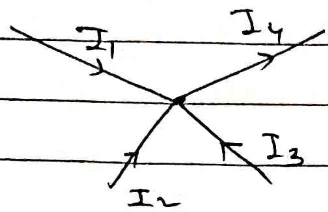
D.C. Circuit

* Kirchhoff's current law

1) The algebraic sum of currents meeting at a junction or node in an electric circuit is zero.
2) Total incoming current is equal to total outgoing current.

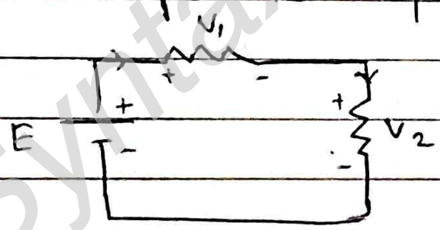


∴ KCL eqn is

$$\boxed{I_1 + I_2 + I_3 - I_4 = 0}$$

* Kirchhoff's voltage law

In any closed loop of electric circuit, the algebraic sum of the electromotive forces and voltage drops is equal to zero.



KVL eqn is

$$\boxed{E - V_1 - V_2 = 0}$$

* Superposition Theorem

In any linear bilateral active network containing more than one source, the current in any branch is the sum of current in that branch when each source is acting separately while all other sources are replaced by their internal resistance.

PAGE No
DATE / /

* Thevenins theorm

In any linear bilateral Active network between given two point can be replaced by its equivalent consisting of single voltage source and serise resistance.
The voltage source is equal to open circuit voltage between given two terminals and the series resistance is the equivalent resistance between two given terminals.

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

* Norton's theorm

Any two terminal network can be replaced by a single current source of magnitude I_N in parallel with a single resistance R_N.

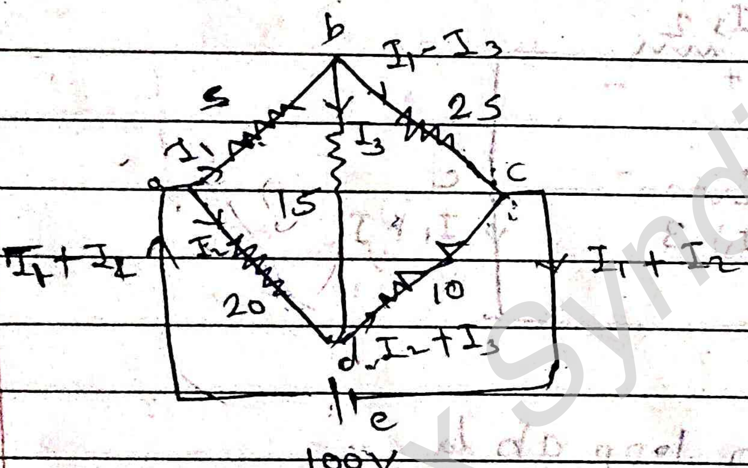
$$\boxed{I_L = I_N \frac{R_N}{R_L + R_N}}$$

* Maximum power transfer theorem.

Maximum power is transfer when load resistance R_L is equal to internal resistance of the source R_i i.e. the condition for maximum power transfer is $R_L = R_i$

$$\boxed{P_{max} = \frac{V_s^2}{4R_L}}$$

Find the current through each branch using KCL / KVL each.



For loop abda

$$-I_1 5 - 15 I_3 + 20 I_2 = 0 \quad (1)$$

~~bdcb~~ bcdb

$$-25(I_1 - I_3) + 10(I_2 + I_3) + 15 I_3 = 0$$

$$-25I_1 + 25I_3 + 10I_2 + 10I_3 + 15I_3 = 0$$

$$-25I_1 + 10I_2 + 50I_3 = 0 \quad \text{—} (2)$$

adcea

$$-\cancel{I_1+I_2} - 20I_2 - 10I_2 + 10I_3 - \cancel{I_1+I_2} + 100 = 0$$

$$\cancel{-2I_1 - 32I_2 - 10I_3 + 100 = 0} \quad \text{—} (3)$$

$$-20I_2 - 10I_2 - 10I_3 + 100 = 0$$

$$-30I_2 - 10I_3 + 100 = 0 \quad \text{—} (3)$$

$I_1 = 4.946A$ $\quad$ $I_2 = 2.688\,A$ $\quad$ $I_3 = 1.935\,A$

$I_1 = 4.94A \rightarrow$ current through $5\,\Omega$

$I_2 = 2.688\,A \rightarrow$ current through $20\,\Omega$

$I_3 = 1.935\,A \rightarrow$ current through $15\,\Omega$

current through $10\,\Omega = I_2 + I_3 = 2.68 + 1.93$

$= 4.61\,A$

current through $25\,\Omega = I_1 - I_3 = 4.94 - 1.93\,A$

$= 3.01\,A$

current through battery $= I_1 + I_2 = 4.94A + 2.688A$

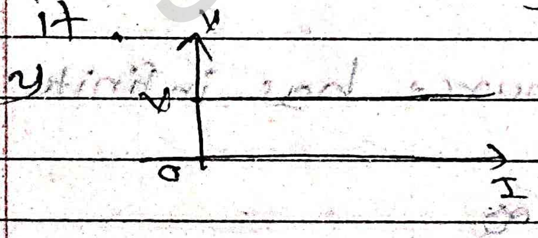
$= 7.62\,A$

* Types of source and source transformation

- source
  - Independent
    - voltage
      - Ideal
        - constant
        - variable
      - Practical
    - current
      - Ideal
      - practical
        - Constant
        - variable
  - dependent
    - voltage
    - current

* Ideal constant voltage sourse

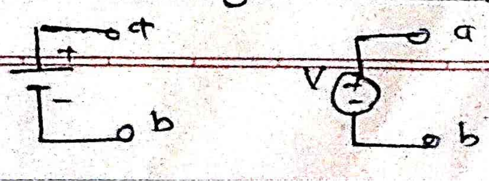
1) The source for which voltage remain constant for any value of current dron from it.

2) 

③ The internal resistance of Ideal voltage source is zero

$$R_i = \frac{\Delta V}{\Delta I} = 0$$

④ an Ideal voltage source is represented by



* Practical

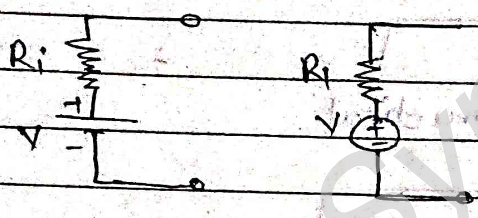
1) A source for which the voltage decreases with increasing current.

2)

3) The internal resistance of practical voltage source is finite

$$R_i = \frac{\Delta V}{\Delta I} = \text{finite}$$

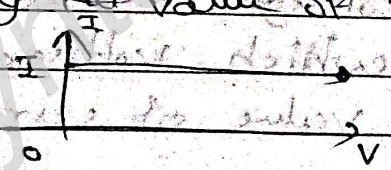
(4)



* Ideal constant current source

1) A source for which current remains constant for any value of voltage across it.

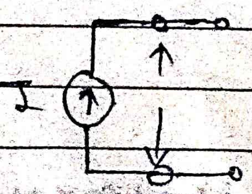
2)



3) Ideal current source has infinite internal resistance.

$$R_i = \frac{\Delta V}{\Delta I} = \infty$$

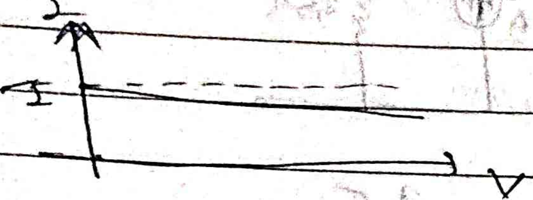
(4)



Practical

① A current source for which current decreases with increase in voltage

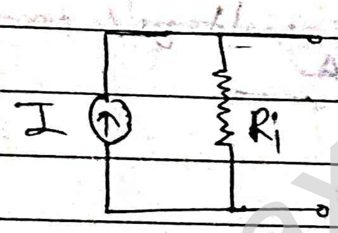
②



③ ~~Ide~~ practical current source has finite internal resistance

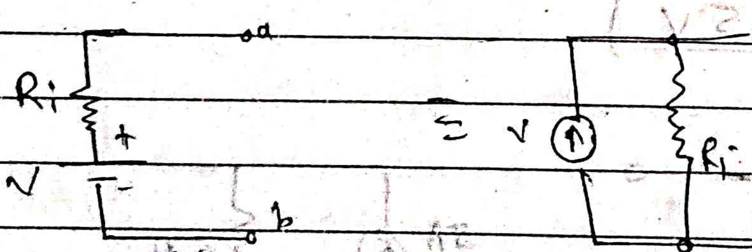
$$R_i = \frac{\Delta V}{\Delta I} = \text{finite}$$

