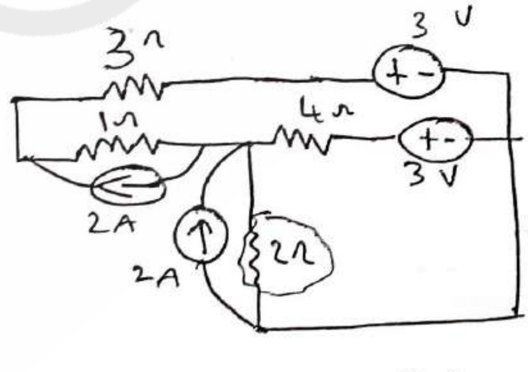


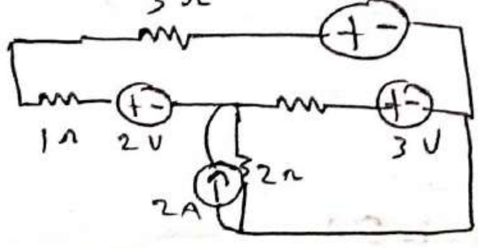
3)

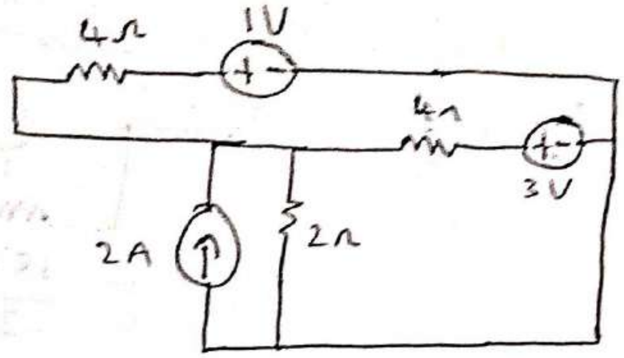


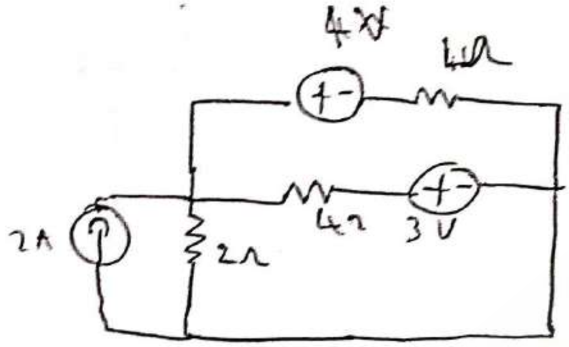
$V_{2\Omega} = I_{2\Omega} R$

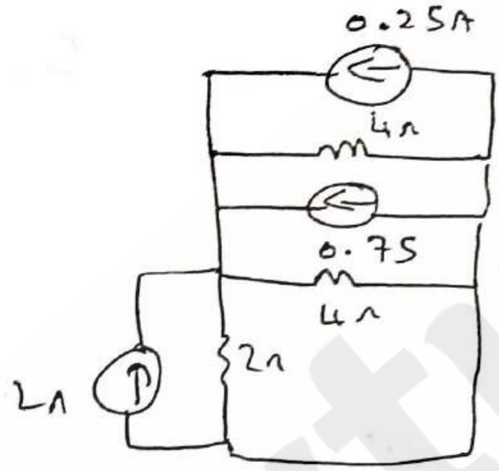
$I_{2\Omega} = ?$

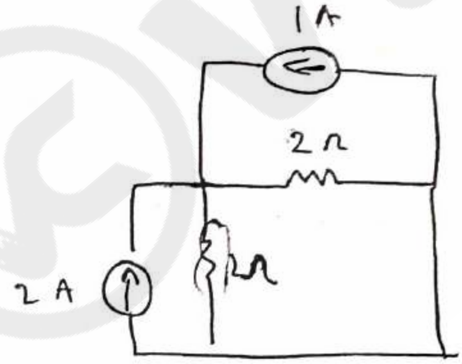


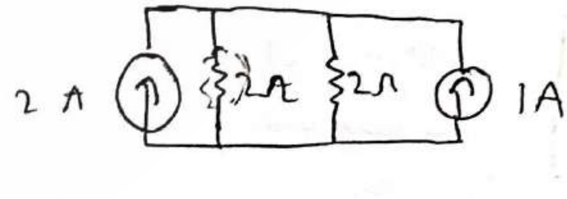


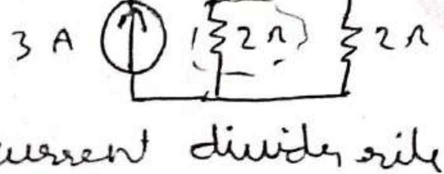












current divider rule

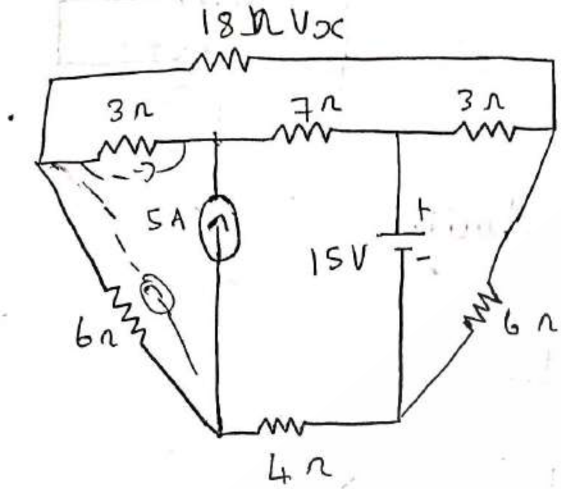
$$I_{2\Omega} = \frac{3 \times 2}{2+2} = \frac{6}{4} = 1.5\,A$$

$V_{2\Omega} = I_{2\Omega} \times R$

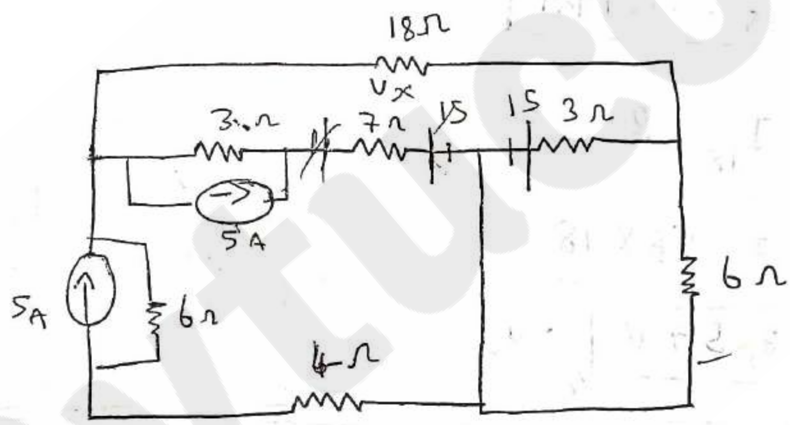
$V_{2\Omega} = 1.5 \times 2$

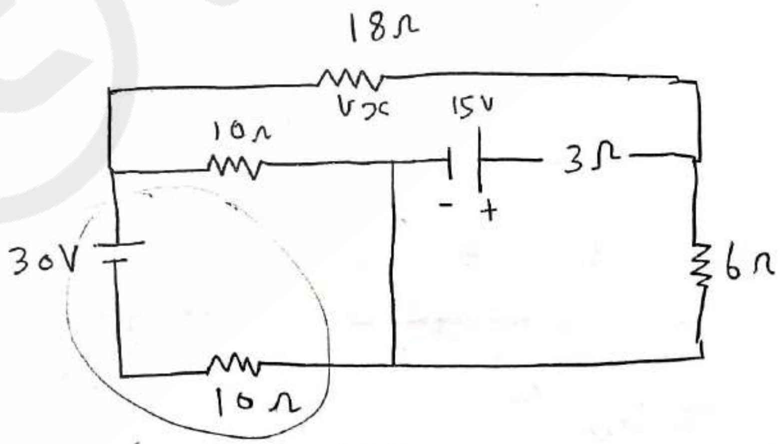
$\boxed{V_{2\Omega} = 3\,V}$

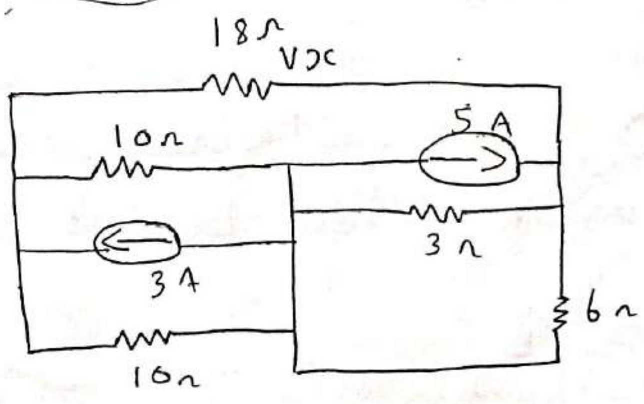
4) Find the voltage (V_x) using source transformation and source shifting.

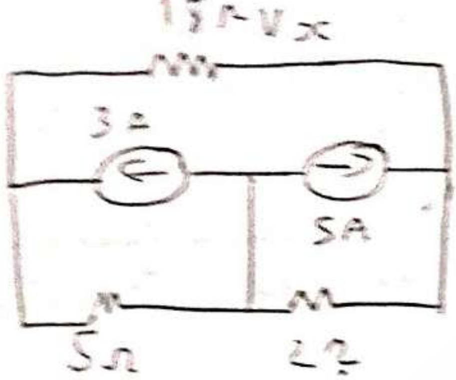


soln:

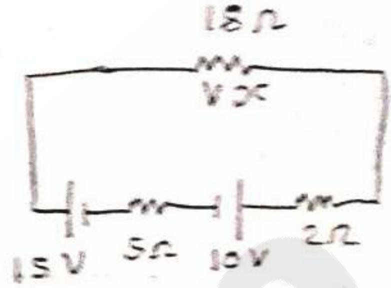


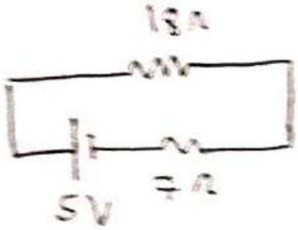




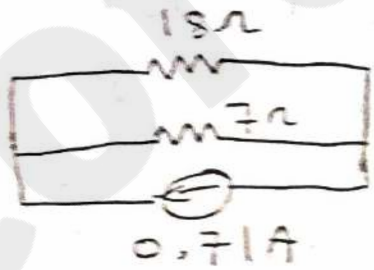


=>





=>



applying current divider

$$I_{18} = \frac{0.71 \times 7}{18 + 7}$$

$$\boxed{I_{18} = 0.198A}$$

$$\therefore V_{18} = I_{18} \times R$$

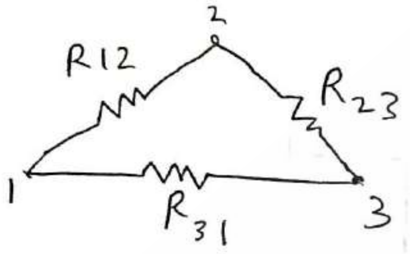
$$V_{18} = 0.198 \times 18$$

$$\boxed{V_{18} = 3.57V} = v_x$$

→ Star to delta and delta to star

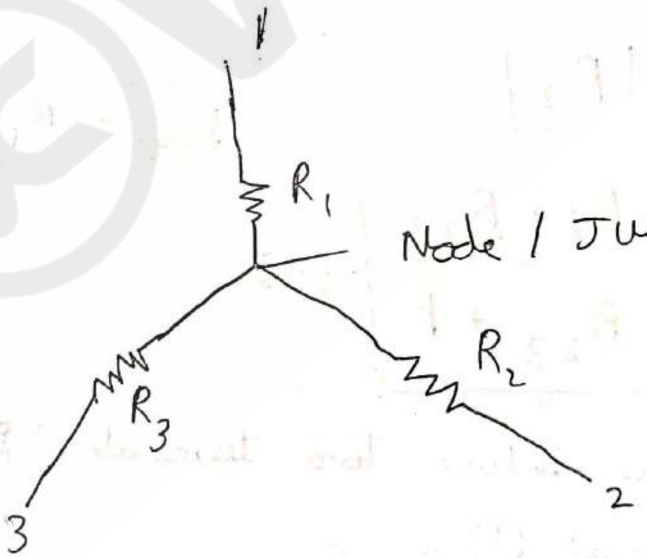
Delta Network:-

Three Resistances or impedences are said to be connect in Delta when they form a closed loop.



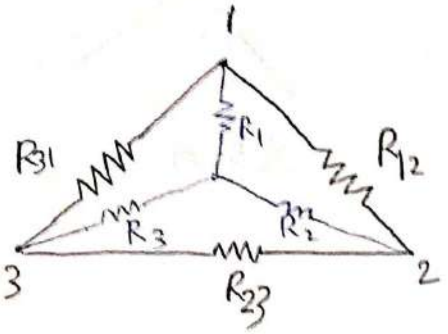
Star Network:

Three Resistor or impedence are said to be connecte in star when they form node or junctio

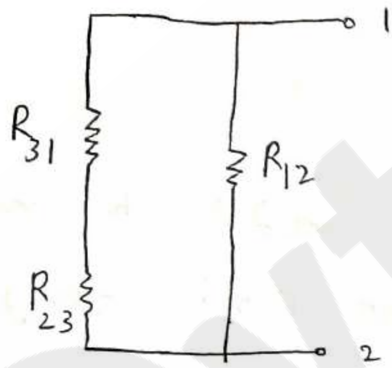


Star and delta connections play a major role in network analysis to find voltage across or current through the given element.

→ Derivation (Delta to star Transformation



consider the following network the equivalent resistance between two terminal 1, 2 in the absence of terminal 3 is given by.

