*** Ohm's Law:** It states that the voltage across the two terminals of a conducting material is proportional to the current flowing through it.

$V \propto I$

$V = RI$ volts $\Rightarrow R = \frac{V}{I}\ \Omega$

$$\boxed{R = \rho \frac{l}{A}}$$

*** EMF & Potential Difference:** EMF is independent on the current & resistance magnitude. But The potential difference depends on current & resistance magnitude.

EMF $\Rightarrow$ Cause
P.d. $\Rightarrow$ Effect.

*** Open circuit:** $I = 0,\ R = \infty$.

*** Short circuit:** $I = I_{S.C.}$ $R_{S.C.} = 0$ $V_{S.C.} = 0$.

*** Limitations of Ohm's Law:** Ohm's law cannot be applied for open circuit & short circuit.

*** Note:**

When elements obeys the ohm's law then it is called as linear element

Every linear element should obey the Bidirectional property but not vice-versa.

If $\frac{V}{I}$ (slope of V vs I) is +ve in both dir^n, then it is passive element.

$C > 0$
$L > 0$
$R > 0$

If $\frac{V}{I}$ is -ve in one or both co-ordinates then it is active element

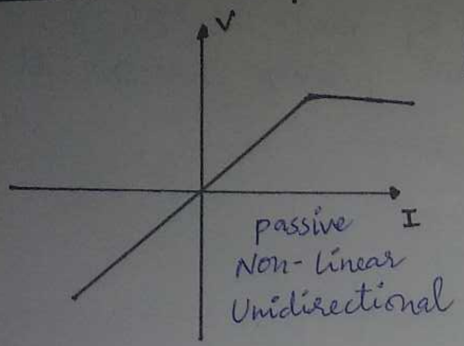
Condition: Above two are valid only when characteristic is passing through origin.

when elements obeys the bidirectional property, characteristic should be identical in opposite co-ordinates but not in adjacent co-ordinates.

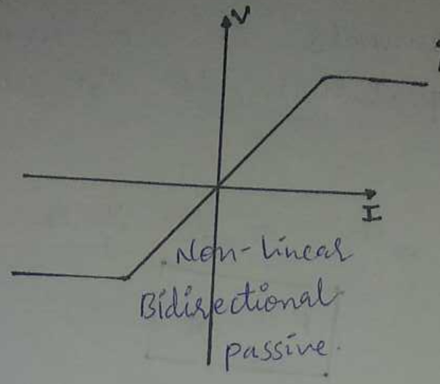
If in adjacent co-ordinates or not identical in opposite co-ordinates then unidirectional.

example: Linear / Non-Linear / Active / Passive / Bidirectional / Unidirectional.

i)



ii)



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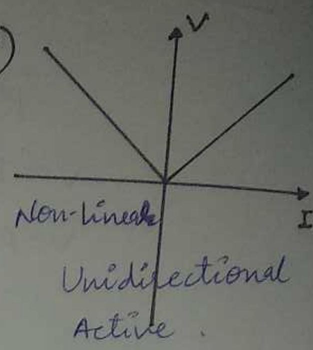

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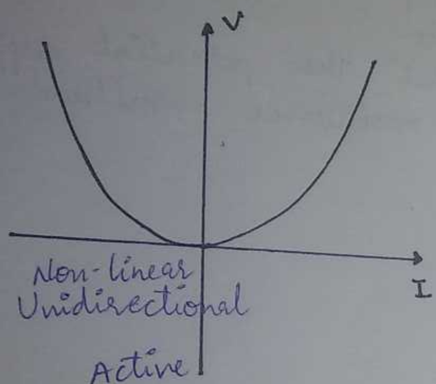
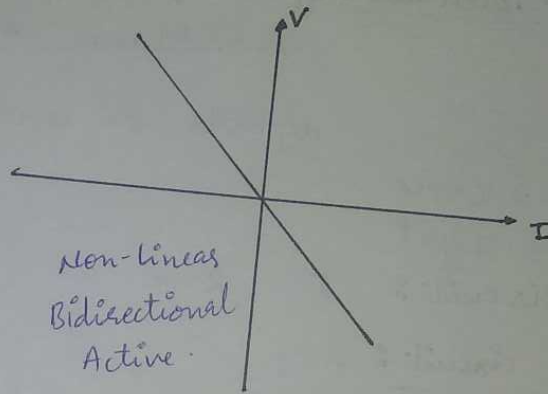


v)