④

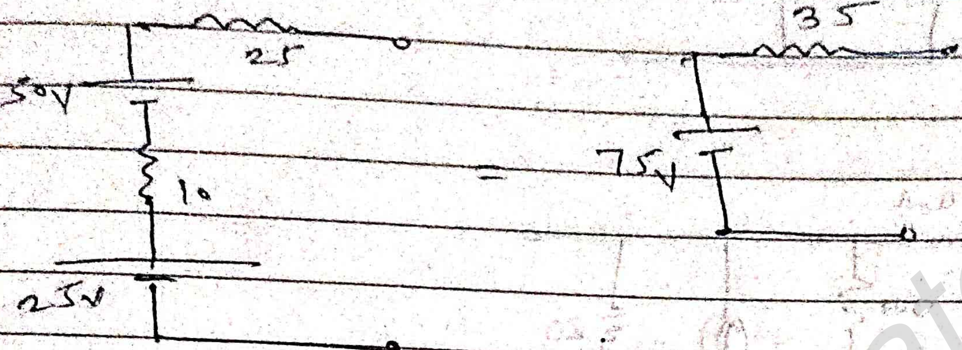


* source Transformation

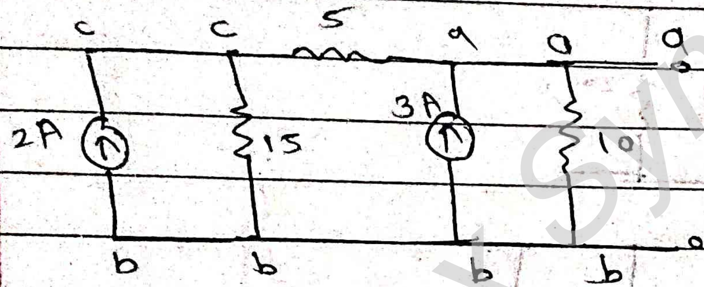
voltage source → current source

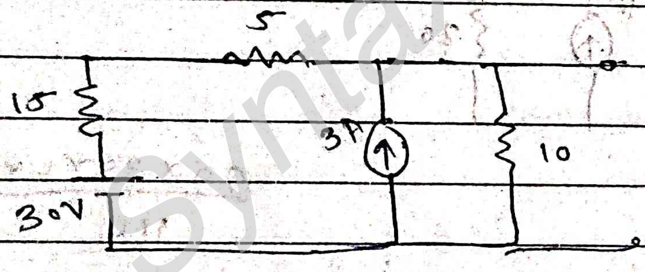


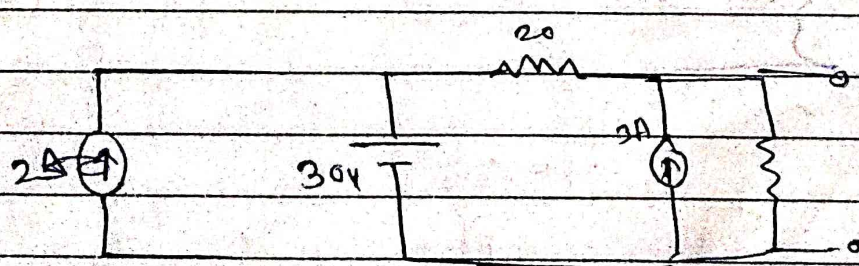
Q.ii) convert the following into single voltage source and series resistance

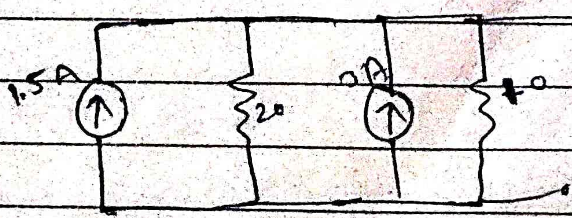


(1)

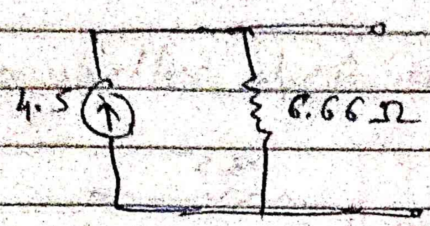




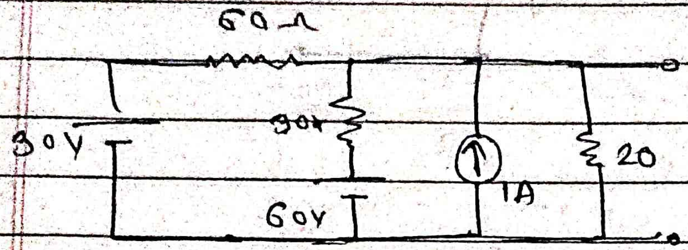


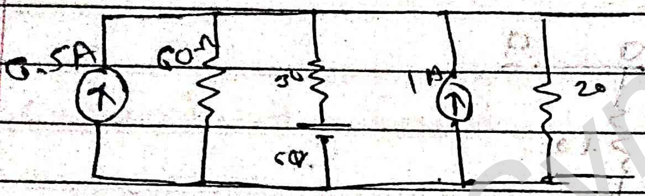


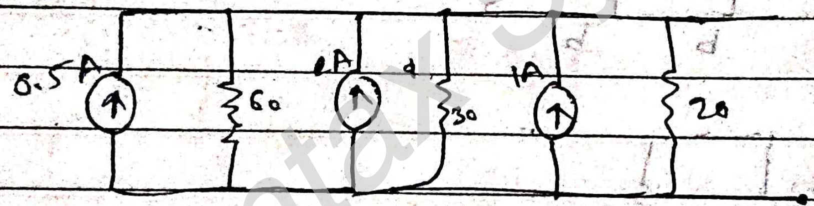
$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

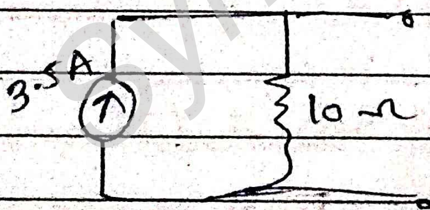


(2)





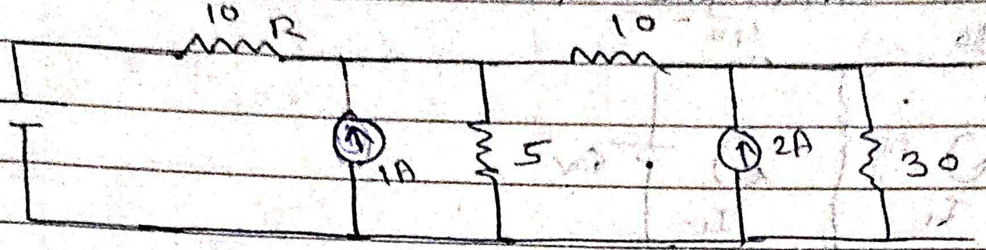


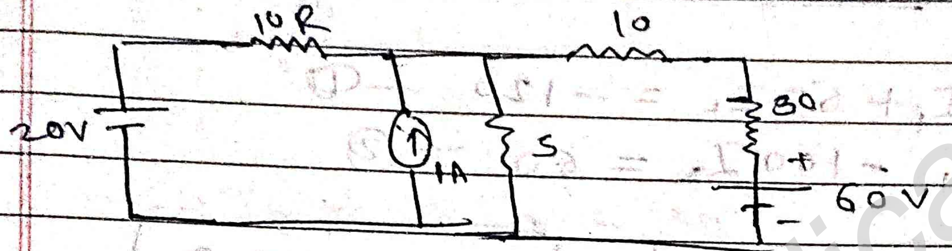


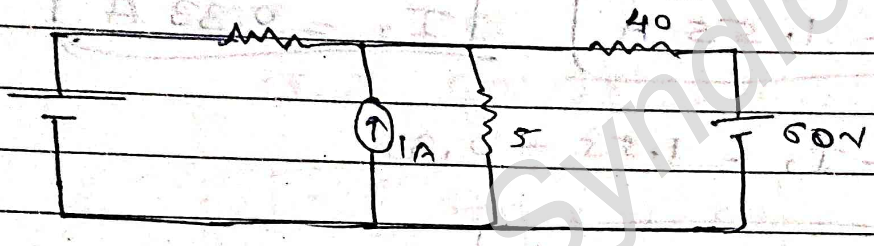
$\frac{60 \times 30 \times 20}{110}$

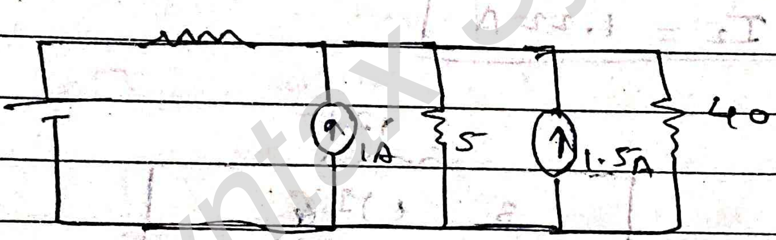
Note - do not convert the resistor in which current is to be found out in voltage or current source.