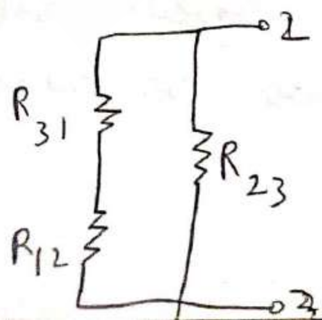


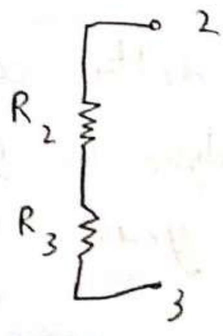
$$\boxed{R_{eq} = (R_{31} + R_{23}) \parallel R_{12}}$$

$$\boxed{R_{eq} = R_1 + R_2} \quad \cdots (2)$$

$$\boxed{R_{eq} = \frac{R_{12}R_{31} + R_{12}R_{23}}{R_{12} + R_{23} + R_{31}}} \quad \cdots (1)$$

The equivalent resistance between two terminals 2 & 3 in the absence of the terminal (1)



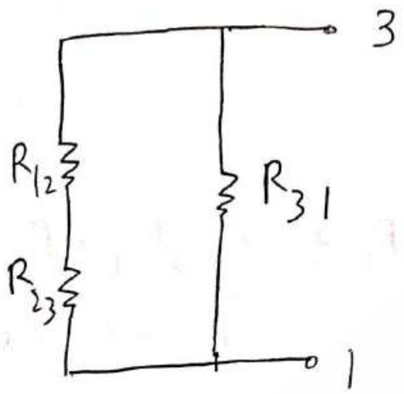


$$R_{eq} = (R_{31} + R_{12}) \,|\, R_{23}$$

$$\boxed{R_{eq} = R_2 + R_3}$$ ... ④

$$\boxed{R_{eq} = \frac{R_{23} R_{31} + R_{23} R_{12}}{R_{23} + R_{12} + R_{31}}}$$ ... ③

The equivalent resistance between two terminals 1 & 3 in the absence of the terminal 2



$$R_{eq} = (R_{12} + R_{23}) \,|\, R_{31}$$

$$\boxed{R_{eq} = R_1 + R_3}$$ ... ⑥

$$\boxed{R_{eq} = \frac{R_{12} R_{31} + R_{31} R_{23}}{R_{12} + R_{23} + R_{31}}}$$ ... ⑤

equating eq ① & ②, ③ & ④, 5 & ⑥

$$\frac{R_{12} R_{31} + R_{12} R_{23}}{R_{12} + R_{23} + R_{31}} = R_1 + R_2 \quad \text{... ⑦}$$

$$\frac{R_{23} R_{31} + R_{23} R_{12}}{R_{23} + R_{12} + R_{31}} = R_2 + R_3 \quad \text{... ⑧}$$

$$\frac{R_{12} R_{31} + R_{31} R_{23}}{R \quad + R \quad + R} = R_1 + R_3 \quad \text{... ⑨}$$

adding eq ⑦ & ⑦

$$\frac{R_{12}R_{31}+R_{12}R_{23}}{R_{12}+R_{23}+R_{31}}+\frac{R_{31}R_{12}+R_{31}R_{23}}{R_{12}+R_{23}+R_{1}}=R_1+R_2+R_{1}+R_3$$

$$\frac{2(R_{12}R_{31})+R_{12}R_{23}+R_{31}R_{23}}{R_{12}+R_{23}+R_{31}}=2R_1+R_2+R_3$$

subs eq ⑧ in above equation

$$\frac{2(R_{12}R_{31})+\cancel{R_{12}}R_{23}+\cancel{R_{31}}R_{23}}{R_{12}+R_{23}+R_{31}}=\cancel{2}R_1+\frac{\cancel{R_{23}}R_{31}+\cancel{R_{23}}R_{12}}{R_{12}+R_{23}+R_{31}}$$

$$\frac{\cancel{2}R_{12}R_{31}+R_{12}\cancel{R_{23}}+R_{31}\cancel{R_{23}}-\cancel{R_{23}}R_{31}-\cancel{R_{23}}R_{12}}{R_{12}+R_{23}+R_{31}}=\cancel{2}R_1$$

$$\boxed{\frac{R_{12}R_{31}}{R_{12}+R_{23}+R_{31}}=R_1} \quad \ldots (10)$$

$$\boxed{R_2=\frac{R_{12}R_{23}}{R_{12}+R_{23}+R_{31}}} \quad \ldots (11)$$

$$\boxed{R_3=\frac{R_{31}R_{23}}{R_{12}+R_{23}+R_{31}}} \quad \ldots (12)$$

Star to delta transformation:

multiply eq 10 & 11, 11 & 12, 12 & 10

$$\frac{R_{12} R_{31}}{R_{12}+R_{23}+R_{31}} \times \frac{R_{12} R_{23}}{R_{12}+R_{23}+R_{31}} = R_1 \times R_2$$

$$\frac{R_{12} R_{23}}{R_{12}+R_{23}+R_{31}} \times \frac{R_{31} R_{23}}{R_{12}+R_{23}+R_{31}} = R_2 \times R_3$$

$$\frac{R_{31} R_{23}}{R_{12}+R_{23}+R_{23}} \times \frac{R_{12} R_{31}}{R_{12}+R_{23}+R_{31}} = R_3 \times R_1$$

$$R_1 \times R_2 = \frac{R_{12}^2 R_{31} R_{23}}{(R_{12}+R_{23}+R_{31})^2} \quad \ldots (13)$$

$$R_2 \times R_3 = \frac{R_{23}^2 R_{12} R_{31}}{(R_{12}+R_{23}+R_{31})^2} \quad \ldots (14)$$

$$R_3 \times R_1 = \frac{R_{31}^2 R_{23} R_{12}}{(R_{12}+R_{23}+R_{31})^2} \quad \ldots (15)$$

adding eq (13) & (14) & (15)

$$R_1 R_2 + R_2 R_3 + R_2 R_1 = \frac{R_{12}^2 R_{31} R_{23} + R_{23}^2 R_{12} R_{31} + R_{31}^2 R_{23} R_{12}}{(R_{12}+R_{23}+R_{31})^2}$$

$$R_1R_2 + R_2R_3 + R_3R_1 = \frac{R_{12}R_{23}R_{31}\cancel{(R_{12}+R_{23}+R_{31})}}{(R_{12}+R_{23}+R_{31})^{\cancel{2}}}$$

$$R_1R_2 + R_2R_3 + R_3R_1 = R_{12}\,\frac{R_{23}R_{31}}{R_{12}+R_{23}+R_{31}}$$

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

$$\boxed{R_{12} = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3}} \quad \ldots (16)$$

$$\boxed{R_{23} = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1}} \quad \ldots (17)$$

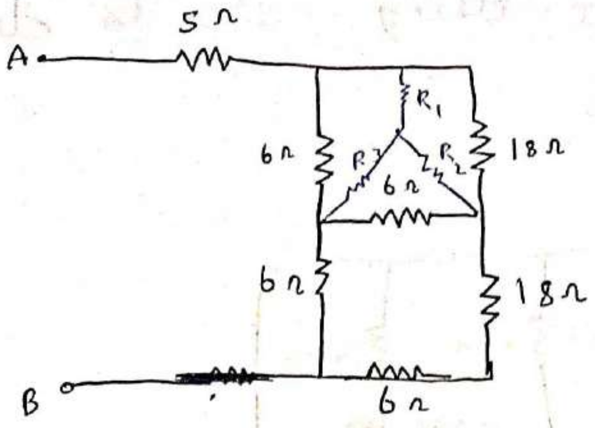
$$\boxed{R_{31} = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2}} \quad \ldots (18)$$

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

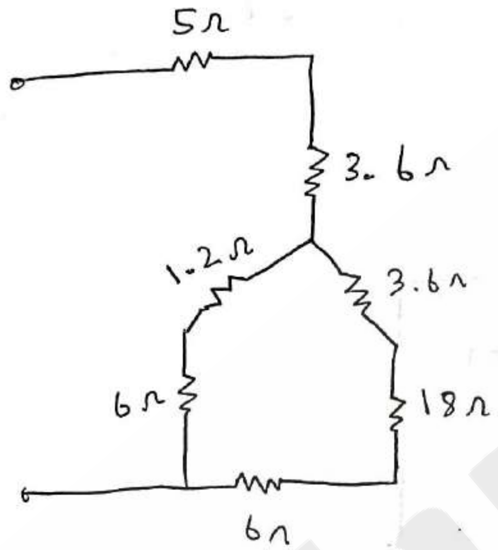
$$R_{23} = R_2 + R_3 + \frac{R_2R_3}{R_1}$$

$$R_{31} = R_3 + R_1 + \frac{R_3R_1}{R_2}$$

1)



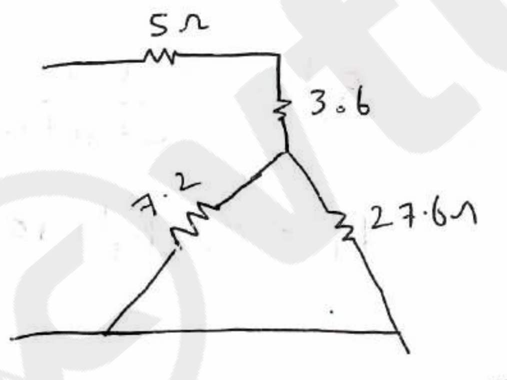
Find the equivalent RAB using star to Delta transform



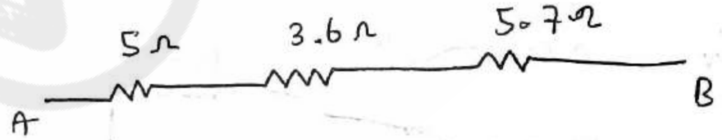
$$R_1 = \frac{6 \times 18}{6+18+6} = 3.6\Omega$$

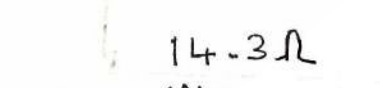
$$R_2 = \frac{6 \times 18}{6+18+6} = 3.6\Omega$$

$$R_3 = \frac{6 \times 6}{6+6+18} = 1.2\Omega$$



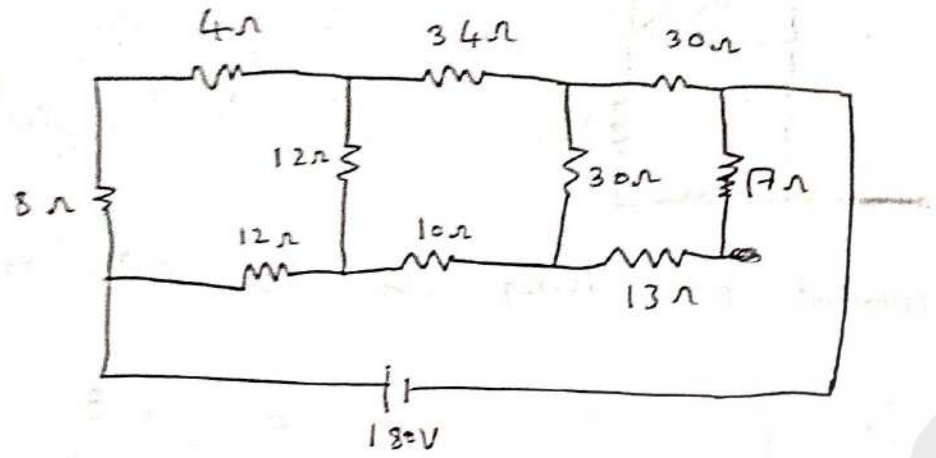
$7.2 \parallel 27.6$

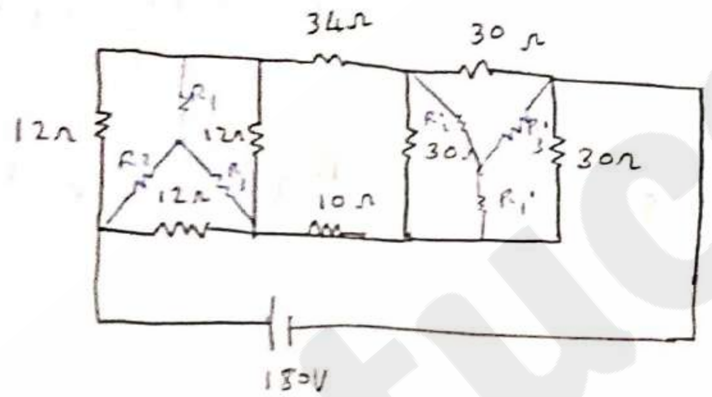




$$\boxed{\therefore RAB = 14.31\Omega}$$

2) Find the current I using star to delta transformation



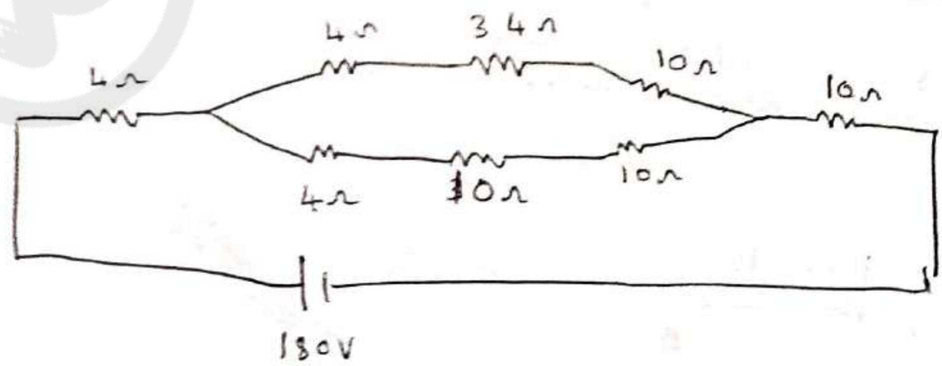


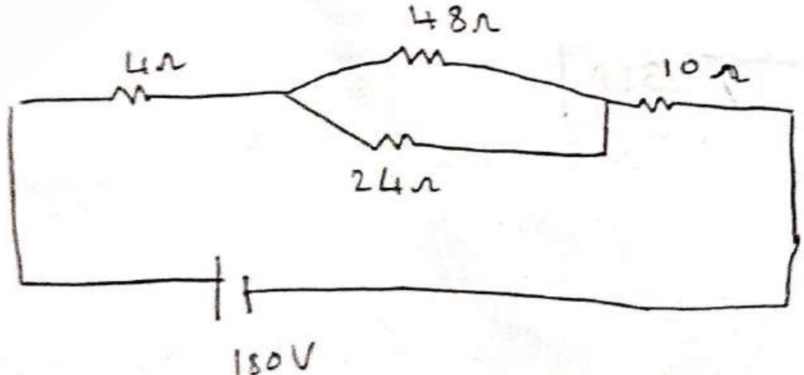
$R_1 = \frac{12 \times 12}{12+12+12} = 4\Omega$