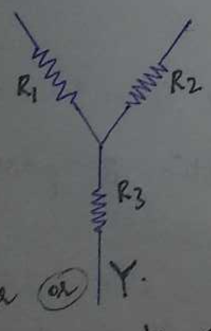
* **Node:** Junction of two or more elemental points.

* **Loop:** loop is a closed path where the transversal ends upon the starting node.

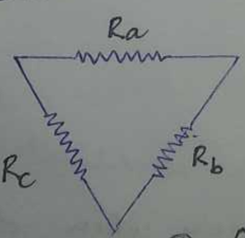
* **Mesh:** Mesh is a loop that does not contain any other loop within it.

* **Independent Mesh:** $\boxed{M = \underbrace{B}_{\text{No. of Branches}} - \underbrace{N}_{\text{Nodes}} + 1}$

* **Star Delta Transformation:**



star or Y.



Delta or Δ.

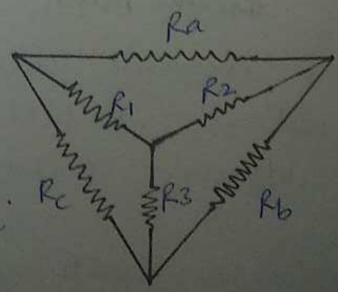
* **Delta to star:**

$R = \dfrac{\text{Product of adjacent sides}}{\text{sum of all.}}$

$R_1 = \dfrac{R_a R_c}{R_a + R_b + R_c}$.

$R_2 = \dfrac{R_a R_b}{R_a + R_b + R_c}$.

$R_3 = \dfrac{R_b R_c}{R_a + R_b + R_c}$.



When resistance of equal value transformed from Delta to star Resistance value decreased by 3 times.

* Star to Delta:

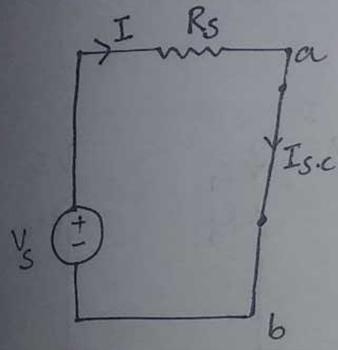
$$R = \frac{\text{sum of all possible products of two elements}}{\text{Resistance of opposite side}}$$

$$R_a = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3} = \frac{\Delta}{R_3}.$$ Let, $R_1R_2 + R_2R_3 + R_3R_1 = \Delta$.

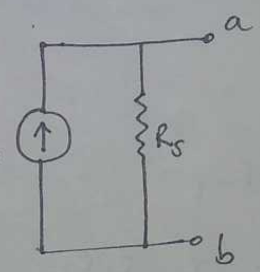
$$R_b = \frac{\Delta}{R_1}. \qquad R_c = \frac{\Delta}{R_2}.$$

* Source Transformation:

By using source Transformation, It is possible to find response of load resistance but not in the internal resistance.



$\Rightarrow I_{s.c.}$

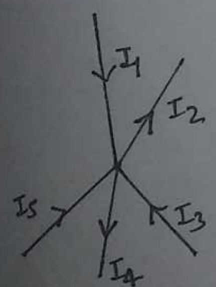


$V_{ab} = V_{o.c.}$

$V_s = I_s \cdot R_s$.

Kirchoff's current law:

Algebraic sum of current going away from and coming towards a node is zero.