Find current from resistor R

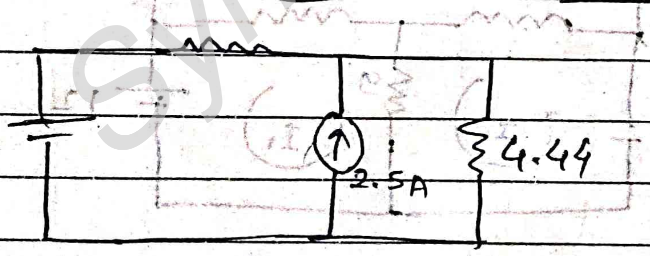


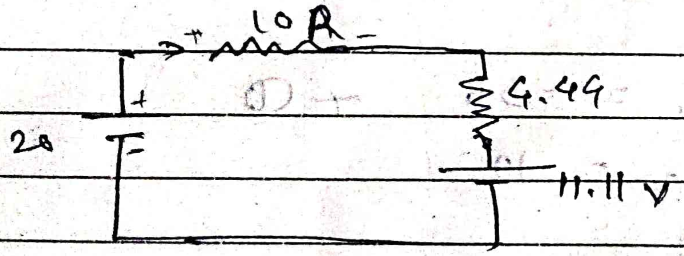






$\frac{40 \times 5}{45}$ 9





$20 - 10 \times I - 4.4 I - 11 = 0$

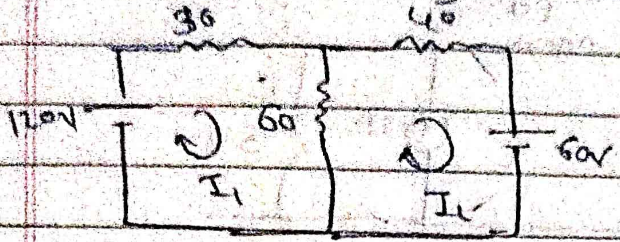
$9 - 14.4 I = 0$

$14.4 I = 9$

$\boxed{I = 0.625 A}$

$I_1 = X = 1.55$
$I_2 = Y = 0.333$

* Mesh Analysis

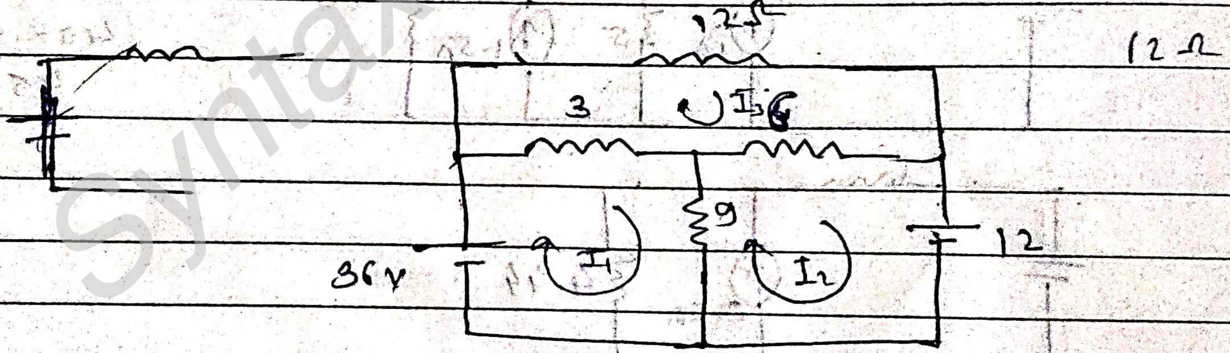


$$-90I_1 + 60I_2 = -120 \quad \text{— (1)}$$
$$6I_1 - 100I_2 = 60 \quad \text{— (2)}$$

$\boxed{I_1 = 1.55\ A}$ $\boxed{I_2 = 0.33\ A}$

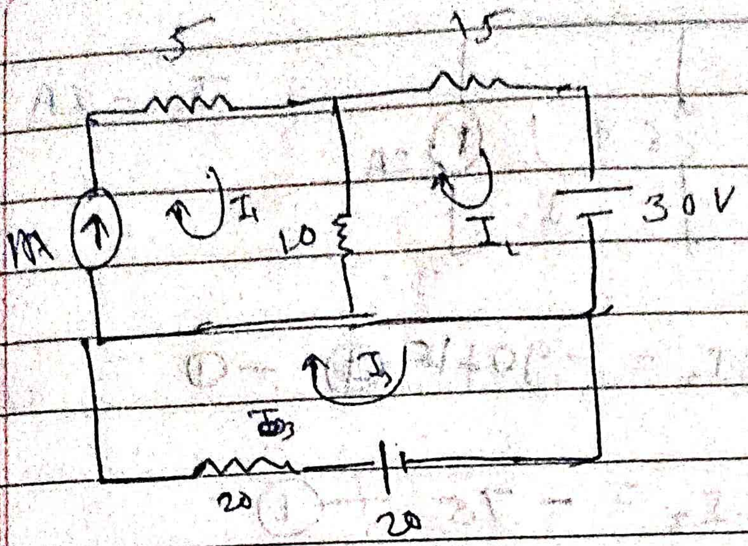
$I_{60} = I_1 - I_2 = 1.55 - 0.33$

$\boxed{I_{60} = I_1 - I_2 = 1.22\ A}$



$$3I_3 - 12I_1 + 9I_2 = -36 \quad \text{— (1)}$$
$$4I_3 + 9I_1 - 15I_2 = 12$$
$$-21I_3 + 3I_1 + 6I_2 = 0$$

$I_3 = 2A$, $I_1 = 6.36$, $I_2 = 3.81\ A$



$-25 I_2 + 10 I_1 = 30$

$-25 I_2 = 20$

$I_2 = \frac{20}{25}$

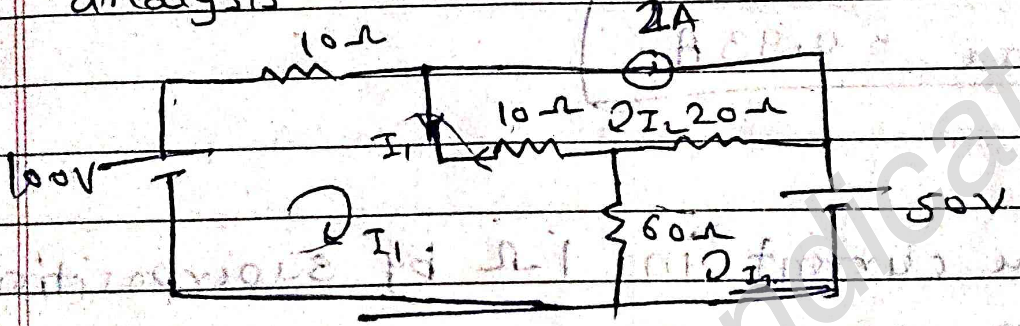
$\boxed{I_2 = -0.8\ A}$

$-20 I_3 = -20$

$\boxed{I_3 = 1\ A}$

7M

① Q. Find the current through 60 Ω by mesh analysis



$$-10 I_1 - 10(I_1 - I_2) - 60(I_1 - I_3) + 100 = 0$$

$$-10 I_1 - 10 I_1 + 10 I_2 - 60 I_1 + 60 I_3 = -100$$

$$-80 I_1 + 10 I_2 + 60 I_3 = +100 \quad \text{—— ①}$$

$I_2 = 2A$

$$-80 I_1 + 20 + 60 I_3 = +100$$

$$-80 I_1 + 60 I_3 = -120 \quad \text{—— ①}$$

$$-20(I_3 - I_2) - 50 + 60(I_3 - I_1) = 0$$

$$-20 I_3 + 20 I_2 - 60 I_3 + 60 I_1 = 50$$

$$60 I_1 - 80 I_3 + 40 = 50$$

$$60 I_1 - 80 I_3 = 10 \quad \text{— ②}$$

from eqn ① and ②

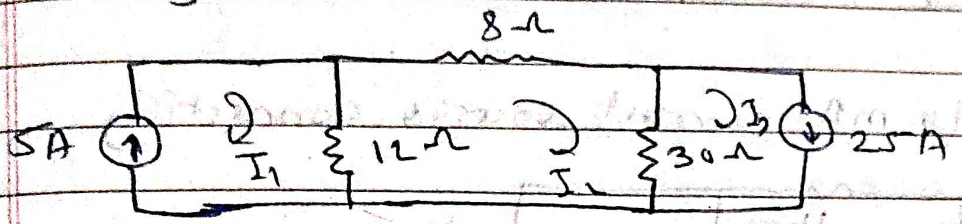
$$\boxed{I_1 = 3.21 \text{ A}}$$

$$\boxed{I_3 = 2.28 \text{ A}}$$

$$I_{60} = I_1 - I_3 = 3.21 - 2.28 = 0.93 \text{ A} \downarrow$$

$$\boxed{I_{60\Omega} = 0.93 \text{ A}}$$

5) Find the current through 8Ω by mesh analysis



$I_1 = 5A$ — ①

$I_3 = 25A$ — ②

$-8I_2 - 12(I_2 - I_1) - 30(I_2 - I_3) = 0$

$-8I_2 - 12I_2 + 12I_1 - 30I_2 + 30I_3 = 0$

$50I_2 = 12I_1 + 30I_3$

$50I_2 = 12 \times 5 + 30 \times 25$

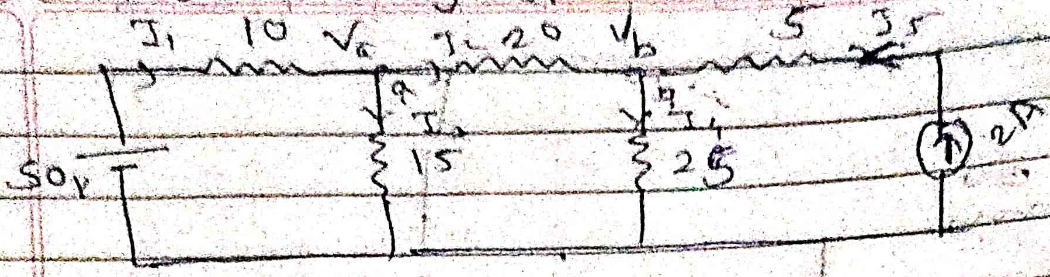
$I_2 = \frac{810}{50}$

$\boxed{I_2 = 16.2A}$

$I_{8\Omega} = I_2$

$\boxed{I_{8\Omega} = 16.2A}$

Nodal Analysis.