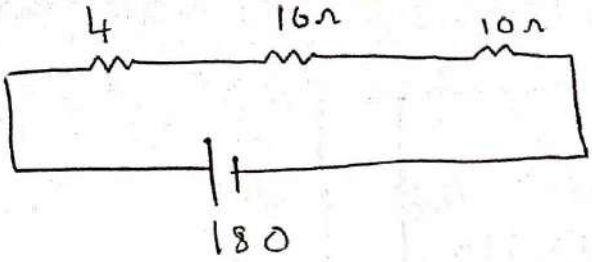
$R_1' = \frac{30 \times 30}{30+30+30}$

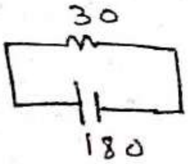
$R_1 = R_2 = R_3 = 4\Omega$

$R_1' = R_2' = R_3' = 10\Omega$





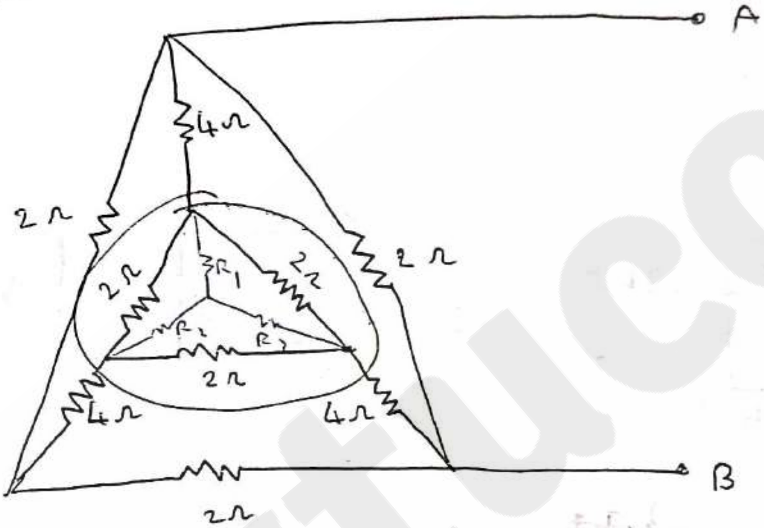




$$I = \frac{V}{R} = \frac{\cancel{180}^{\,6}}{\cancel{30}_{\,1}}$$

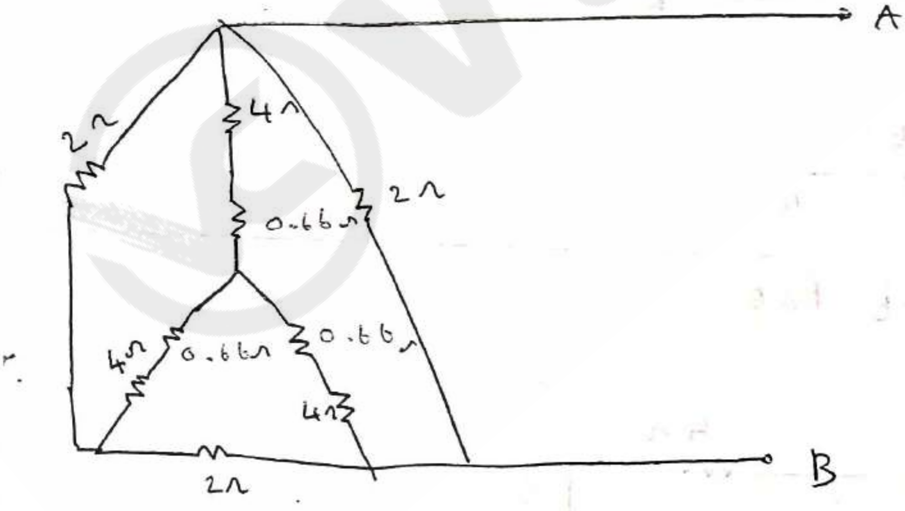
$$\boxed{I = 6A}$$

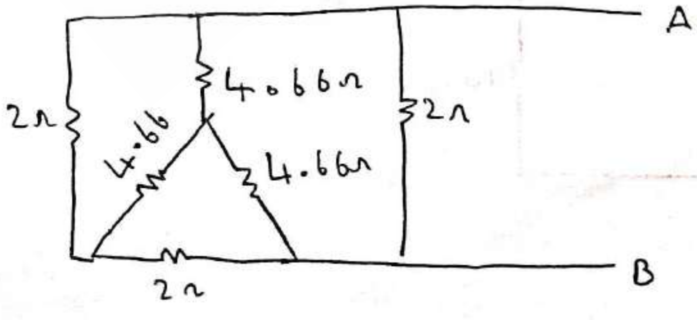
3) Find R_{AB}

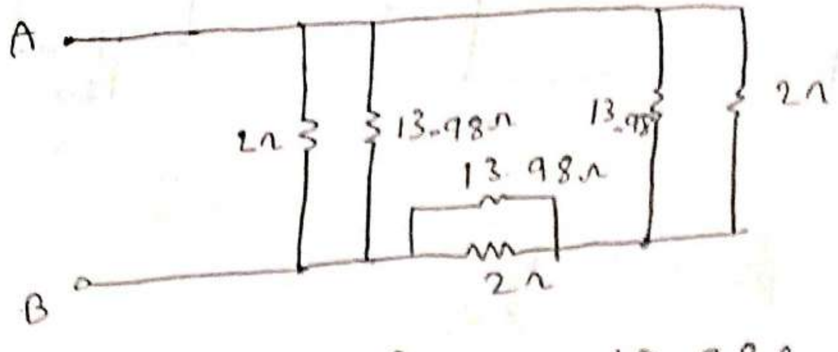


$R_1 = R_2 = R_3$

$R_1 = \frac{2 \times 2}{2+2+2}$



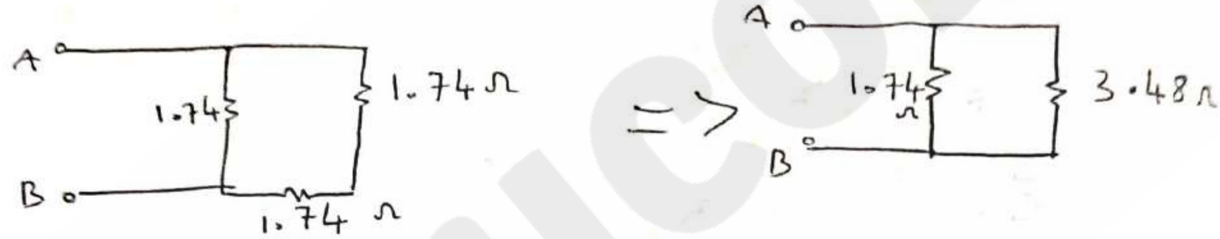




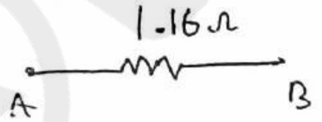
$$R_{12} = R_1 + R_2 + \frac{R_1 R_2}{R_3} = 13.98\,\Omega$$

$$R_{23} = 13.98\,\Omega$$

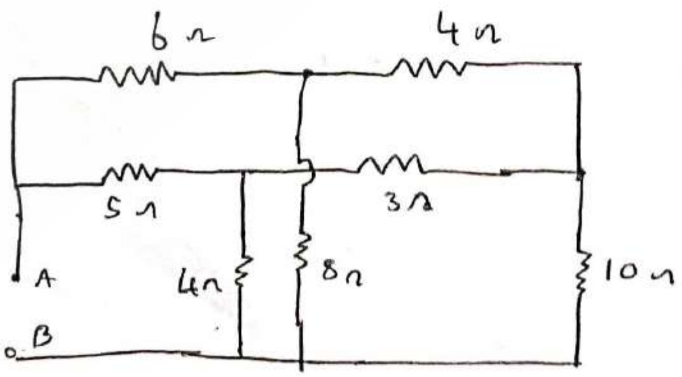
$$R_{31} = 13.98\,\Omega$$

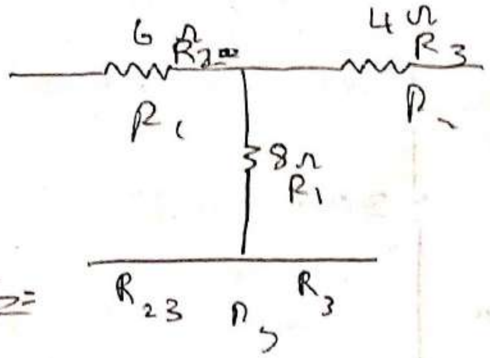


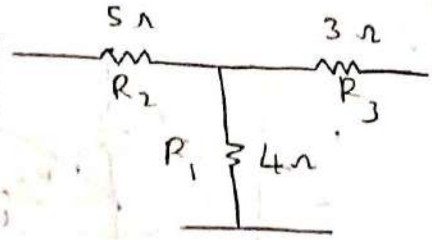
$\therefore$

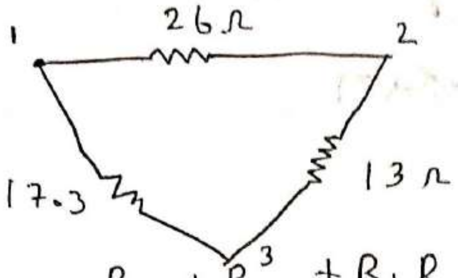


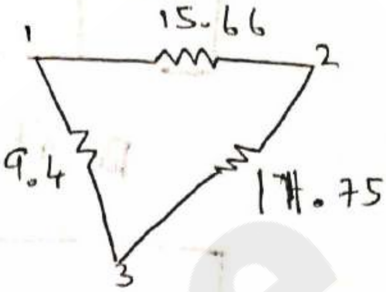
4) Find the value of R_{AB}











$$R_{12} = R_1 + R_2 + \frac{R_1 R_2}{R_3} = 26\Omega$$

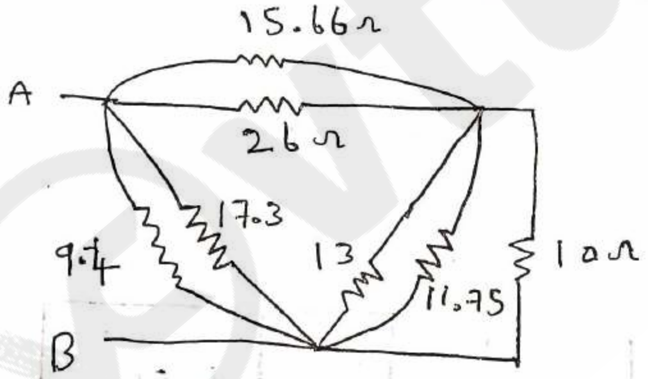
$$R_{23} = R_2 + R_3 + \frac{R_2 R_3}{R_1} = 13\Omega$$

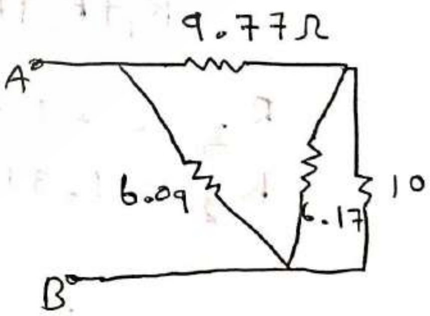
$$R_{31} = R_3 + R_1 + \frac{R_3 R_1}{R_2} = 17.3\Omega$$

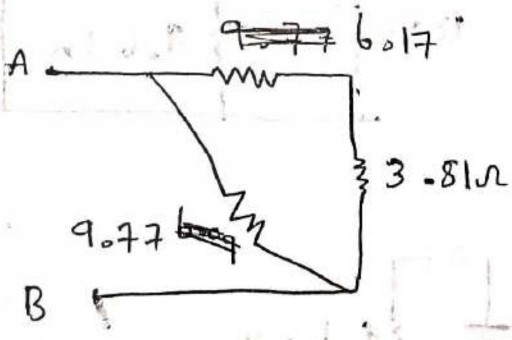
$$R_{12} = R_1 + R_2 + \frac{R_1 R_2}{R_3} = 15.66$$

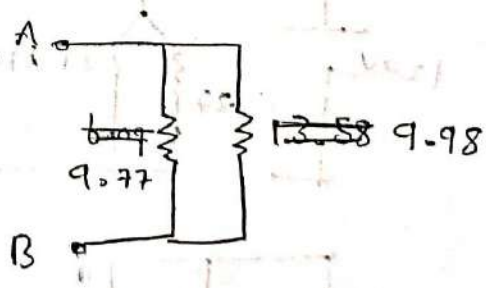
$$R_{23} = R_2 + R_3 + \frac{R_2 R_3}{R_1} = 11.75$$

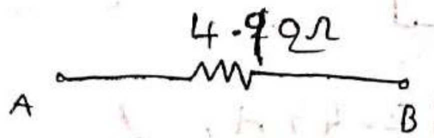
$$R_{31} = R_3 + R_1 + \frac{R_3 R_1}{R_2} = 9.4$$