$I_1 - I_2 + I_3 - I_4 + I_5 = 0$

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

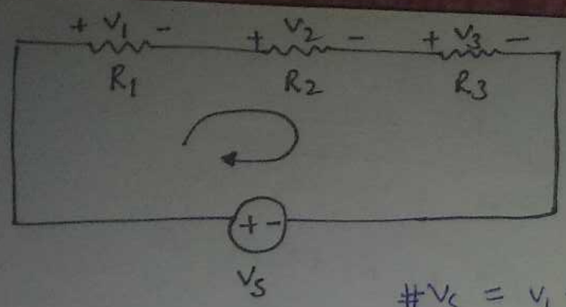
Incoming current = +ve.

outgoing current = -ve.

KCL gives unknown node voltage, This is consequence of charge conservation.

Kirchoff's voltage Law:

The algebraic sum of voltage drops (or rise) in the loop or mesh, in specific direction is zero.



voltage drop = +ve.

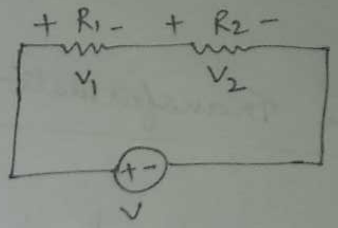
voltage rise = -ve

$-V_s + V_1 + V_2 + V_3 = 0$

$V_s = V_1 + V_2 + V_3$

This KVL is consequence of energy conservation.

Voltage Division Rule:

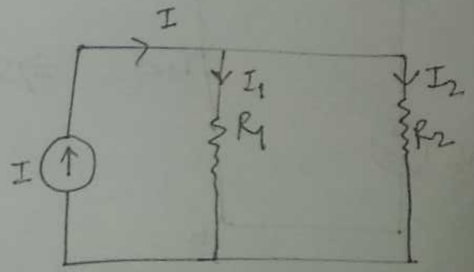


$I = \frac{V}{R_{eq.}} = \frac{V}{R_1+R_2}$.

$\boxed{V_1 = I \cdot R_1 = \frac{V}{R_{eq.}} \cdot R_1}$

$\boxed{V_2 = \frac{R_2}{R_1+R_2} \cdot V}$

Current Division Rule:



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

$I_1 = \frac{V_1}{R_1} = \frac{I \cdot R_{eq.}}{R_1} = \frac{I}{R_1} \frac{R_1 R_2}{R_1+R_2}$

$\therefore \boxed{I_1 = \frac{R_2}{R_1+R_2} \cdot I}$ |||ly $\boxed{I_2 = \frac{R_1}{R_1+R_2} \cdot I}$

$\therefore$

* Mesh Analysis:

i) Identify total no. of meshes in given network

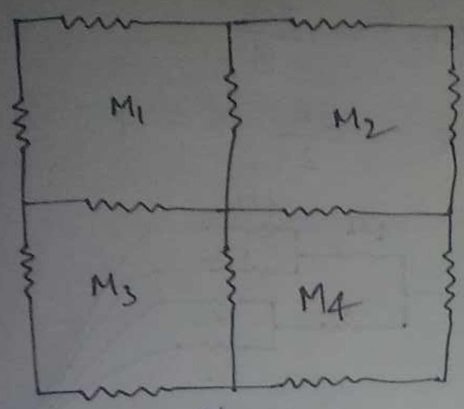
ii) Assign the current direction for each mesh.

iii) Develop KVL eqn^n for each mesh.

iv) By solving KVL eqn^n, find loop current

Total no. of eqn^{ns} is equal to total no. of meshes.

Planar Network: No cross over circuit.