Find current through 20 Ω

apply kcl at node a

$$I_1 - I_2 - I_3 = 0 \quad \text{--- (1)}$$

at node b

$$I_2 - I_4 + I_5 = 0 \quad \text{--- (2)}$$

$$I_1 = \frac{50 - V_a}{10}$$

$$I_2 = \frac{V_a - V_b}{20}$$

$$I_3 = \frac{V_a - 0}{15}$$

$$I_4 = \frac{V_b - 0}{25}$$

$$I_5 = 2A$$

$$\frac{50 - V_a}{10} - \frac{V_a - V_b}{20} - \frac{V_a}{15} = 0$$

$$\frac{6(50 - V_a) - 3(V_a - V_b) - 4V_a}{60} = 0$$

$$300 - 6V_a - 3V_a + 3V_b - 4V_a = 0$$

$$13V_a - 3V_b = 300 \quad \text{--- (3)}$$

$$\frac{(V_a - V_b)}{20} - \frac{V_b}{25} + 2 = 0$$

$$\frac{5(V_a - V_b) - 4V_b + 200}{100} = 0$$

$$5V_a - 5V_b - 4V_b + 200 = 0$$

$$5V_a - 9V_b = -200 \quad \text{--- (4)}$$

$V_a = 19.32$ $\qquad$ $V_b = 16.28$

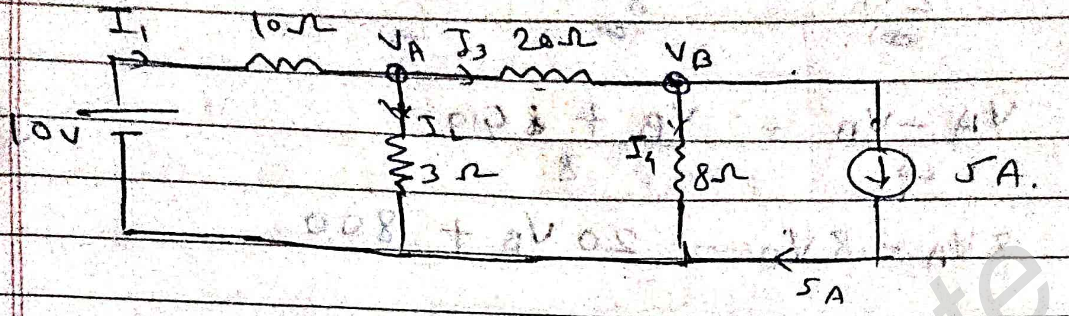
~~$V_a = 27.94$~~ $\qquad$ $V_b = 21.07$

I_{20}

$\boxed{V_a = 32.35}$ $\qquad$ $\boxed{V_b = 40.19}$

4M

① Find Nodal valtage V_A and V_B



At node A

$$I_1 = I_2 + I_3 \quad — ①$$

~~at node B~~

$$I_3 = I_4 + I_5$$

$$I_1 = \frac{10 - V_A}{10} \qquad I_2 = \frac{V_A}{3} \qquad I_3 = \frac{V_A - V_B}{20}$$

$$I_4 = \frac{V_B}{8} \qquad I_5 = 5$$

$$\frac{10 - V_A}{10} = \frac{V_A}{3} + \frac{V_A - V_B}{20}$$

$$\frac{10 - V_A}{\cancel{10}} = \frac{20V_A + 3V_A - 3V_B}{\cancel{60}\,6}$$

$$60 - 6V_A = \frac{23V_A - 3V_B}{6}$$

$$29V_A + - 3V_B = 60 \quad — ③$$

$$\frac{V_A - V_B}{20} = \frac{V_B + 40}{8}$$

$$\frac{V_A - V_B}{20} = \frac{V_B + 40}{8}$$

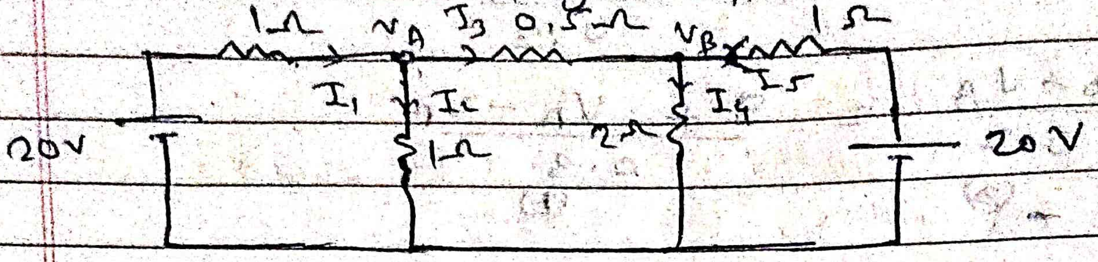
$$8V_A - 8V_B = 20V_B + 800$$

$$8V_A - 28V_B = 800 \quad \text{—— (4)}$$

$$\boxed{V_A = -0.91V}$$

$$\boxed{V_B = -28.83V}$$

(5) Find Nodal voltage V_A and V_B



At node A

$I_1 = I_2 + I_3$ —(1)

At node B

$I_4 = I_3 + I_5$ —(2)

$I_1 = \frac{20 - V_A}{1}$ $\quad I_2 = \frac{V_A}{1}$

$I_3 = \frac{V_A - V_B}{0.5}$ $\quad I_4 = \frac{V_B}{2}$

$I_5 = \frac{20 - V_B}{1}$

eqn (1) becomes

$20 - V_A = V_A + \frac{V_A - V_B}{0.5}$

$20 - V_A = V_A + 2V_A - 2V_B$

$\boxed{4V_A - 2V_B = 20}$ —(3)

eqn (2) become

$\frac{V_B}{2} = \frac{V_A - V_B}{0.5} + 20 - V_B$

$$\frac{V_B}{2} = 2V_A - 2V_B + 20 - V_B$$

$$\frac{V_B}{2} = 2V_A - 3V_B + 20$$

$$V_B = 4V_A - 6V_B + 40$$

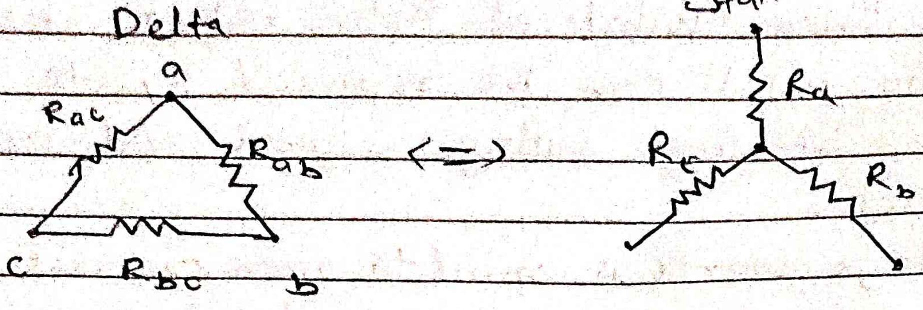
$$4V_A - 7V_B = -40 \quad — (4)$$

$$\boxed{V_A = 11\ V}$$

$$\boxed{V_B = 12\ V}$$

PAGE No.
DATE / /

* Star / delta transformer

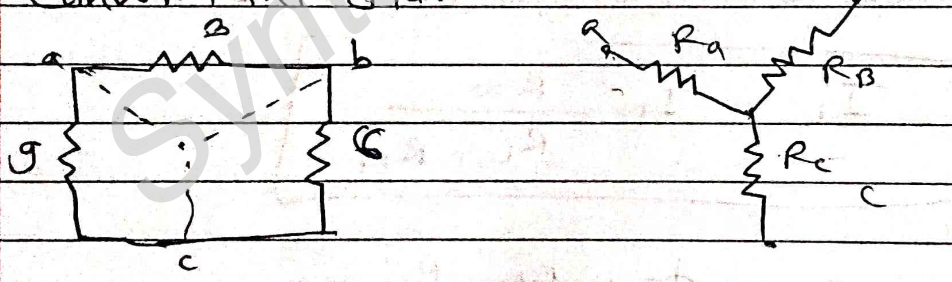


$$R_a = \frac{R_{ca} R_{ab}}{R_{ac} + R_{ab} + R_{bc}} \qquad R_{ab} = R_a + R_b + \frac{R_a R_b}{R_c}$$

$$R_b = \frac{R_{bc} R_{ab}}{R_{ab} + R_{bc} + R_{ca}} \qquad R_{bc} = R_b + R_c + \frac{R_b R_c}{R_a}$$

$$R_c = \frac{R_{ac} \cdot R_{bc}}{R_{ab} + R_{bc} + R_{ca}} \qquad R_{ac} = R_a + R_c + \frac{R_a R_c}{R_b}$$