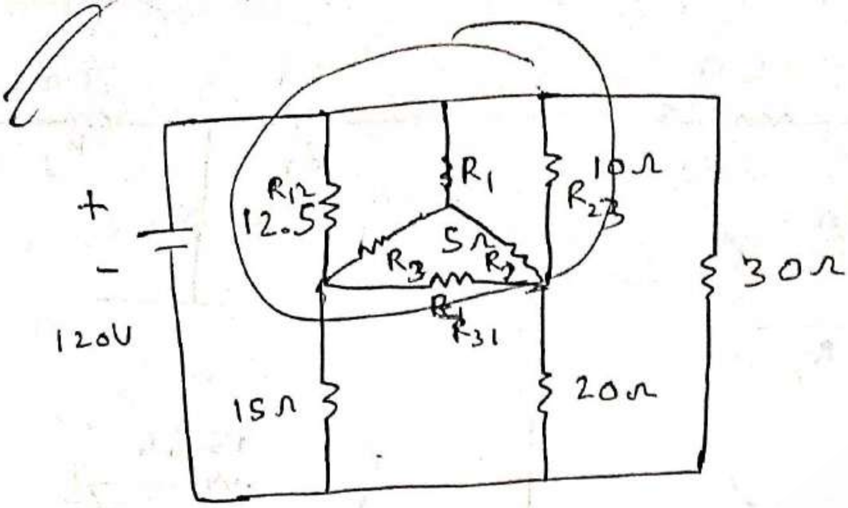








5)



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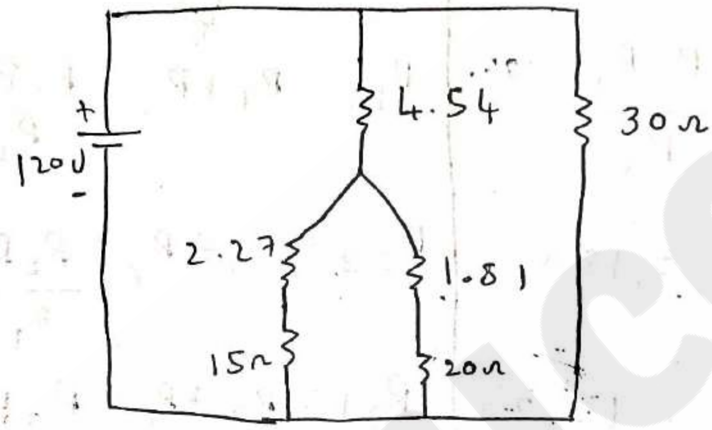
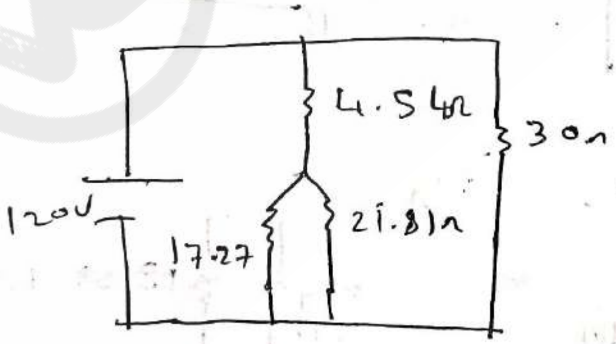
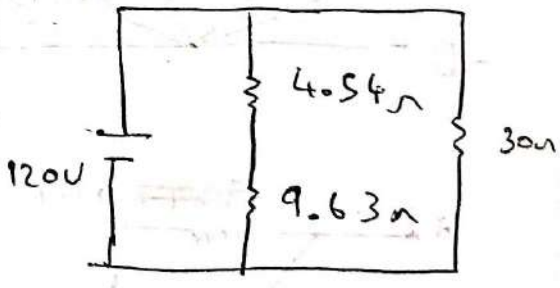


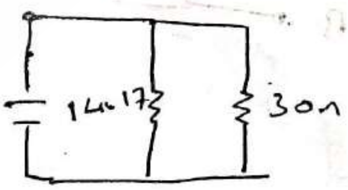
$$R_1 = \frac{R_{12}\ R_{23}}{R_1 + R_2 + R_3} = 4.54$$

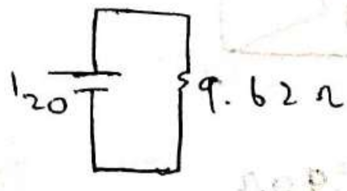
$R_3 = 2.27\ \Omega$

$R_2 = 1.81\ \Omega$



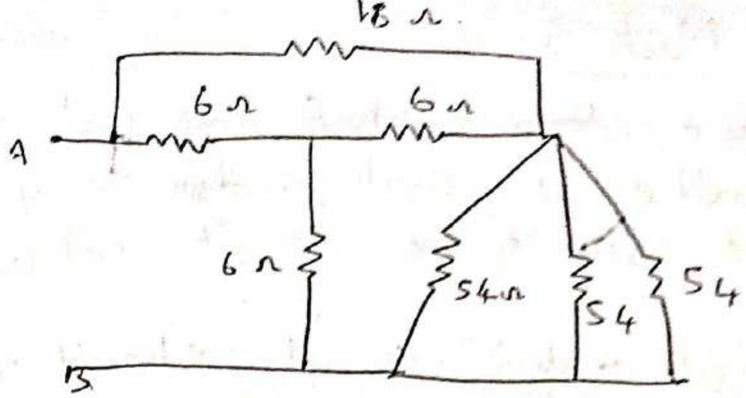


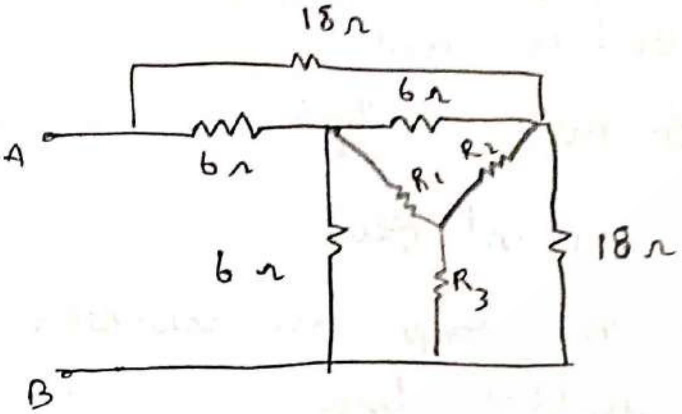


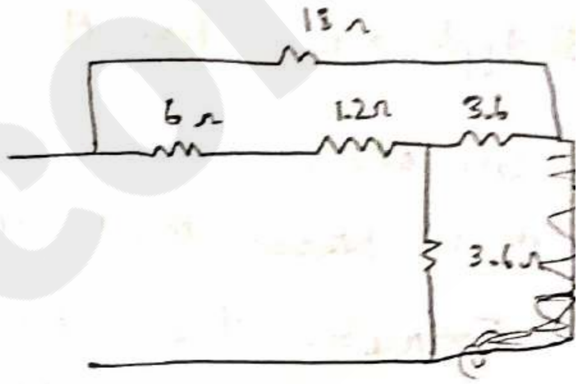


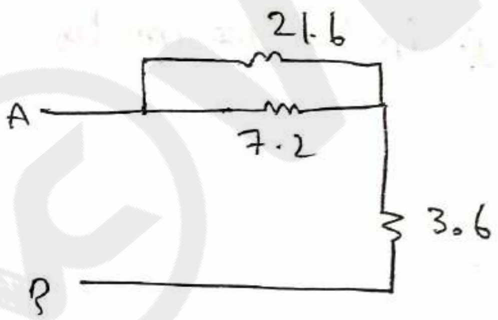
$$I = \frac{V}{R} = \frac{120}{9.62} = 12.47\ A$$

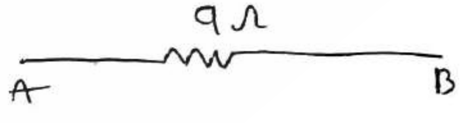
6)











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Mesh Analysis

- A mesh is defined as a loop which does not contain any other loops within it. Mesh analysis is applicable for a planar network (elements of network not crossing with each other)
- while applying mesh analysis circuit should contain voltage sources & KVL is used.

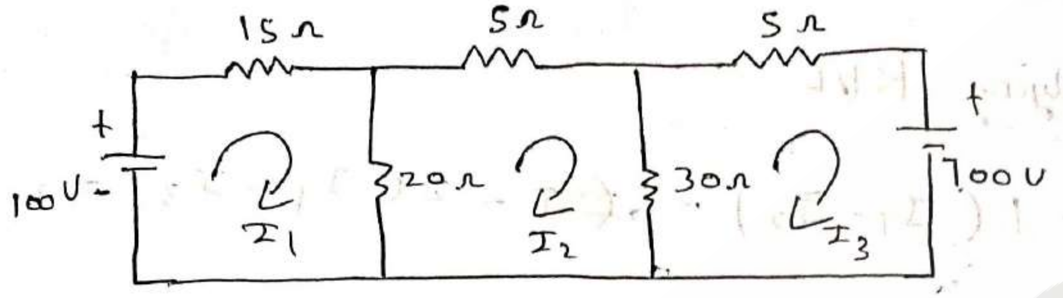
Steps to be followed in mesh analysis:

1) choose a conventional current flow
2) Identify and number the loops for convenience
3) Apply KVL for the identified loops.
4) use ohm's law to express branch voltages in terms of unknown mesh currents & the resistance
5) Formulate the ckt equations.
6) solve the simultaneous equations:

When the current source is in the perimeter or/ boundary of the ckt.

→ loop or mesh analysis:

1) Find the current through the 30Ω in the network shown using, loop analysis



$$100 - 15 I_1 - 20(I_1 - I_2) = 0$$

$$100 - 15 I_1 - 20 I_1 + 20 I_2 = 0$$

$$100 - 35 I_1 + 20 I_2 = 0$$

$$\boxed{-35 I_1 + 20 I_2 = -100} \quad \ldots (1)$$

$$-5 I_2 - 30(I_2 - I_3) - 20(I_2 - I_1) = 0$$

$$-5 I_2 - 30 I_2 + 30 I_3 - 20 I_2 + 20 I_1 = 0$$

$$20 I_1 - 55 I_2 + \cancel{30 I_3} = 0$$

$$\boxed{20 I_1 - 55 I_2 = 0} \quad \ldots (2)$$

$$-5 I_3 - 100 - 30(I_3 - I_2) = 0$$

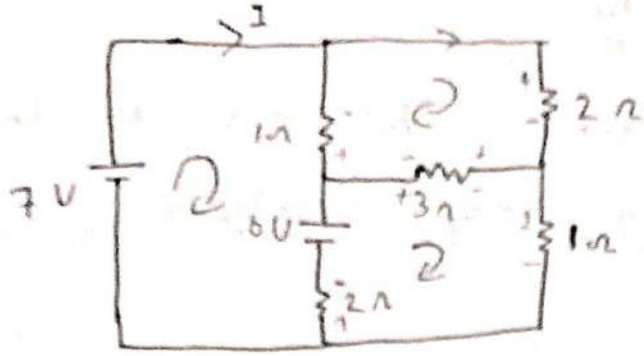
$$-5 I_3 - 30 I_3 + 30 I_2 = 100$$

$$\boxed{30 I_2 - 35 I_3 = 100} \quad \ldots (3)$$

$$I_{30\Omega} = (I_2 - I_3) = -1.6 + 4.22$$

$$\boxed{I_{30} = 2.62\,A}$$

2)



Applying KVL

$$7 - 1(I_1 - I_2) - 6 \cancel{} - 2(I_1 - I_3) = 0$$

$$7 - I_1 + I_2 - 6 - 2I_1 + 2I_3 = 0$$

$$-3I_1 + I_2 + 2I_3 + 1 = 0$$

$$\boxed{-3I_1 + I_2 + 2I_3 = -1} \quad (1)$$

Applying KVL to loop 2

$$-2(I_2) - 3(I_2 - I_3) - 1(I_2 - I_1) = 0$$

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

$$\boxed{I_1 - 6I_2 + 3I_3 = 0} \;..\; (2)$$

Applying KVL to loop 3

$$-3(I_3 - I_2) - 1(I_3) - 2(I_3 - I_1) = -6$$

$$-3I_3 + 3I_2 - I_3 - 2I_3 + 2I_1 = -6$$

$$\boxed{2I_1 + 3I_2 - 6I_3 = -6}$$

$\boxed{I_1 = 3}$ $\boxed{I_2 = 2A}$ $\boxed{I_3 = 3A}$

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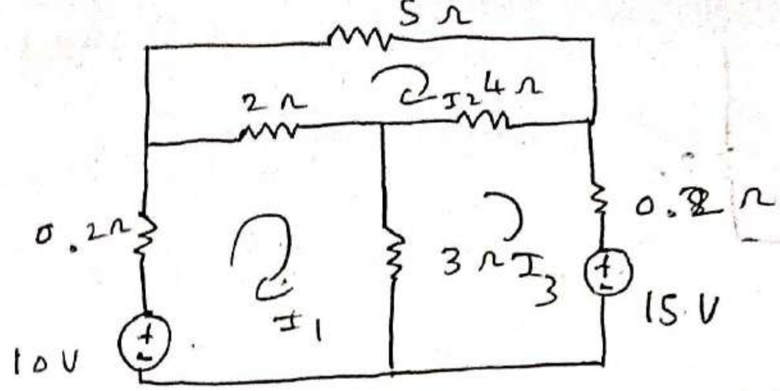
3)



$$-0.2\, I_1 - 2(I_1 - I_2) - 3(I_1 - I_3) = 0$$

$$-0.2\, I_1 - 2 I_1 + 2 I_2 - 3 I_1 + 3 I_3 = 0$$

$$\boxed{-5.2\, I_1 + 2 I_2 + 3 I_3 = -10} \quad \ldots (1)$$

$$-5 I_2 - 4 I_2 + 4 I_3 - 2 I_2 + 2 I_1 = 0$$

$$\boxed{2 I_1 - 11 I_2 + 4 I_3 = 0} \quad \ldots (2)$$

$$-0.2\, I_3 - 15\,V - 3(I_3 - I_1) - 4(I_3 -$$

$$-0.2\, I_3 - 3 I_3 + 3 I_1 - 4 I_3 + 4 I_2 = 15$$

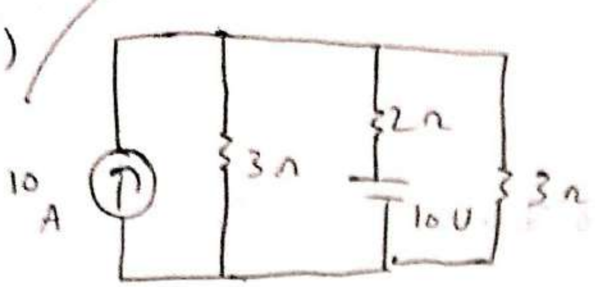
$$\boxed{3 I_1 + 4 I_2 - 7.2\, I_3 = 15} \quad \ldots (3)$$