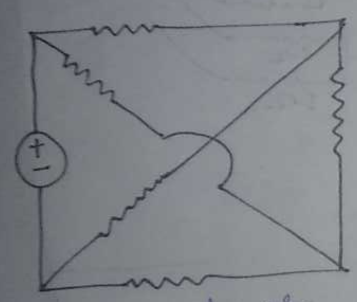


Planar

Mesh = 4

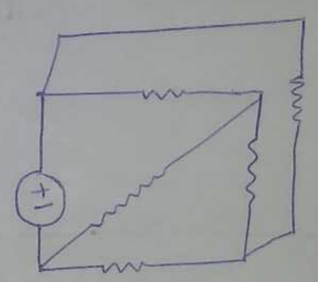
Loop = 11

Non-Planar network: Cross over other current.

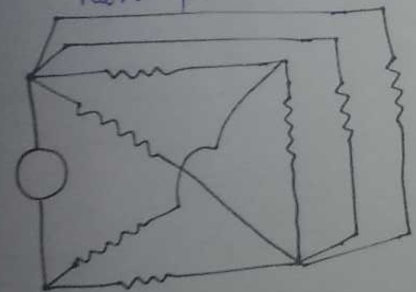


Non-planar

$\Rightarrow$



Planar.



Non-planar Network

Nodal analysis can be applied for both planar & Non-planar networks.

procedure

(I) Identify total no. of principle nodes of the network.

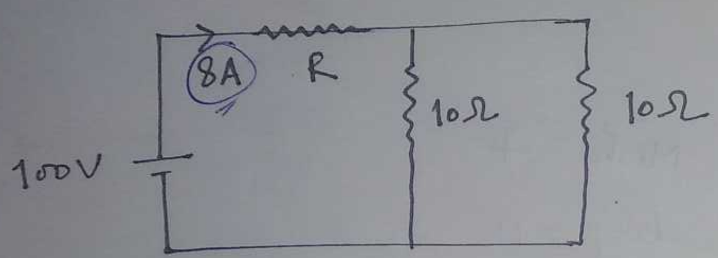
(II) Assign the voltage at each node. one of the node is taken as a reference node and the reference potential. The potential should be ground potential.

(III) Develop KCL at each non reference node.

(IV) By solving KCL eqn, we find node voltage.