Convert int star



$$R_a = \frac{R_{ab} + R_{ac}}{R_{ab} + R_{bc} + R_{ac}} = \frac{3 \times 9}{3+9+6} = \frac{27}{18}$$

$$\boxed{R_a = 1.5\,\Omega}$$

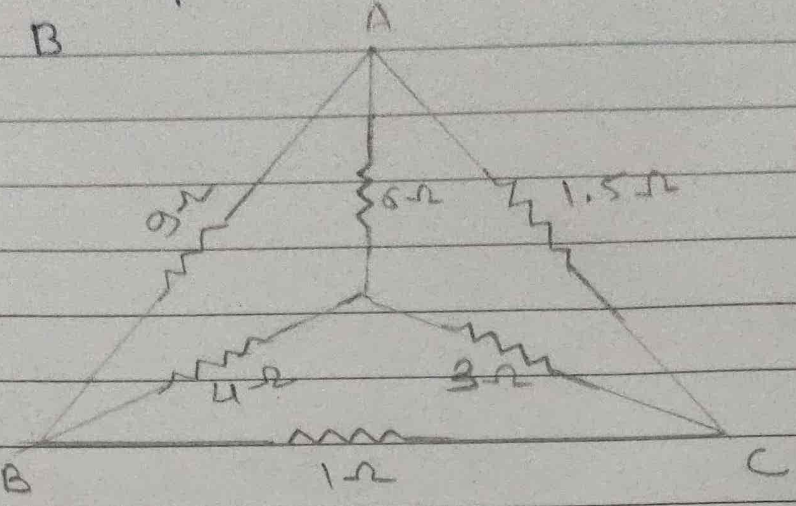
$$R_c = \frac{6 \times 9}{3+9+6} = \frac{54}{18}$$

$$\boxed{R_c = 1}$$

$$R_b = \frac{3 \times 6}{3+9+6}$$

$$R_b = 1$$

Find an equivalent resistance between terminals A and B



Convert star into delta.

$$R_{AB} = R_A + R_B + \frac{R_A R_B}{R_C}$$

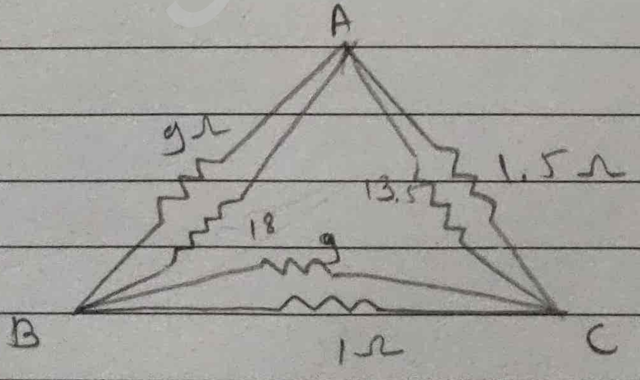
$$R_{AB} = 6 + 4 + \frac{6 \times 4}{3} = 18\,\Omega.$$

$$R_{BC} = 4 + 3 + \frac{4 \times 3}{6}$$

$$\boxed{R_{BC} = 9\,\Omega}$$

$$R_{AC} = 6 + 3 + \frac{6 \times 3}{4}$$

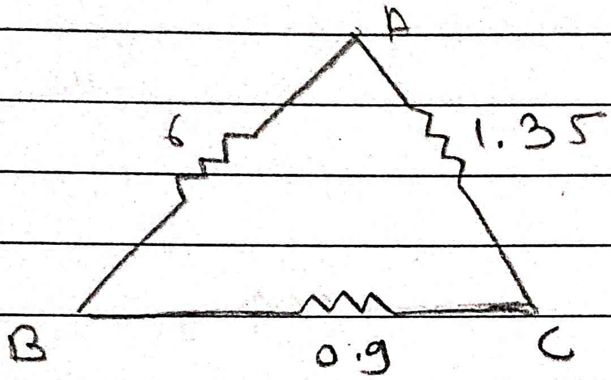
$$\boxed{R_{AC} = 13.5\,\Omega}$$



$$R_{AB} = \frac{9 \times 18}{27} = 6\,\Omega$$

$$R_{BC} = \frac{9 \times 1}{10} = 0.9\,\Omega$$

$\boxed{R_{AC} = 13.5\,\Omega}$ $\qquad R_{AC} = \frac{13.5 \times 1.5}{15} = 1.35$



$$R_{AB\,eq} = R_{AB} \parallel R(AC + AC)$$

$$= \frac{6 \times (0.9 + 1.35)}{6 + (0.9 + 1.35)}$$

$$= \frac{13.5}{8.25}$$

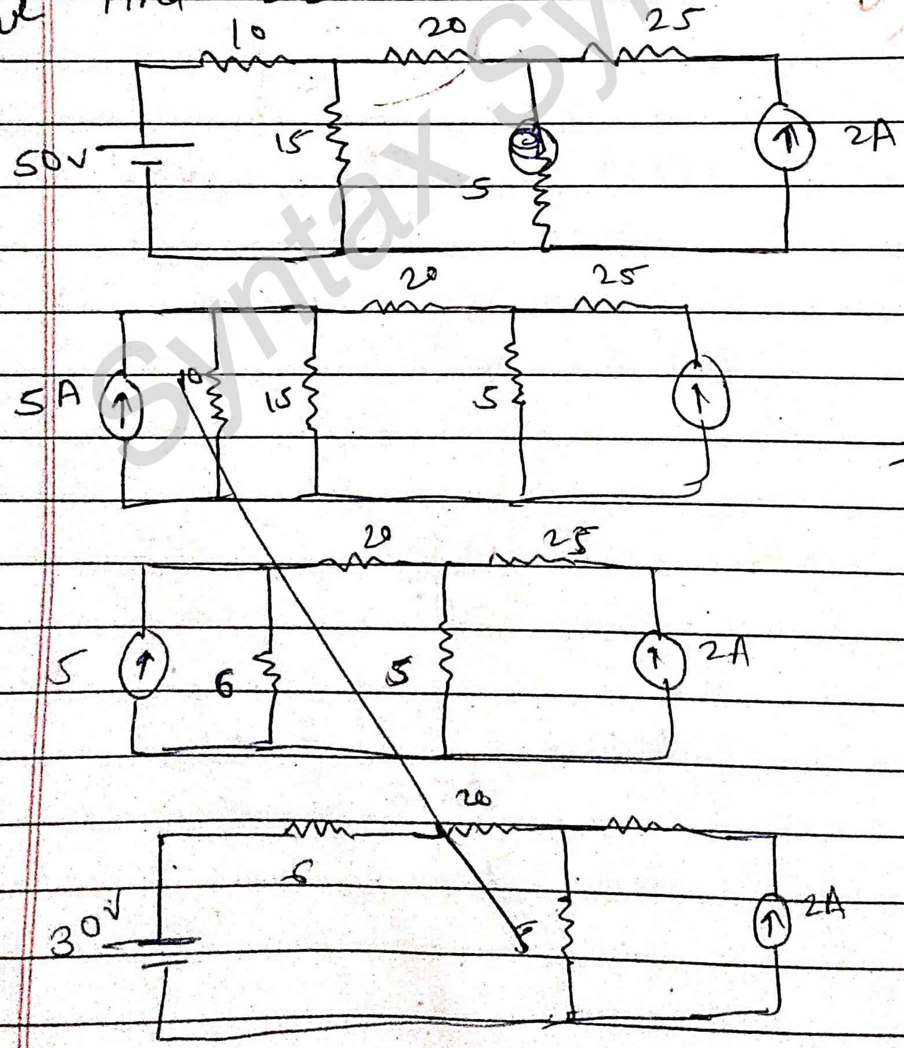
$$\boxed{R_{AB} = 1.636\,\Omega}$$

* Supperposition Theorm
This theorm is applicable for linear network only.

Statement - In any linear bilateral active network containing more than one source, The current in any branch is the sum of current in that Branch when each source is acting separately while all other sources are replaced by their internal resistance

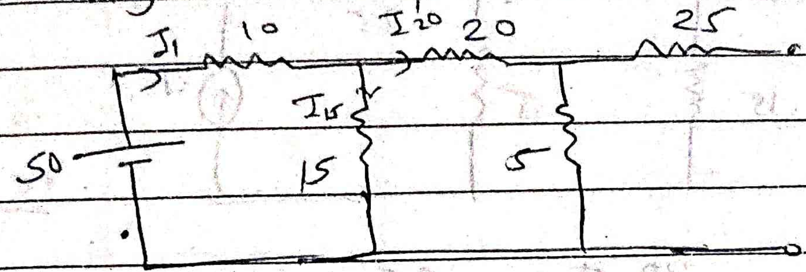
Que Find I_{20}

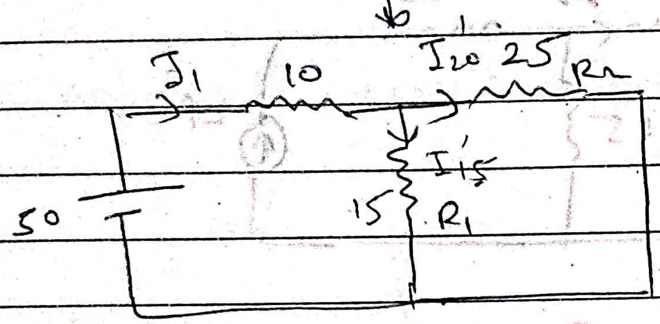
Find current through 20 Ω



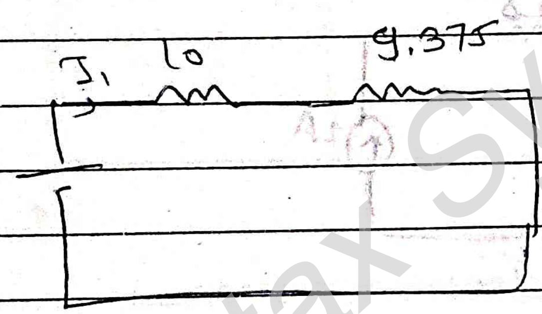
$\frac{\cancel{10}^{2}\times\cancel{15}^{3}}{\cancel{25}_{5}}$