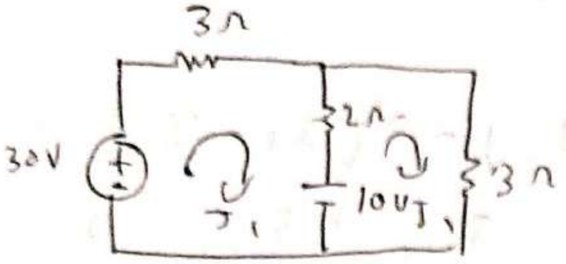
$$\boxed{I_1 = 0.111}$$

$$\boxed{I_2 = -0.902}$$

$$\boxed{I_3 = -2.53}$$

4)





Applying KVL

$30 - 3I_1 - 2I_1 + 2I_2 - 10 = 0$

$\boxed{-5I_1 + 2I_2 = -20}$ . . . ①

Applying KVL

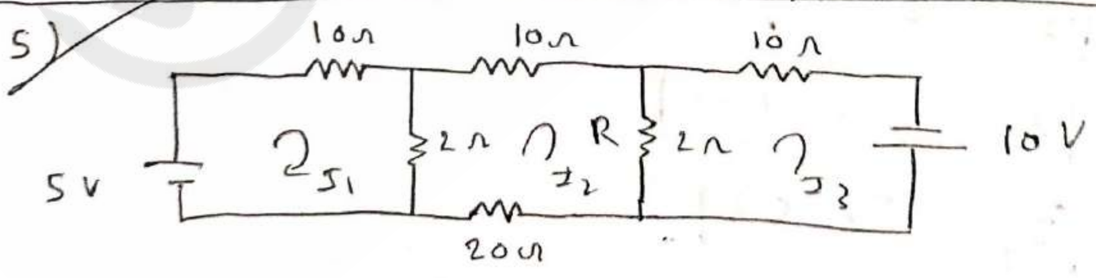
$10 - 2I_2 + 2I_1 - 3I_2 = 0$

$\boxed{2I_1 - 5I_2 = -10}$ . . . ②

$\boxed{I_1 = 5.714}$

$\boxed{I_2 = 4.285}$

5)



Applying KVL to loop 1

$5 - 10I_1 - 2I_1 + 2I_2 = 0$

$\boxed{-12I_1 + 2I_2 = -5}$

Applying KVL to loop 2

$$-2(I_2 - I_1) - 10(I_2) - 2(I_2 - I_3) = (20 I_2) = 0$$

$$-2I_2 + 2I_1 - 30 I_2 - 2I_2 + 2I_3 = 0$$

$$\boxed{2I_1 - 34 I_2 + 2I_3 = 0}$$

Applying KVL to loop 3

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

$$\boxed{2I_2 - 12 I_3 = -10}$$

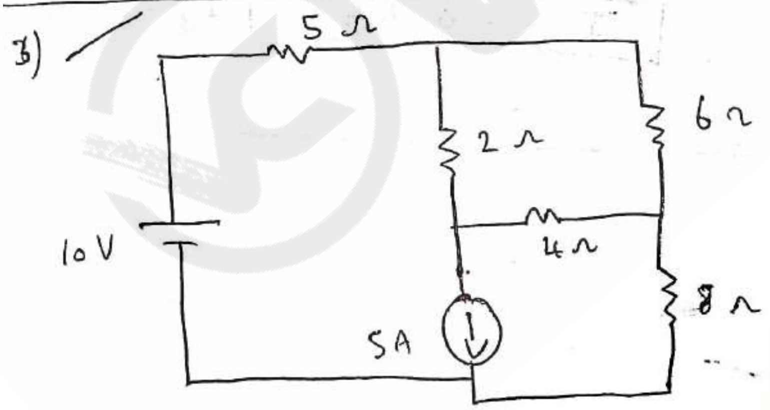
$$\boxed{I_1 = 0.429A} \quad \boxed{I_2 = 0.075A} \quad \boxed{I_3 = 0.8458A}$$

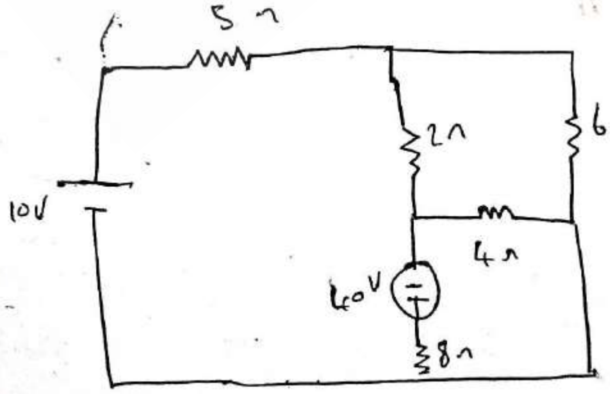
$$V_R = 2(I_2 - I_3)$$

$$V_R = 2(0.075A - 0.8458)$$

$$\boxed{V_R = -1.5416V}$$

3)





Apply KVL to loop 1

$+10 - 5I_1 - 2I_1 + 2I_2 - 8I_1 + 8I_3$

$$\boxed{-15I_1 + 2I_2 + 8I_3 = -50}$$

Apply KVL

$-6I_2 - 4(I_2 - I_3) - 2(I_2 - I_1) = 0$

$-6I_2 - 4I_2 + 4I_3 - 2I_2 + 2I_1 = 0$

$$\boxed{2I_1 - 12I_2 + 4I_3 = 0}$$

$-40 - 4I_3 + 4I_2 - 8(I_3) + 8I_1 = 0$

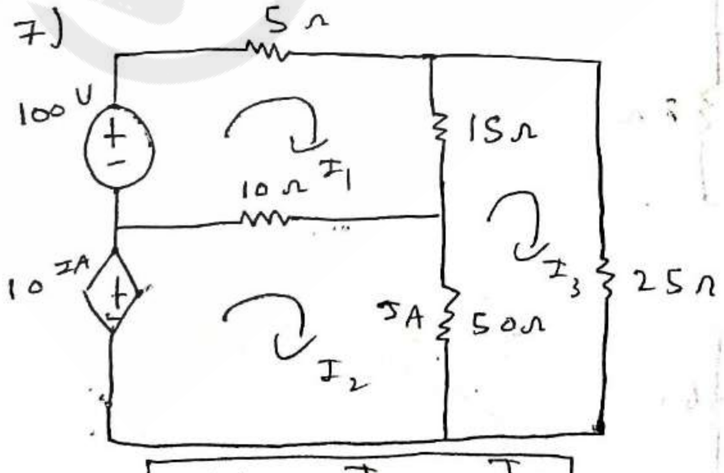
$-40 - 8I_3 - 4I_3 + 4I_2 + 8I_1 = 0$

$-40 - 12I_3 + 8I_1 + 4I_2 = 0$

$$\boxed{8I_1 + 4I_2 - 12I_3 = 40}$$

$\boxed{I_1 = 2.29\,A}$ $\boxed{I_2 = -0.24}$ $\boxed{I_3 = -1.885}$

7)



$$\boxed{I_A = I_2 - I_3}$$

Apply KVL to loop 1

$$100 - 5I_1 - 15I_1 + 15I_3 - 10I_1 + 10I_2 = 0$$

$$\boxed{-30I_1 + 10I_2 + 15I_3 = -100}$$

$$-10(I_2 - I_1) - 50(I_2 - I_3) + 10(I_2 - I_3) = 0$$

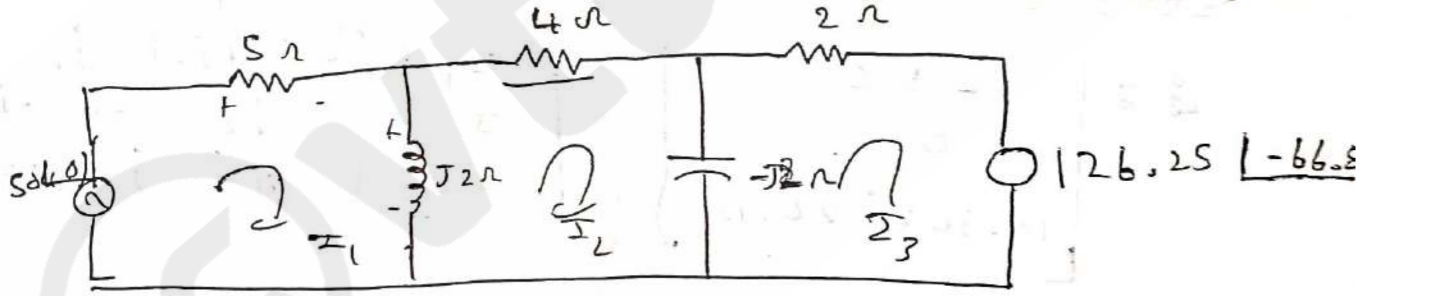
$$\boxed{10I_1 - 50I_2 + 40I_3 = 0 \quad \ldots (2)}$$

$$-15I_3 - 50I_3 + 50I_2 - 15I_3 + 25I_1 = 0$$

$$\boxed{25I_1 + 50I_2 - 80I_3 = 0 \quad \ldots (3)}$$

$\boxed{I_1 = 6.06\,A}$ $\boxed{I_2 = 3.136\,A}$ $\boxed{I_3 = 3.030\,A}$

8) Find the current through 4Ω Resistance in the network shown using loop analysis.



$$50\angle 0 - 5I_1 - J2(I_1 - I_2) = 0$$

$$50 - 5I_1 - I_1 J2 + J2 I_2 = 0$$

$$50 - I_1(5 + J2) + J2 I_2 = 0$$

$$-I_1(5 + 2j) + j2I_2 = -50$$

$$\boxed{-(5+2j)I_1 + J2 I_2 = -50}$$

$$-4I_2 - (-j2)(I_2 - I_3) - j2(I_2 - I_1) = 0$$

$$-4I_2 + \cancel{j2 I_2} - j2 I_3 \cancel{- j_2 I_2} + j_2 I_1 = 0$$

$$\boxed{+j2 I_1 - 4 I_2 - j_2 I_3 = 0} \quad \text{(2)}$$

Applying KVL to loop 3

$$-2I_3 + (10.34 - j24.12)\cancel{I_2} - (-j_2)(I_3 - I_2)$$

$$-2I_3 + (10.34 - j24.12) + j2 I_3 - j_2 I_2 = 0$$

$$I_3(-2 + j3) - j2 I_2 + (10.34 - j24.12)$$

$$\cancel{j2}$$

$$(10.34 - j24.12) = j2 I_2 - (-2 + j\cancel{2}) I_3 \quad \text{(3)}$$

$$V = I \cdot R$$

$$\begin{bmatrix} -50 \\ 0 \\ 10.34 - j24.12 \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} \begin{bmatrix} -(5+j2) & j2 & 0 \\ j2 & -4 & -j2 \\ 0 & j_2 & (2+j2) \end{bmatrix}$$

$$= \begin{bmatrix} -5+j2) & j2 & 0 \\ j2 & -4 & -j_2 \\ 0 & j2 & (2-j2) \end{bmatrix}$$

$$36 - 32i \quad + 8 - j8$$

$$\Delta = \left(-(5+2j)\left((-4(2-j2) - j2(j2)\right) - j_2(j_2(2-j2)\right)$$

$$= -5 - 2j(-8 + 8j \cancel{+ I + j^2}) - j_2(\cancel{4j} \cancel{+ j^2} + 4)$$

$\Delta = -(5 + 2j)\left[-8 + 8j - 4\right] - j2(4j + 4)$ $j^2 = -1$

$\Delta = -(5 + 2j)(-12 + j8) + 8 - j8$

$j = j$
$j^2 = -1$
$j^3 = j^2 j$

$\Delta = (-5 - j2)(-12 + j8) + 8 - j8$

$\Delta = 60 - 40j + 24j + 16 + 8 - j8$

$\boxed{\Delta = 84 - 24j}$

$\boxed{\Delta = 87.36 \angle -15.94}$

$I_1 = \frac{\Delta_1}{\Delta}$

$$\Delta_1 = \begin{bmatrix} -50 & j2 & 0 \\ 0 & -4 & -j2 \\ 10.34 - 24.12j & j2 & (2 - j2) \end{bmatrix}$$

$\Delta_1 = -50\left(-4(2 - j2) - (-j2(j2))\right)$
$-j2\left(-j2(10.34 - 24.12j)\right)$

$\Delta_1 = -50(-12 + 8j) + 41.36 - 96.48i$

$\Delta_1 = 600 - 400i + 41.36 - 96.48i$

$I_1 = \frac{\Delta_1}{\Delta}$

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$\Delta_1 = 641.36 - 491.48i$

$\Delta_1 = 811.07 \angle -37.74$

$I_1 = \dfrac{811.07 \angle -37.74}{87.36 \angle -15.94}$

$\boxed{I_1 = 9.284 \angle -21.8}$

$$\Delta_2 = \begin{bmatrix} -(5+j2) & -50 & 0 \\ j2 & 0 & -j2 \\ 0 & 10.34-24.12i & (2-j2) \end{bmatrix}$$