(V) Total no. of eqns = N − 1
↳ No. of nodes

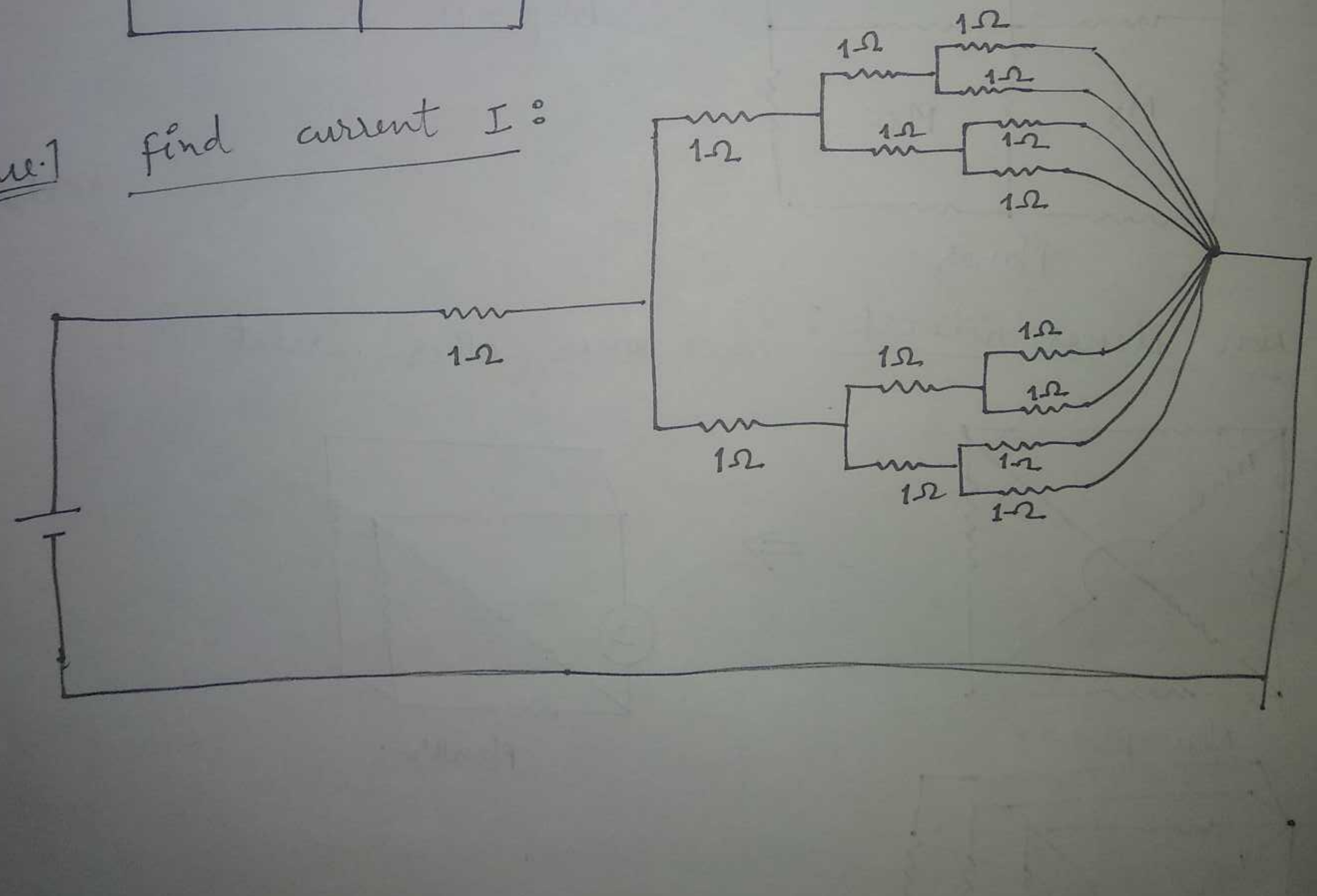
Que.1 Find Resistance R:



$$(R+5) = \frac{100}{8}$$

$$R = \frac{25}{2} - 5 = 7.5\ \Omega.$$

Que.1 find current I:



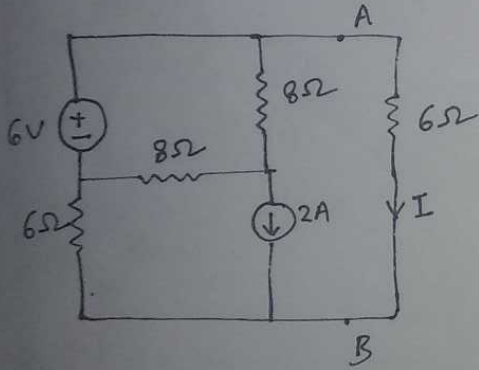
* **Theorems:** If the network is having ~~more~~ no. of nodes & more no. of meshes ~~…~~ then response in any one of the branches can be easily obtained by using Theorems.

1) **Superposition Theorem:** In any linear bidirectional circuit having more than one independent sources, the response in any one of the branch is equal to algebraic sum of the responses caused by individual source, while the rest of source ~~are~~ is replaced by internal resistance.

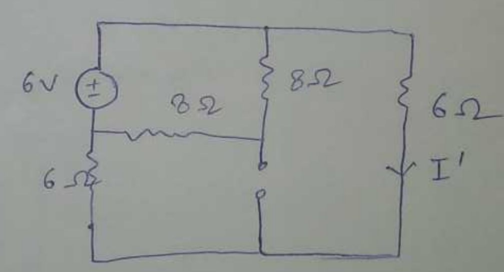
Current source is opened circuit.