① only 50V source connected





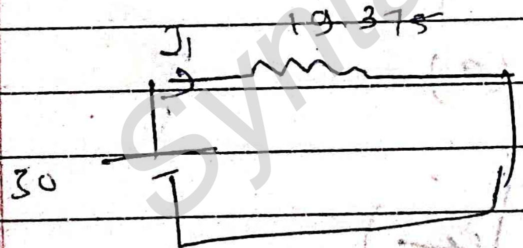
$$\frac{25 \times 15}{40} = 9.375$$



$$I_{20} = \left(\frac{R_1}{R_1+R_2}\right) I_1$$

$$I_{20} = \left(\frac{15}{40}\right) 2.58$$

$$\boxed{I_{20} = 0.967 \text{ A} \rightarrow}$$



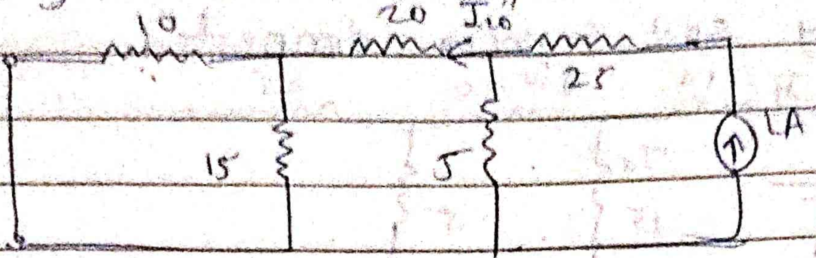
$$I_1 = \frac{50}{19.37} = 2.58 \text{ A}$$

$$I'_{20} = \frac{15}{40} \times 2.58$$

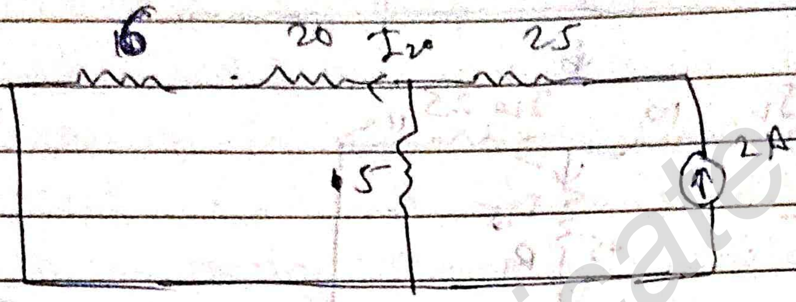
$$\boxed{I'_{20} = 0.967 \text{ A} (\rightarrow)}$$

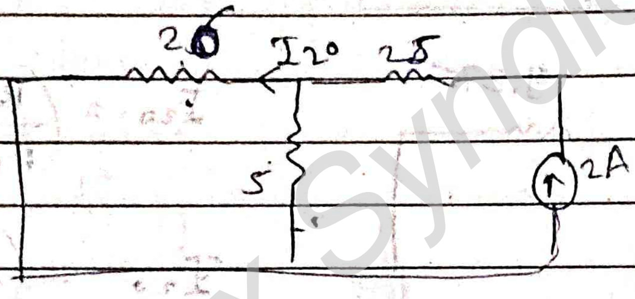
$$\left(\frac{R_1}{R_1+R_2}\right) I$$

only 2A source connected



10×15





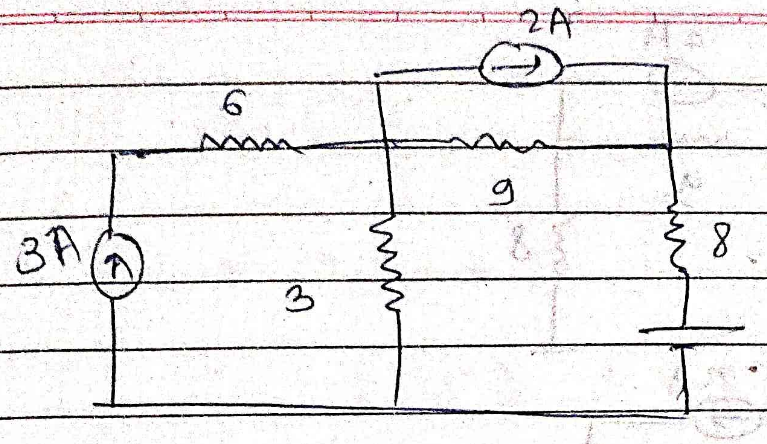
$$I_{20}'' = \frac{5}{26 + 5}(2)$$

$$\boxed{I_{20}'' = 0.32\ A}\ (\leftarrow)$$

$$I_{20} = I_{20}' + I_{20}''$$

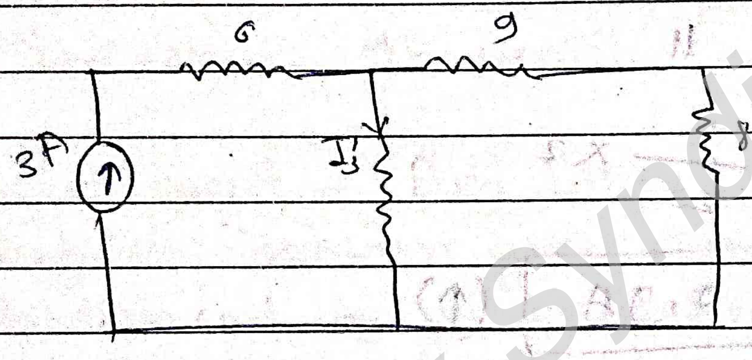
$$= 0.967(\rightarrow) + 0.32(\leftarrow)$$

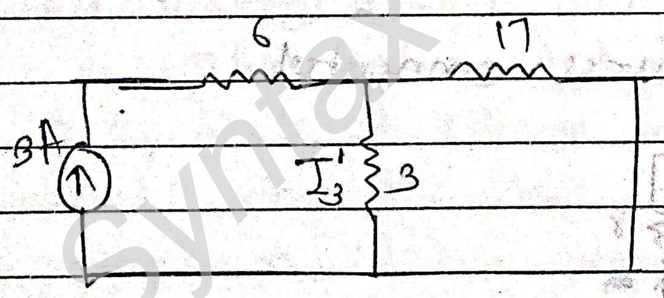
$$\boxed{I_{20} = 0.656(\rightarrow)\ A}$$



Find current through 3 Ω

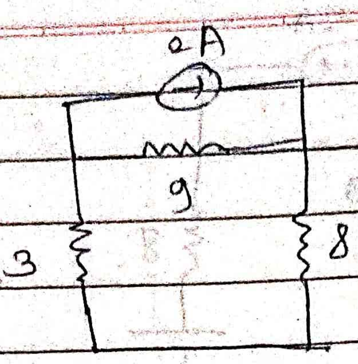
only 3A current source connected

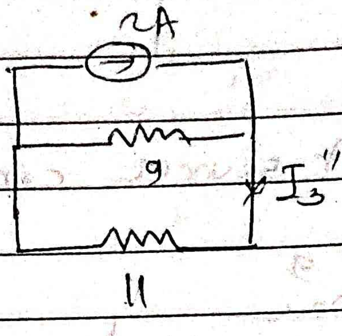




$$I_3' = \frac{17}{20} \times 3$$

$$\boxed{I_3' = 2.55A} \ (\downarrow)$$

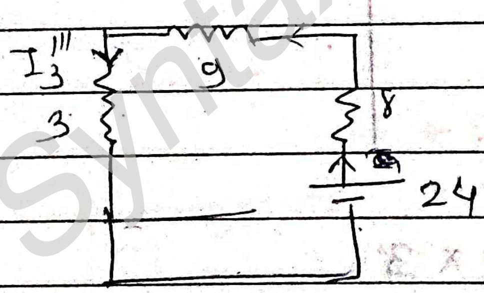


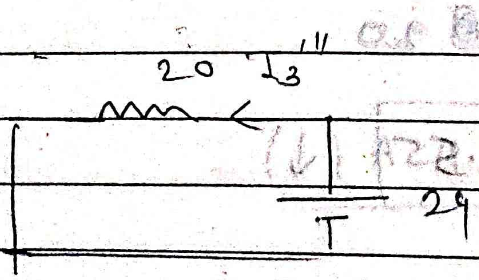


$$I_3'' = \frac{9}{20} \times 2$$

$$\boxed{I_3'' = 0.9A} \; (\uparrow)$$

only 24 V source connected





$$I_3 = \frac{24}{20}$$

$$\boxed{I_3''' = 1.2\,A \,(\downarrow)}$$

$$I_3 = I_3' + I_3'' + I_3'''$$

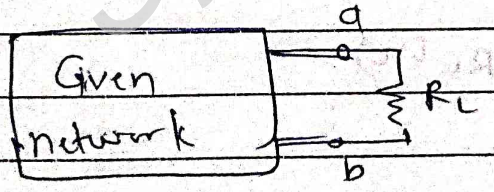
$$= 2.55\downarrow + 0.9\uparrow + 1.2\downarrow$$

$$= 3.75\downarrow + 0.9\uparrow$$

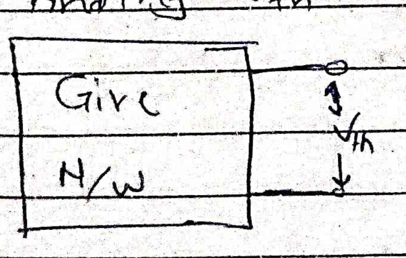
$$\boxed{I_3 = 2.85\downarrow A}$$

* Thevenin's theorem

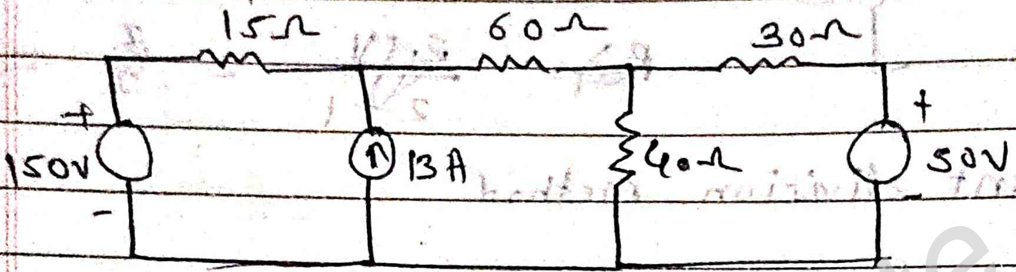
statement - Any linear Bilateral Active network between given two point can be replaced by its equivalent consisting of single voltage source and series resistance. The value of voltage source is equal to open circuit voltage between given two terminals and the series resistance is the equivalent resistance between two given terminals.