$\Delta_2 = -(5+j2)\,(\cancel{-50(}\;0 + j2(10.34-24.12i)$

$+50\,(j2(2-j2) - (-j2(0)))$

$\Delta_2 = -5 - j2\,(48.24 + 20.68i) + 50(4+4i)$

$\Delta_2 = 36.36 - 96.48i + 200 + 200i$

$\boxed{\Delta_2 = 236.36 + 103.52i}$

$\boxed{\Delta_2 = 258.03 \angle 23.65}$

$I_2 = \dfrac{258.03 \angle 23.65}{87.36 \angle -15.94}$

$\boxed{I_2 = 2.95 \angle 39.59}$

$\Delta_2 = 243.24 + 218.4i$

$\Delta_2 = 327.08 \angle 41.93$

$I_2 = \dfrac{327.08 \angle 41.93}{87.36 \angle -15.94}$

$\boxed{I_2 = 3.74 \angle 57.81}$

$$\Delta_3 = \begin{bmatrix} -(5+j2) & j2 & -50 \\ j2 & -4 & 0 \\ 0 & j2 & 10.34-24.12j \end{bmatrix}$$

$\Delta_3 = -(5+j2)\big(-4(10.34 - 24.12j) - 0\big) - j2$

$(j2(10.34 - 24.12j) - 0) - 50(j2(j2) + \ldots$

$$\Delta_3 = -5 - j2(-41.36 + 96.48i) - 41.36 + 96.48i + 200$$

$$\Delta_3 = 187.96 + 82.72i - 41.36 + 96.48i + 200$$

$$\boxed{\Delta_3 = 346.6 + 179.2i} \qquad \boxed{\Delta_3 = 390.18\angle 27.33}$$

$$\therefore I_3 = \frac{\Delta_3}{\Delta} \qquad I_3 = \frac{390.18\angle 27.33}{87.36\angle -15.94}$$

$$\boxed{I_3 = 4.46\angle 43.27}$$

$$\Delta_2 = \begin{bmatrix} -(5+j2) & -50 & 0 \\ j2 & 0 & -j2 \\ 0 & 10.34-24.12i & (2-j2) \end{bmatrix}$$

$$\Delta_2 = (-5-j2(\ j2(10.34-24.12i) + 50(j2(2-j2$$

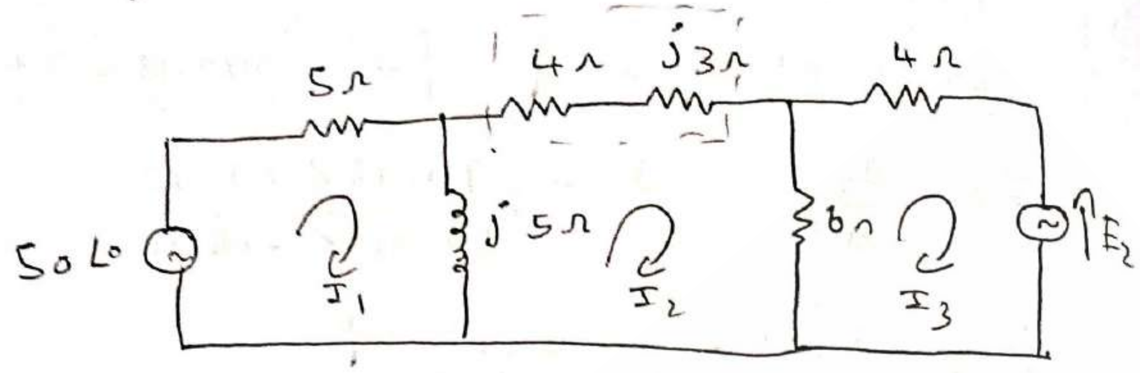
$$\Delta_2 = 0.16 + 0.12j$$

$$\Delta_2 = 0.2\angle 36.86$$

$$I_2 = \frac{\Delta_2}{2} \quad \frac{0.2\angle 36.86}{87.36\angle -15.94}$$

$$\boxed{I_2 = 2.28 \times 10^{-3}\angle +52.8}$$

9) Find the value of voltage source E_2 in the Network shown such that current through $4+j3\Omega$ is 0



$E_2 = ?$

$I_{4+j3} = 0 = I_2 = 0$

$\boxed{V = 50\angle 0}$

$\boxed{V = 50}$

Apply KVL at loop 1

$50 - 5I_1 - j5(I_1 - I_2) = 0$

$50 - 5I_1 - I_1 j5 + I_2 j5 = 0$

$50 - I_1(5 + j5) + I_2 j5 = 0 \quad \ldots (1)$

$50 - 5I_1(1 + j) + I_2 j5 = 0$

$\boxed{50 = 5I_1(1+j) \cancel{-I_2 j5}} \quad \ldots (1) \quad \because I_2 = 0$

$I_1 = \dfrac{50}{5+j5}$

$I_1 = 5 \cancel{+} -5j$

$\boxed{I_1 = 7.07\angle 45 A}$

Apply KVL to loop 2

$$-\cancel{(4+j3\,\Omega)I_2} - 6(I_2 - I_3) - j5(I_2 - I_1) = 0$$

$$\cancel{-6I_2} + 6I_3 - \cancel{j5I_2} + j5I_1 = 0$$

$$6I_3 + j5I_1 = 0$$

subs I_1 in above eq

$$6I_3 + j5(5 - 5j) = 0$$

$$6I_3 = -j5(5 - j5)$$

$$I_3 = \frac{-j5(5-j5)}{6}$$

$$\boxed{I_3 = -(4.166 + 4.16j)}$$

Apply KVL to loop 3

$$-4I_3 - E_2 - 6I_3 + \cancel{6I_2} = 0$$

$$-10I_3 = E_2$$

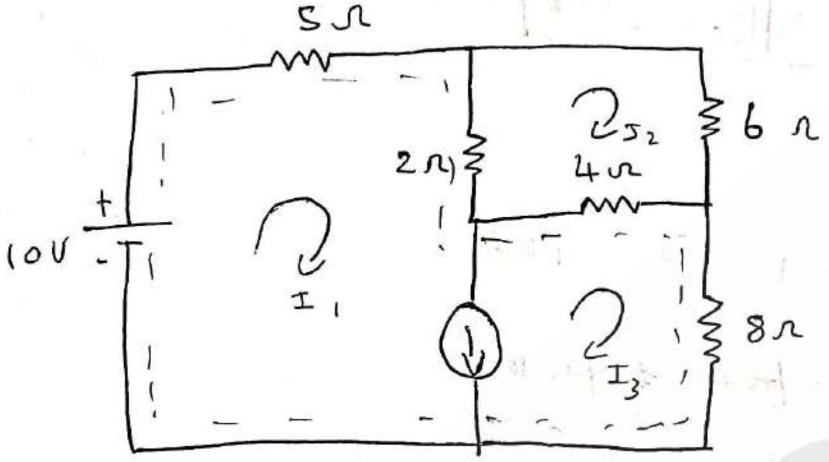
$$E_2 = -10(-(4.166 + 4.166j))$$

$$\boxed{E_2 = 41.66 + 41.66j\ V}$$

$$\boxed{E_2 = 58.916 \angle 45}$$

1) Find all the loop current using loop or mesh analysis.

Note (If there is an ideal current source between any two loops, that loop we call it as superloop)



From super mesh.

$$\boxed{I_1 - I_3 = 5} \quad \ldots (1)$$

Apply KVL to super mesh

$$10 - 5I_1 - 2(I_1 - I_2) - 4(I_3 - I_2) - 8I_3 = 0$$

$$10 - 5I_1 - 2I_1 + 2I_2 - 4I_3 + 4I_2 - 8I_3 = 0$$

$$\boxed{-7I_1 + 6I_2 - 12I_3 = -10} \quad \ldots (2)$$

KVL loop (2)

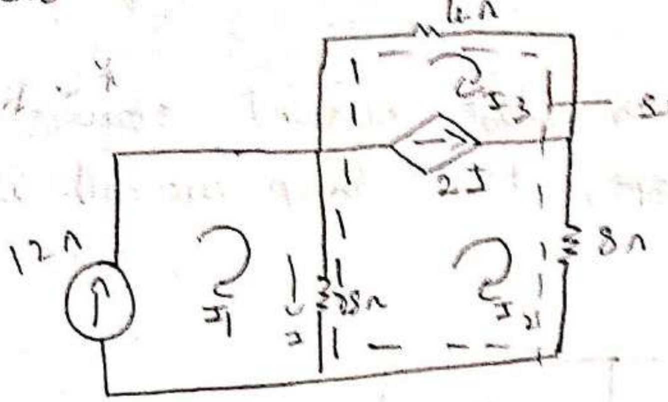
$$-6I_2 - 4(I_2 - I_3) - 2(I_2 - I_1) = 0$$

$$-6I_2 - 4I_2 + 4I_3 - 2I_2 + 2I_1 = 0$$

$$\boxed{2I_2 - 12I_2 + 4I_3 = 0}$$

$\boxed{I_1 = 3.75A}$ $\boxed{I_2 = 0.208A}$ $\boxed{I_3 = -1.25A}$

2) Find current I in 28 Ω resistor by Mesh analysis



I_{28} ?

Soln: from loop 1 $I_1 = 12\,A$

loop 2 & 3 forms super mesh

$I_2 - I_3 = 2I$

from ckt $I = I_1 - I_2$

$I_2 - I_3 = 2I_1 - 2I_2$

$3I_2 - I_3 = 2I_1$

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

$-2(12) + 3I_2 - I_3 = 0$

$\boxed{3I_2 - I_3 = 24}$ ... (1)

Apply KVL to super mesh

$-4I_3 - 8I_2 - 28I_2 + 28I_1 = 0$

$28I_1 - 36I_2 - 4I_3 = 0$

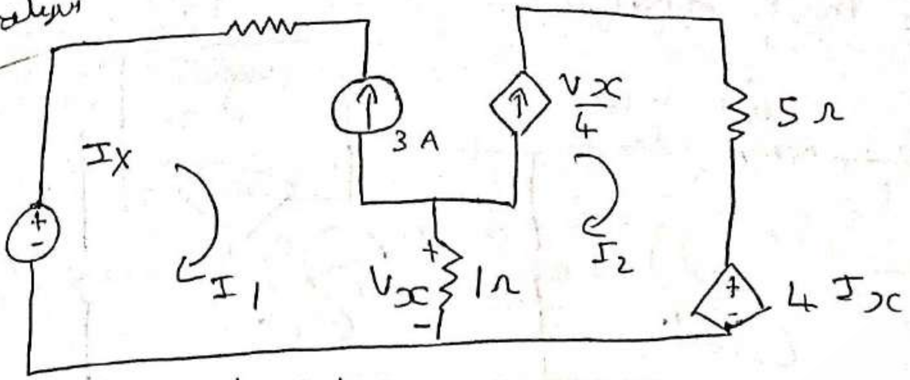
$-36I_2 - 4I_3 = -336$

$\boxed{I_2 = 9\,A}$ $\boxed{I_3 = 3\,A}$

$I_{28\Omega} = I_1 - I_2$

$\boxed{I_{28\Omega} = 3\,A}$

3) Find I_x & V_x for the ckt shown using mesh analysis



From loop 1

$I_x = 3\,A$

$I_1 = -I_x = -3\,A$

$\boxed{I_1 = -3A}$

from loop - 2

$I_2 = \frac{V_x}{4}$

$V_x = IR$
$= (I_1 - I_2) \times 1$

$V_x = I_1 - I_2$

$\therefore I_2 = \frac{I_1 - I_2}{4}$

$4 I_2 = -3 - I_2$

$5 I_2 = -3$

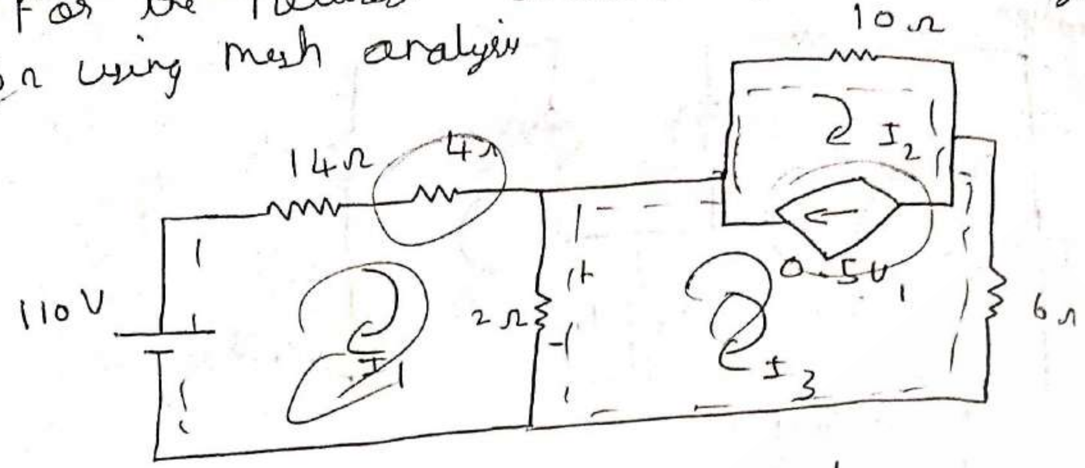
$I_2 = \frac{-3}{5}$

$I_2 = -0.6\,A$

$V_x = 4 \times (-0.6)\,A$

$\boxed{V_x = -2.4\,V}$

4) For the network shown find I through 4Ω, 6Ω using mesh analysis



Loop 2 & 3 forms supermesh

given

$I_{4\Omega} = I_1$

$I_{6\Omega} = I_3 =$

$$I_2 - I_3 = 0.5V_1 \quad \cdots \text{①}$$

$$V_1 = IR$$

$$= (I_1 - I_3)2$$

$$V_1 = 2I_1 - 2I_3$$

$$I_2 - I_3 = 0.5(2I_1 - 2I_3)$$

$$I_2 - I_3 = I_1 - I_3$$

$$I_2 - \cancel{I_3} - I_1 + \cancel{I_3} = 0$$

$$I_2 - I_1 = 0 \quad \cdots \text{②}$$

$$\boxed{I_1 = I_2}$$

Apply KVL to super mesh.