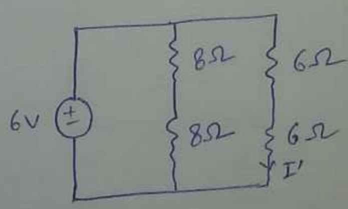
Voltage source is short circuit.

ex) Find the value of I by using superposition Theorem :-



Case-1) current source open circuit

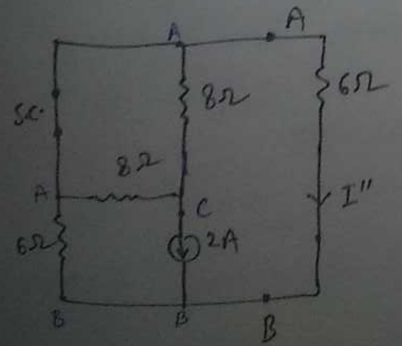


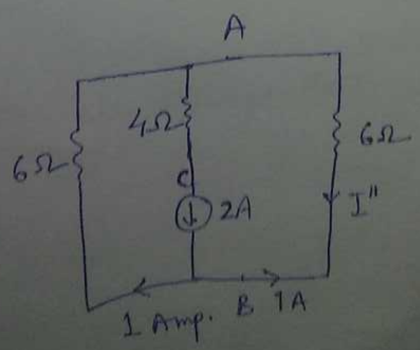


$I' = \frac{V_s}{6+6}$

$= \frac{6}{12} = 0.5A$

Case-2) voltage source short circuit:





$I'' = -1\,A.$

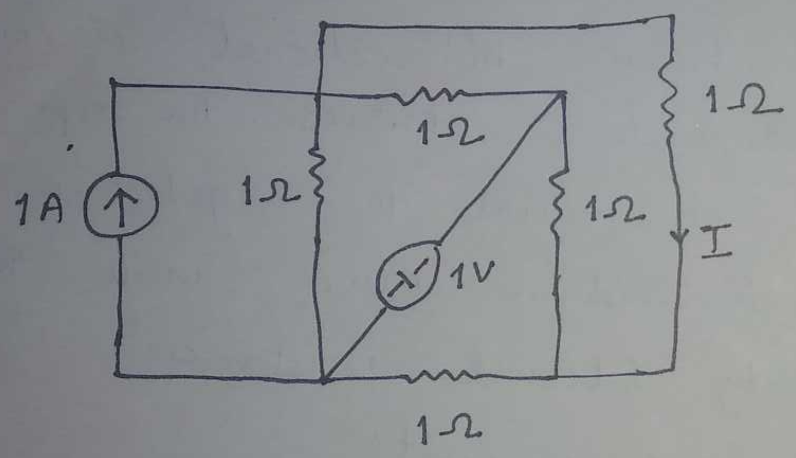
$I = I' + I''$

$= 0.5 - 1$

$\boxed{I = -0.5A.}$

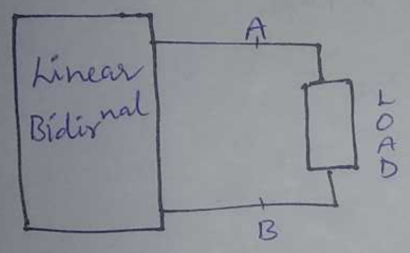
Ans.

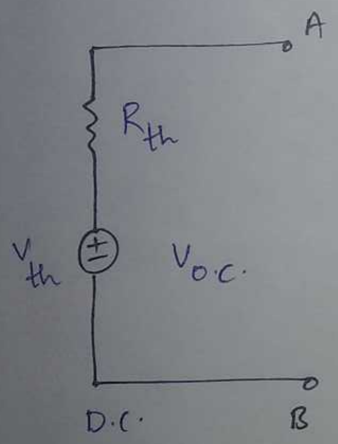
Que.] Find value of I using super position Theorem.