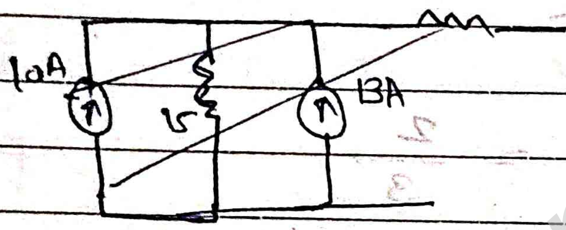


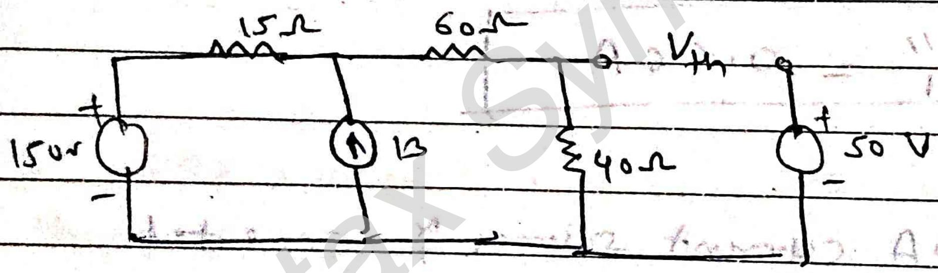
i) Finding V_{th}

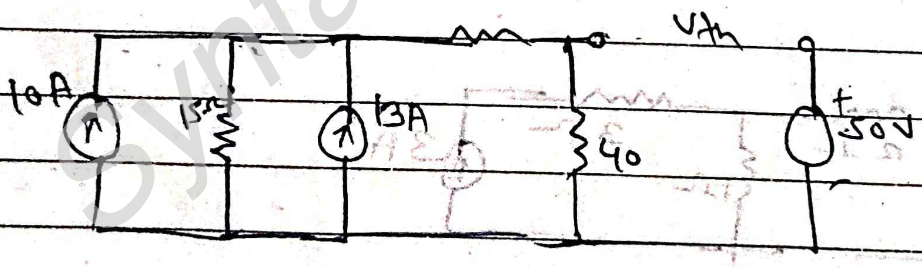


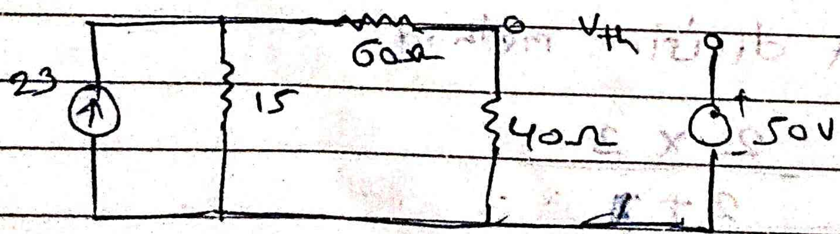
(3) Find the current through 30 Ω by thevenin theorem

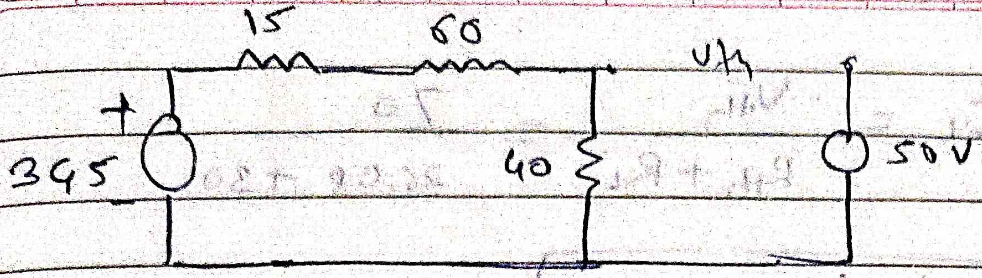


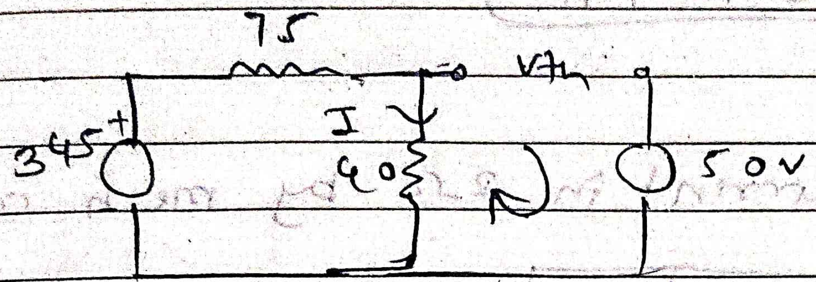












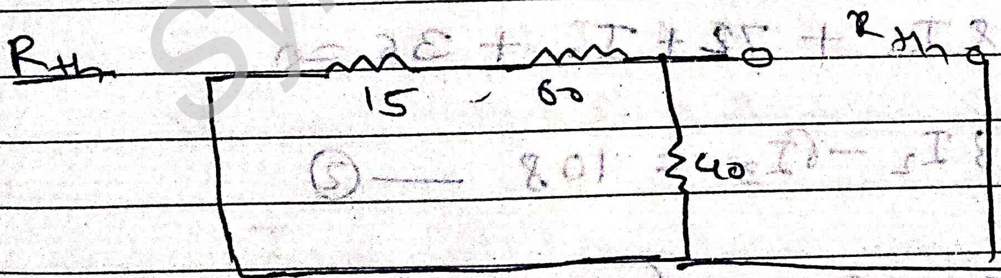
$$I = \frac{345}{115}$$

$$\boxed{I = 3\ A}$$

$$-V_{th} - 50 + 40I = 0$$

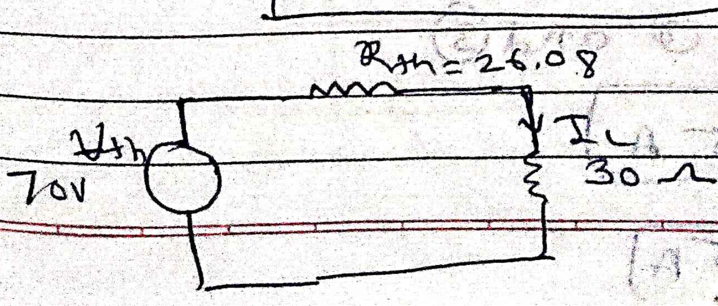
$$V_{th} = -50 + 40 \times 3$$

$$\boxed{V_{th} = 70\ V}$$



$$R_{th} = \frac{75 \times 40}{75 + 40}$$

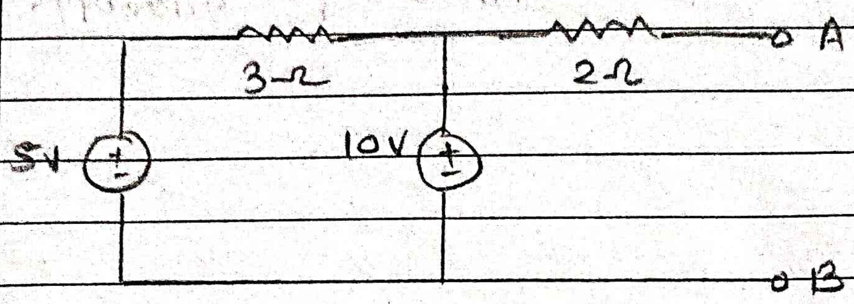
$$\boxed{R_{th} = 26.08}$$



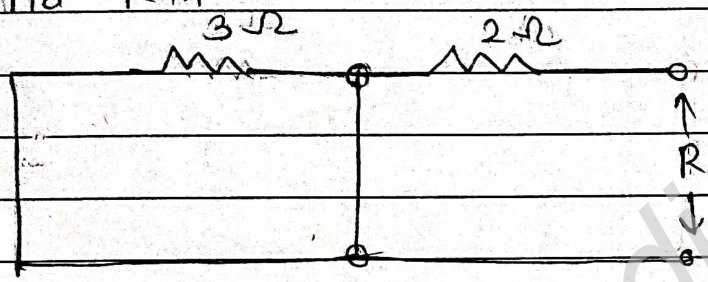
$$I_L = \frac{V_{th}}{R_{th} + R_L} = \frac{70}{26.08 + 30}$$

$$\boxed{I_L = 1.24\ A}$$

Q4) Find Thevenin's and Norton's equivalent circuit across A & and B.