$$-10I_2 - 6I_3 - 2I_3 + 2I_1 = 0$$

$$2I_1 - 10I_2 - 8I_3 = 0 \quad \cdots \text{③}$$

Apply KVL to loop

$$110 \cancel{-2I_1} - 18I_1 - 2I_1 + 2I_3 = 0$$

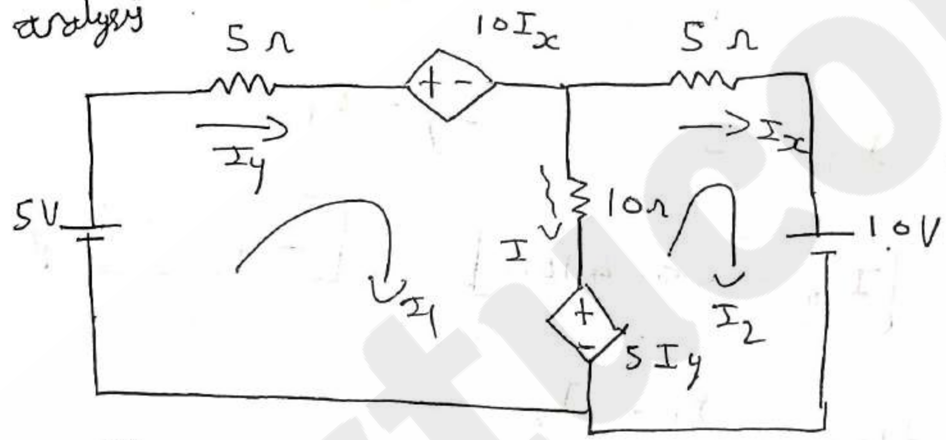
$$-20 I_1 + 2I_3 = -110 \quad \ldots \quad (4)$$

$\boxed{I_1 = 5A}$ $\boxed{I_2 = 5A}$ $\boxed{I_3 = -5A}$

$$\boxed{I_{4\Omega} = I_1 = 5A}$$

$$I_{6\Omega} = I_3 = -5A$$

5) Find I through 10Ω Resistor using mesh analysis



soln : $I_{10\Omega} = ?$

$$I_1 = I_y, \quad I_2 = I_x$$

$$I = I_1 - I_2$$

Apply KVL to loop 1

$$5 - 5I_1 \cancel{-10I_2} - 10I_1 \cancel{+10I_2} - 5I_y = 0$$

$$5 - 20I_1 = 0$$

$$20I_1 = 5$$

$$I_1 = \frac{5}{20}$$

$$\boxed{I_1 = 0.25A}$$

Apply KVL to loop 2

$$-5I_2 - 10 + 5I_1 - 10I_2 + 10I_1 = 0$$

$$15I_1 - 15I_2 = 10$$

$$15(0.25) - 15I_2 = 10$$

$$3.75 - 15I_2 = 10$$

$$-I_2 = \frac{10 - 3.75}{15}$$

$$\boxed{I_2 = -0.416\ A}$$

$$\therefore I_x = I_2 \qquad I_y = I_1$$

$$\boxed{I_x = -0.416A} \qquad \boxed{I_y = 0.25}$$

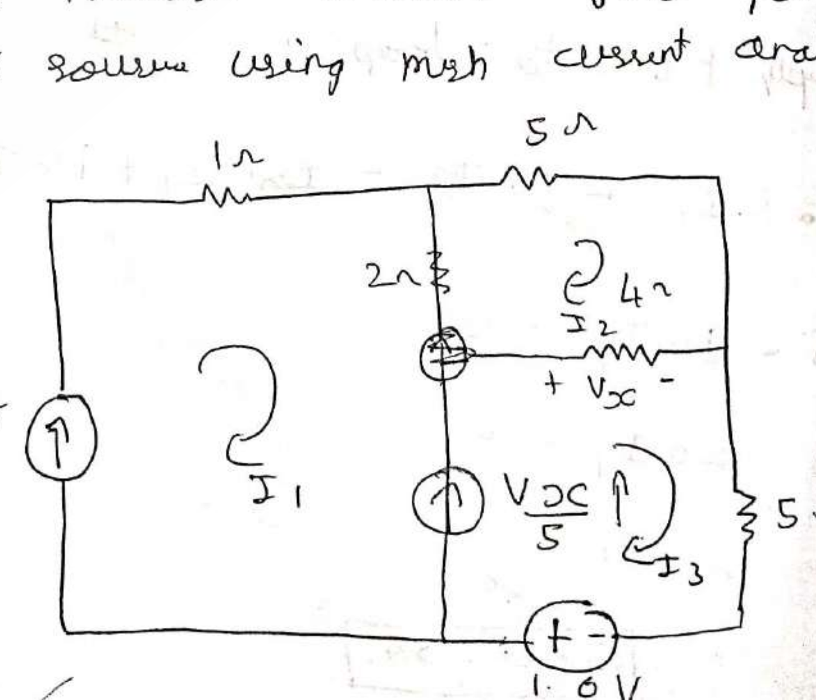
$$I_{10\Omega} = I_1 - I_2$$

$$I_{10\Omega} = 0.25 + 0.416$$

$$\boxed{I_{10\Omega} = 0.66A}$$

---

6) For the network shown find power by 10V source using mesh current analysis



from loop - 1

$I_1 = 1A$

loop 2 & 3 forms supermesh.

$I_2 - I_1 = \frac{V_x}{5}$

$V_x = IR$

$V_x = (I_3 - I_2)4$

$V_x = 4I_3 - 4I_2$

$(I_2 - I_1) = \frac{4I_3 - 4I_2}{5}$

$5I_2 - 5I_1 = 4I_3 - 4I_2$

$5I_2 - 5 = 4I_3 - 4I_2$

$\boxed{4I_2 + 1I_3 = 5}$ ... ②

Apply KVL to loop 2

$-5I_2 - 4I_2 + 4I_3 - 2I_2 + 2I_1 = 0$

$-11I_2 + 4I_3 = -2$

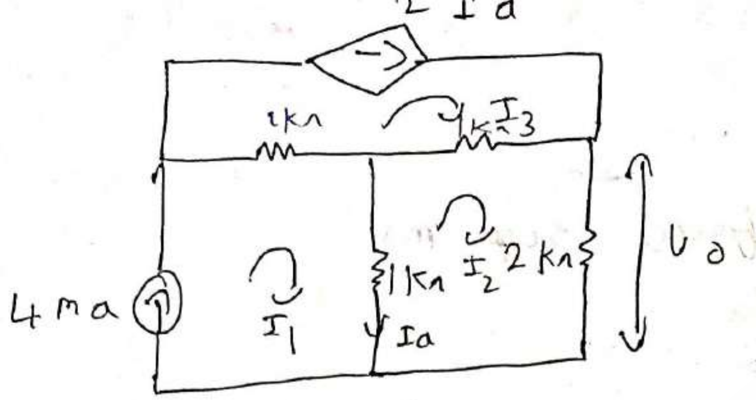
$\boxed{I_2 = 0.8148\,A}$ $\boxed{I_3 = 1.74\,A}$

$P = V \times I$

$P = 10 \times 1.74$

$\boxed{P = 17.4\,W}$

7)



$I_1 = 4mA$
$I_2 = 2mA$
$V_0 = 4$

from the above ckt

From loop 1

$$\boxed{I_1 = 4mA}$$

$$\boxed{I_a = I_1 - I_2}$$

From loop 3

$$I_3 = 2 I_a$$

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

$$I_3 = 2I_1 - 2I_2$$

$$\boxed{2I_2 + I_3 = 8} \quad \text{.......} (1)$$

Apply KVL to loop 2

$$-1I_3 - 1I_2 - 2 \cdot I_2 \cancel{+2I} -1 I_2 - I_1 = 0$$

$$I_1 - 4I_2 + I_3 = 0$$

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

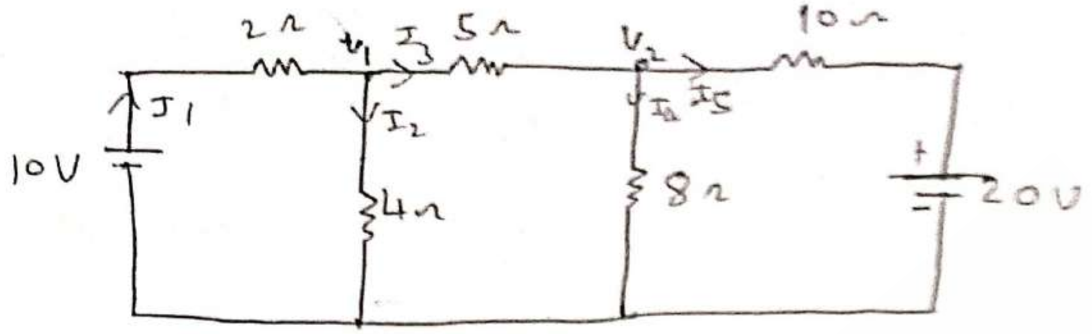
$$\boxed{-4I_2 + I_3 = -4}$$

$$\boxed{I_2 = 2mA} \qquad \boxed{I_3 = 4mA}$$

$$V_0 = 2mA \times 2k\Omega$$

$$\boxed{V_0 = 4V}$$

1) Find all branch currents using nodal analysis



Apply KCL at v_1

$$\frac{V_1-10}{2}+\frac{V_1}{4}+\frac{V_1-V_2}{5}=0$$

$$\frac{V_1}{2}-\frac{10}{2}+\frac{V_1}{4}+\frac{V_1}{5}-\frac{V_2}{5}=0$$

$$v_1\left(\frac{1}{2}+\frac{1}{4}+\frac{1}{5}\right)-V_2\left(\frac{1}{5}\right)=5$$

$$\boxed{0.95\,V_1-0.2V_2=5}\quad\ldots\ (1)$$

Apply KCL to V_2

$$\frac{V_2-V_1}{5}+\frac{V_2}{8}+\frac{V_2-20}{10}=0$$

$$\frac{V_2}{5}-\frac{V_1}{5}+\frac{V_2}{8}+\frac{V_2}{10}-\frac{20}{10}=0$$

$$V_2\left(\frac{1}{5}+\frac{1}{8}+\frac{1}{10}\right)-V_1(0.2)=2$$

$$\boxed{-0.2V_1+0.425\,V_2=2}\quad\ldots\ (2)$$

$\boxed{V_1=6.941\,V}$ $\boxed{V_2=7.97\,V}$

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$$I_1 = \frac{V_1 - 10}{2}, \quad I_1 = \frac{6.9411 - \cancel{18}}{\cancel{2}}$$

$$\boxed{I_1 = -1.53A}$$

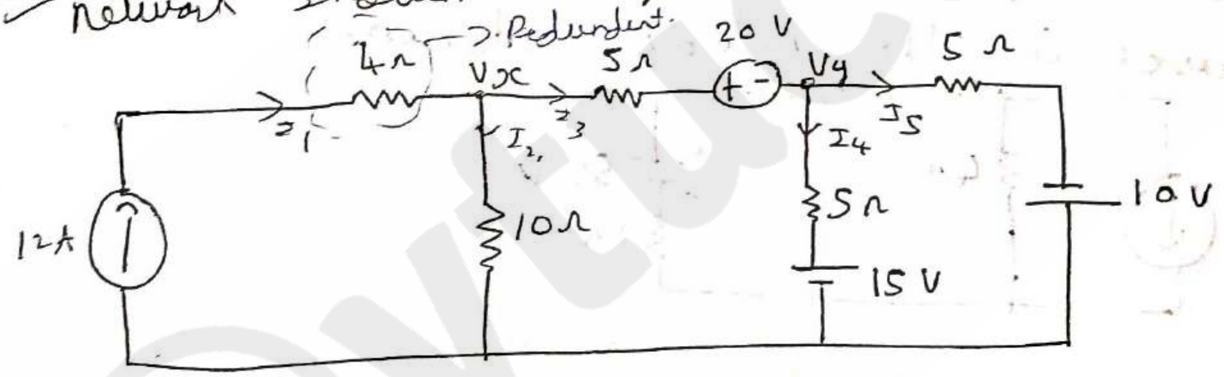
$$I_2 = \frac{V_1}{4} = \frac{6.941}{4} = 1.735A$$

$$I_3 = \frac{V_2 - V_1}{5} = \frac{6.94 - 7.97}{.5} = -0.206A$$

$$I_4 = \frac{V_2}{8} = \frac{7.97}{8} = 0.996A$$

$$I_5 = \frac{V_2 - 20}{10} = -1.203A$$

2) Find the node voltage V_x & V_y in the network shown using nodal analysis.