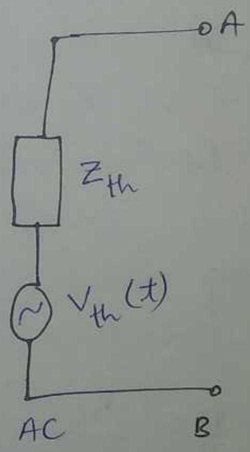


2) Thevenin's Theorem:

In any Linear Bidirectional circuit having more no. of active & passive elements, It can be replaced by single equivalent circuit. consisting of equivalent voltage source (V_{th}) in series with equivalent resistance (R_{th}) where, V_{th} is the open circuit voltage w.r. to load terminals & R_{th} is an equivalent resistance w.r.t. load terminals when all the independent sources are deactivated.







To Find V_{th}:

To find o.c. voltage (V_{th}), remove load resistance.

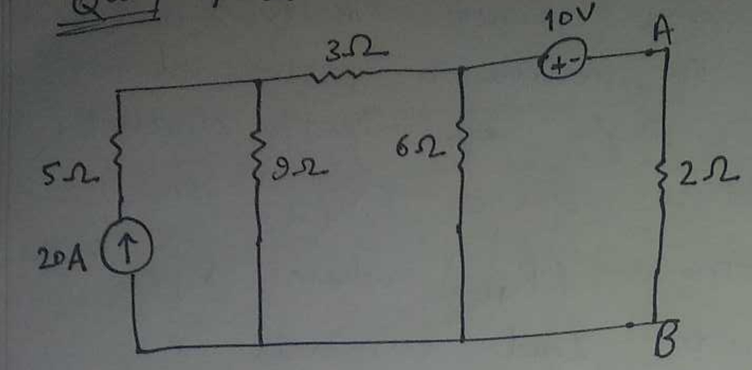
To Find R_{th}:

Deactivate all independent source.

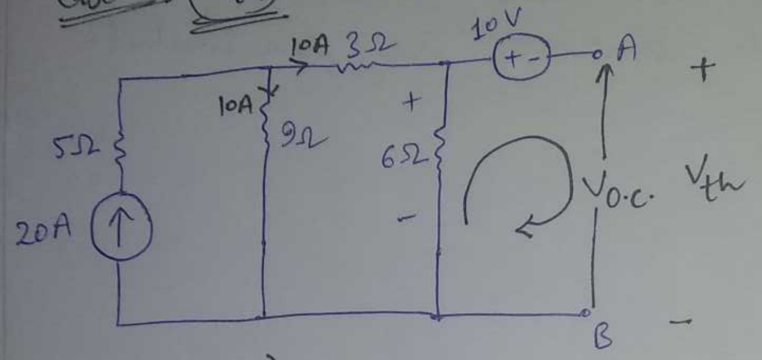
current source ⇒ O.C.

voltage source ⇒ S.C.

Que] Find current in the 2Ω resistance.



Case-1) (V_{th}): Load Resistance 2Ω will be removed.

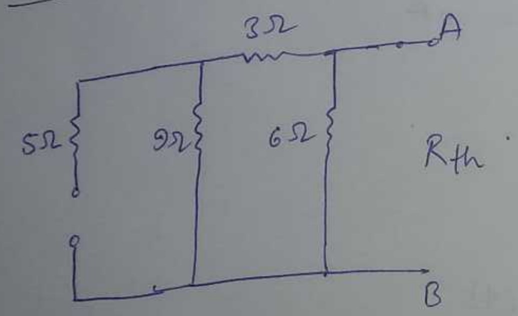


KVL

$10V + V_{th} - 60V = 0$

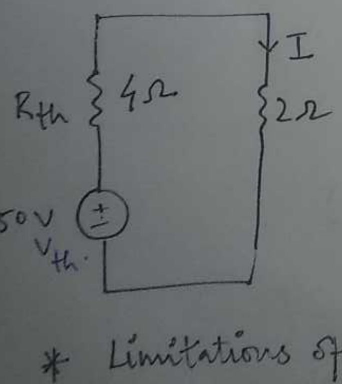
$V_{th} = 50V.$

Case-II) (R_{th}):