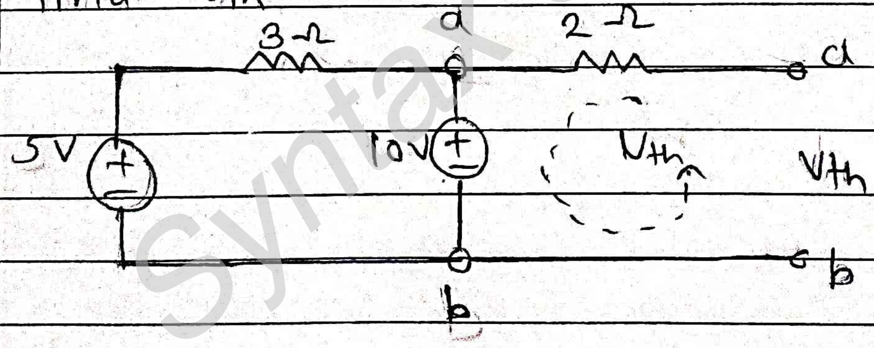


Find R_{th}



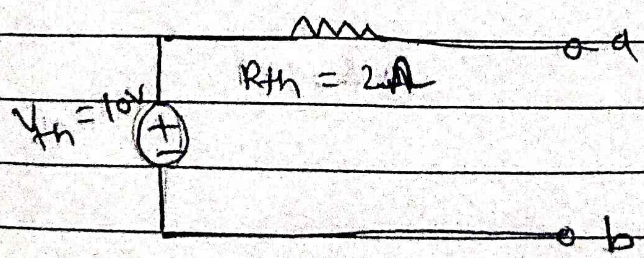
$$\boxed{R_{th} = 2\,\Omega}$$

Find V_{th}

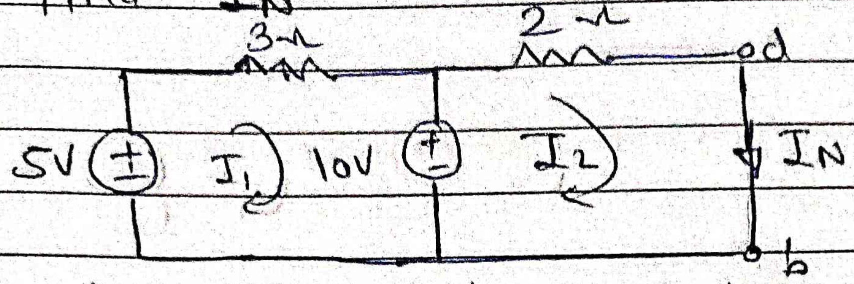


$$\boxed{V_{th} = 10\,V}$$

Thevenins equivalent circuit is



Find I_N



by the mesh Analysis

$$-3I_1 - 10 + 5 = 0$$

$$I_1 = \frac{-5}{3}$$

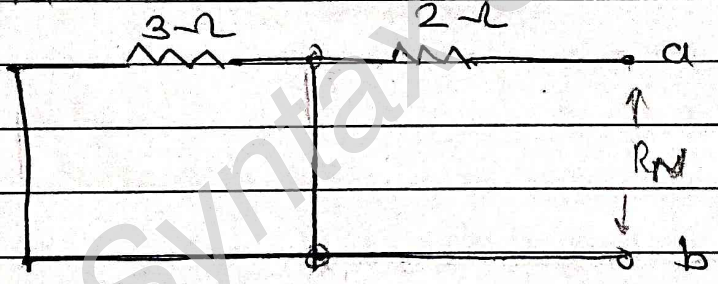
$$\boxed{I_1 = -1.667A}$$

$$-2I_2 + 10 = 0$$

$$\boxed{I_2 = 5A}$$

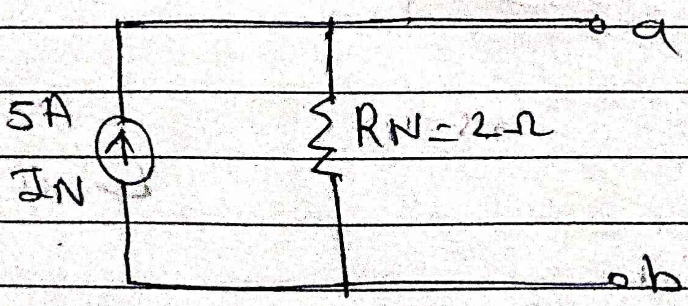
$$\boxed{I_2 = I_N = 5A}$$

Find R_N



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

Norton equivalent circuit is



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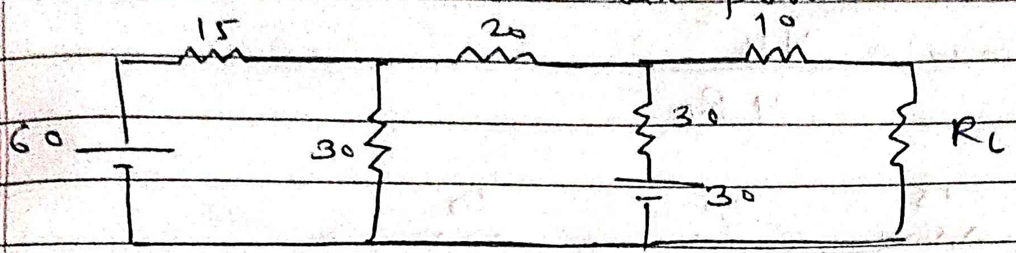
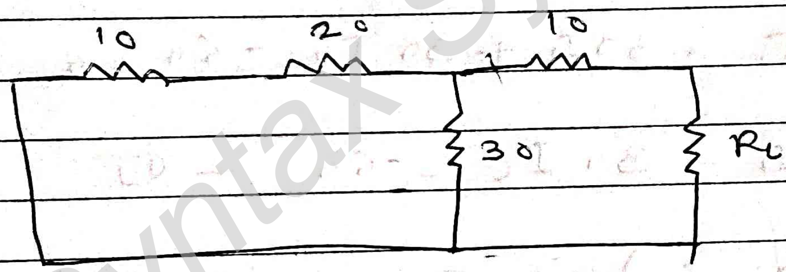
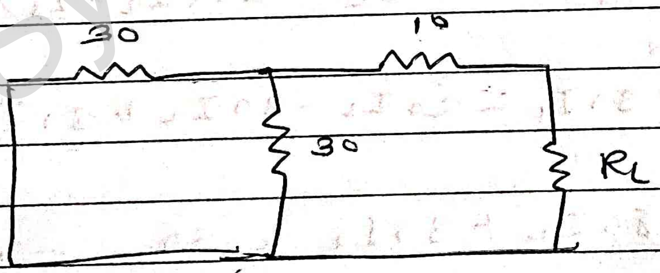
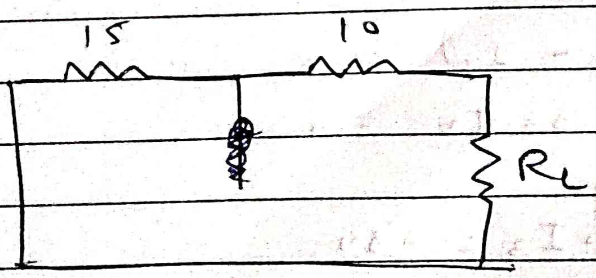
Que Find the value of R_L for max power transfer
Find the value of max power

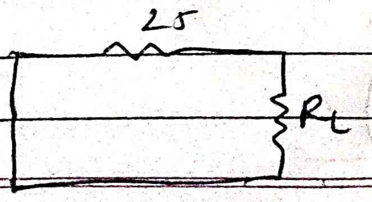


we know that for max power transfer
$R_L = R_i$





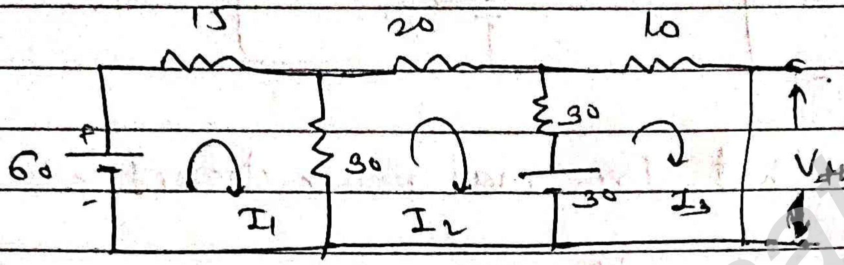




$\boxed{R_L = 25\,\Omega}$

Value of R_L for maximum power transfer is 25Ω

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



by mesh analysis

$-60 - 15I_1 - 30(I_1 - I_2) = 0$

$-15I_1 - 30I_1 + 30I_2 - 60 = 0$

$45I_1 - 30I_2 = -60$ — ①

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

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

$30I_1 - 80I_2 + 30I_3 = 30$ — ②

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

$30 - 3I_3 + 30I_2 = 0$

$30I_2 - 30I_3 = -30$

$\boxed{I_1 = 1.44\,A}$

$$\boxed{I_3 = 0.1667\ A}$$

$$\boxed{I_2 = 1.1667\ A}$$

$$-V_{th} + 30 + 0.567 \times 10 = 0$$

$$\boxed{V_{th} = 35\ V}$$

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

$$= \frac{35^2}{4 \times 25}$$

$$\boxed{P_{max} = 12.25\ W}$$