Apply KCL to V_x

$$\frac{V_x}{10} + \frac{V_y - V_x - 20}{5} = 12$$

$$\frac{V_x}{10} + \frac{V_y}{5} - \frac{V_x}{5} = 12 + 4$$

$$V_x\left(\frac{1}{10} + \frac{1}{5}\right) - 0.2V_y = 16$$

$$\boxed{0.3V_x - 0.2V_y = 16}$$

Applying KCL to node y:

$$\frac{V_y - V_x}{5} + \frac{V_y}{5} + \frac{V_y - 15}{5} + \frac{V_y + 10}{5} = 0$$

$$\frac{V_y}{5} - \frac{V_x}{5} + \frac{V_y}{5} + \frac{V_y}{5} - \frac{15}{5} + \frac{V_y}{5} + \frac{10}{5} = 0$$

$$-0.2V_x + 0.6V_y = -3 \quad \ldots (2)$$

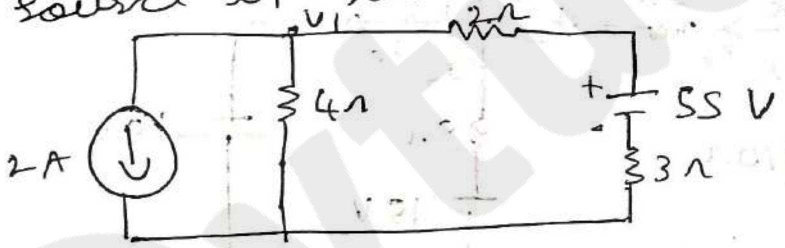
solve (1) & (2)

$$\boxed{V_x = 64.28\ V}$$

$$\boxed{V_y = 16.42V}$$

---

3) Find the power delivered by 2 A current source in the network shown.



$$\frac{V_1}{4} + \frac{V_1 - 55}{5} = -2$$

$$\frac{V_1}{4} + \frac{V_1}{5} - \frac{55}{5} = -2$$

$$V_1\left(\frac{1}{4} + \frac{1}{5}\right) = -2 + 11$$

$$V_1(0.45) = 9$$

$$V_1 = \frac{9}{0.45}$$

$$\boxed{V_1 = 20V}$$

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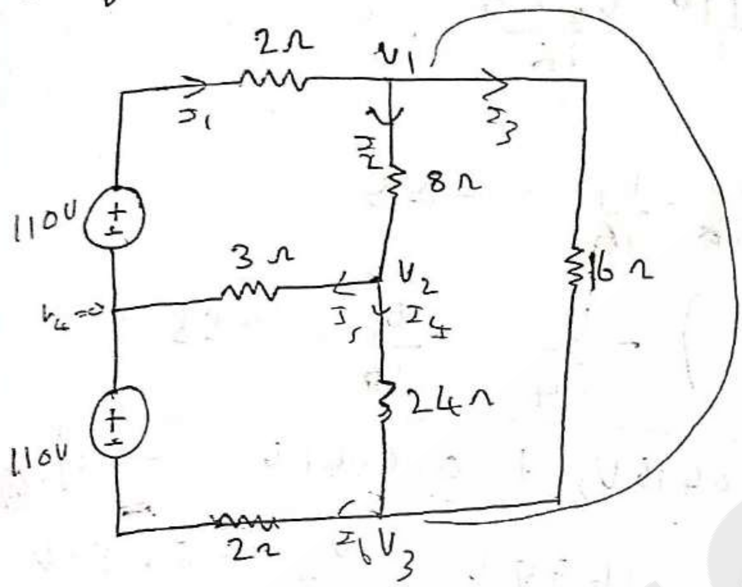
Power delivered $= V_1 \times I$

$$P = 20 \times 2$$

$$\boxed{P = 40\,W}$$

4) Find all the Branch currents using nodal analysis.



$$\frac{V_1 - V_4}{2} + \frac{V_1 - V_2}{8} + \frac{V_1 - V_3}{16} = 55$$

$$\frac{V_1}{2} - \frac{V_4}{2} + \frac{V_1}{8} - \frac{V_2}{8} + \frac{V_1}{16} - \frac{V_3}{16} = 55$$

$$V_1\left(\frac{1}{2} + \frac{1}{8} + \frac{1}{16}\right) - \frac{V_2}{8} - \frac{V_3}{16} = 55$$

$$\boxed{0.687\,V_1 - 0.125\,V_2 - 0.0625\,V_3 = 55}$$

KCL to node 2

$$\frac{V_2 - V_1}{8} + \frac{V_2}{3} + \frac{V_2 - V_3}{24} = 0$$

$$\frac{V_2}{8} - \frac{V_1}{8} + \frac{V_2}{3} + \frac{V_2}{24} - \frac{V_3}{24} = 0$$

$$V_2\left(\frac{1}{8}+\frac{1}{3}+\frac{1}{24}\right)-\frac{V_1}{8}-\frac{V_3}{24}=0$$

$$-0.125V_1+0.5V_2-0.0416V_3=0$$

Apply KCL to node 3

$$\frac{V_3-V_2}{24}+\frac{V_3}{2}+\frac{110}{2}\ \frac{V_3-V_1}{16}=0$$

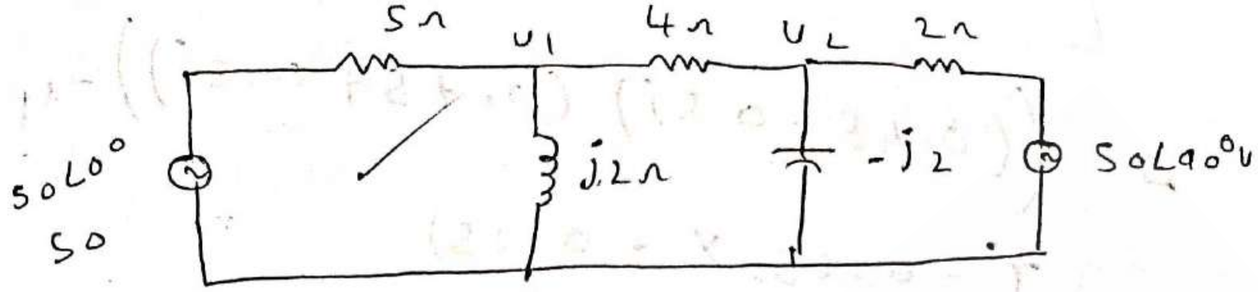
$$\frac{V_3}{24}-\frac{V_2}{24}+\frac{V_3}{2}+\frac{V_3}{16}-\frac{V_1}{16}=-55$$

$$V_3\left(\frac{1}{24}+\frac{1}{16}+\frac{1}{2}\right)-\frac{V_2}{24}-\frac{V_1}{16}=-55$$

$$\boxed{-0.0625V_1-0.0416V_2+0.6041V_3=-55}$$

$V_1=74.64V$ $\quad V_2=11.79V$ $\quad V_3=-82.50V$

→ Find the value of current I in the network shown using nodal analysis.



Apply KCL to node 1

$$\frac{V_1 - 50}{5} + \frac{V_1}{j2} + \frac{V_1 - V_2}{4} = 0$$

$$\frac{V_1}{5} - \frac{50}{5} + \frac{V_1}{j2} + \frac{V_1}{4} - \frac{V_2}{4} = 0$$

$$V_1\left(\frac{1}{5} + \frac{1}{j2} + \frac{1}{4}\right) - \frac{V_2}{4} = 10$$

$$\boxed{(0.45 - 0.5j) - 0.25V_2 = 10} \quad \ldots (1)$$

Apply KCL to node 2

$$\frac{V_2 - V_1}{4} + \frac{V_2}{-j2} + \frac{V_2 - 50i}{2\Omega} = 0$$

$$\frac{V_2}{4} - \frac{V_1}{4} + \frac{V_2}{-j2} + \frac{V_2}{2} - \frac{50i}{2} = 0$$

$$V_2\left(\frac{1}{4} + \frac{1}{-j2} + \frac{1}{2}\right) - 0.25V_1 = 25i$$

$$-0.25V_1 + (0.75 + 0.5i)V_2 = 25j \quad \ldots (2)$$

$$V = I \cdot R$$

$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 10 \\ 25j \end{bmatrix} \begin{bmatrix} (0.45 - 0.5j) & -0. \\ -0.25 & (0.75+0.5i \end{bmatrix}$$

$$\Delta = \begin{bmatrix} (0.45 - 0.5j) & -0.25 \\ -0.25 & (0.75 + 0.5j \end{bmatrix}$$

$$\Delta = ((0.45 - 0.5j)(0.75 + 0.5j)) - (-0.25 \times -0.25)$$

$$\boxed{\Delta = (0.525 - 0.15i)}$$

$$\Delta_1 = \begin{bmatrix} 10 & -0.25 \\ 25j & (0.75 + 0.5j) \end{bmatrix}$$

$$\Delta_1 = ((10)(0.75 + 0.5i)) - 0.25\,(25j$$

$$\Delta_1 = 7.5 + 11.25i$$

$$V_1 = \frac{\Delta_1}{\Delta} = \qquad = \frac{7.5 + 11.25j}{0.525 - 0.15i}$$

$$\boxed{V_1 = 24.76 \angle 72.25}$$

$$\Delta_2 = \begin{bmatrix} (0.45 - 0.5j) & 10 \\ -0.25 & 25j \end{bmatrix}$$

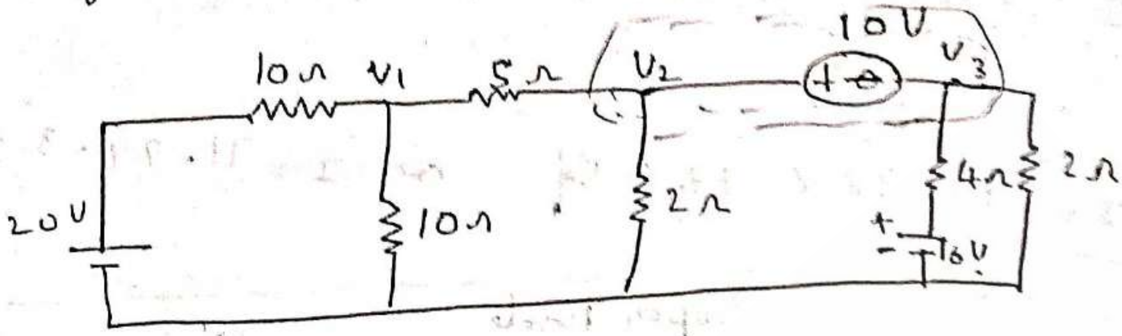
$$\Delta_2 = 15 + 11.25j$$

$$V_2 = \frac{\Delta_2}{\Delta} = \frac{15 + 11.25j}{0.525 - 0.15j} \qquad \therefore V_2 = 20.75 + 27.$$

$$\{$$

$$34.34 \angle 52.8$$

1) Find the value $I_{4\Omega}$ in the given network using nodal analysis.



node 2 & 3 forms super node.

$$\boxed{V_2 - V_3 = 10} \quad \text{— ①}$$

Apply KCL to node.

$$\frac{V_1 - 20}{10} + \frac{V_1}{10} + \frac{V_1 - V_2}{5} = 0$$

$$\frac{V_1}{10} + \frac{V_1}{10} + \frac{V_1}{5} - \frac{V_2}{5} = 2$$

$$V_1\left(\frac{1}{10} + \frac{1}{10} + \frac{1}{5}\right) - \frac{V_2}{5} = 2$$

$$\boxed{0.4V_1 - 0.2V_2 = 2} \quad \text{.. ②}$$

Apply KCL to super nod.

$$\frac{V_2 - V_1}{5} + \frac{V_2}{2} + \frac{V_3 - 16}{4} + \frac{V_3}{2} = 0$$

$$\frac{V_2}{5} - \frac{V_1}{5} + \frac{V_2}{2} + \frac{V_3}{4} + \frac{V_3}{2} = 4$$

$$-\left(\frac{V_1}{5}\right) + V_2\left(\frac{1}{5} + \frac{1}{2} + \frac{1}{2}\right) + \frac{V_3}{4} + \frac{V_3}{2} = 4$$

$$\boxed{-0.2V_1 + 0.7V_2 + 0.75V_3 = 4} \quad \text{.. ③}$$

$\boxed{V_1 = 9.62}$ $\boxed{V_2 = 9.25}$ $\boxed{V_3 = -0.7407\,V}$

$$I_{4\Omega} = \frac{V_3 - 16}{4}$$

$$I_{4\Omega} = \frac{-0.7407 - 16}{4}$$

$$\boxed{I_{4\Omega} = -4.18\,A}$$

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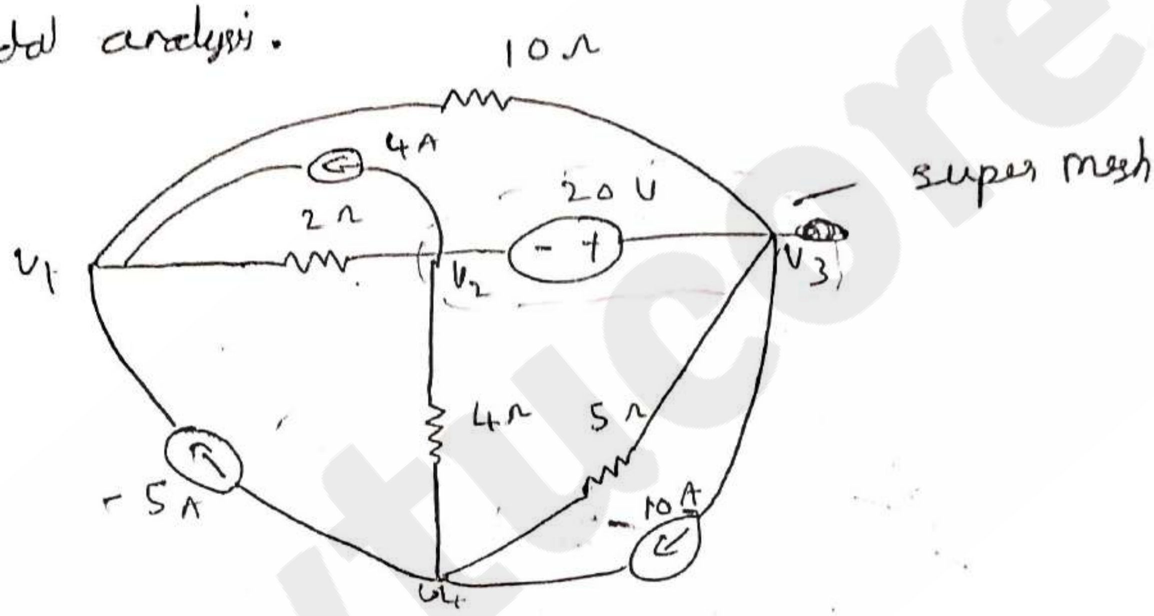
2) Find all node voltages V_1, V_2, V_3 using nodal analysis.



$$\boxed{V_3 - V_2 = 20} \quad \ldots \text{(1)}$$

$$\frac{V_1 - V_2}{2} + \frac{V_1 - V_3}{10} = -4 - 5$$

$$\frac{V_1}{2} - \frac{V_2}{2} + \frac{V_1}{10} - \frac{V_3}{10} = -4 - 5$$

$$V_1\left(\frac{1}{2} + \frac{1}{10}\right) - 0.5V_2 - 0.1V_3 = -9$$

$$\boxed{0.6V_1 - 0.5V_2 - 0.1V_3 = -9}$$

$$\frac{V_2}{4} + \frac{V_3}{5} + \frac{V_3 - V_1}{10} = 10$$

$$\frac{V_2}{4} + \frac{V_3}{5} + \frac{V_3}{10} - \frac{V_1}{10} = 10$$

$$\boxed{-0.1V_1 + 0.25V_2 + 0.3V_3 = 10} \quad \ldots (3)$$