$(9+3) \parallel 6\Omega$

$R_{th} = 4\Omega$



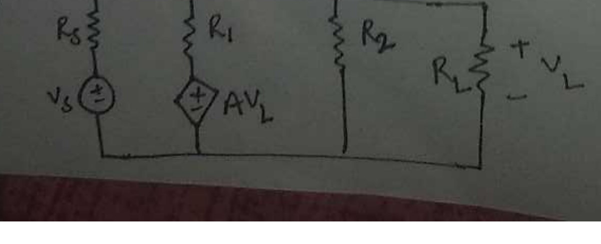
$I = \frac{V_{th}}{R_{th}+R_L} = \frac{50}{4+2} = \frac{50}{6}$

$= \frac{25}{3} = 8.33$ Amp.

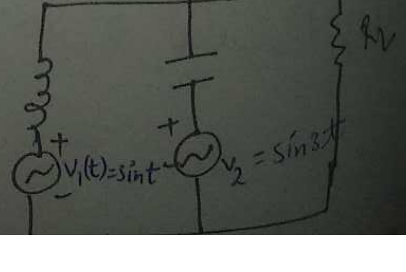
* Limitations of Thevenin's Theorem:

① When dependent source value depends on load component Thevenin's Theorem can not be applied.

(b) (I)



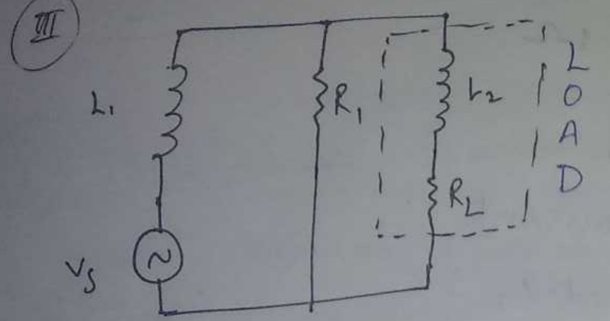
(II)



(2) If the sources have unequal values of frequency, Thevenin's Thm. cannot be applied.

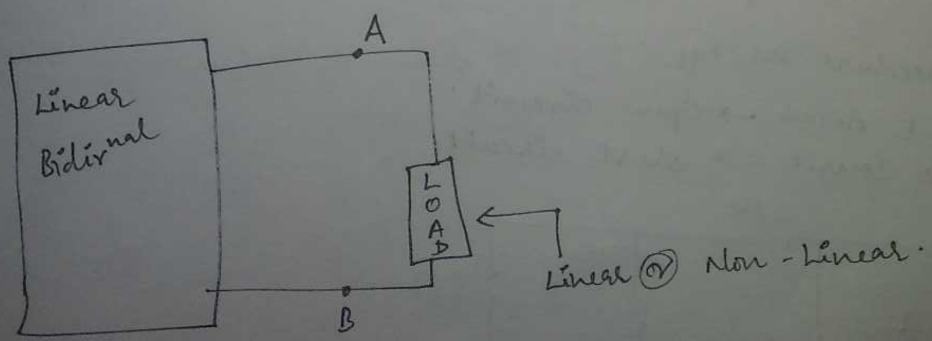
(3) When the mutual Inductance depends on Load component Thevenin's Thm. can not be applied.

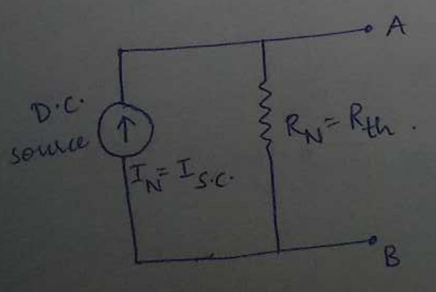
(III)

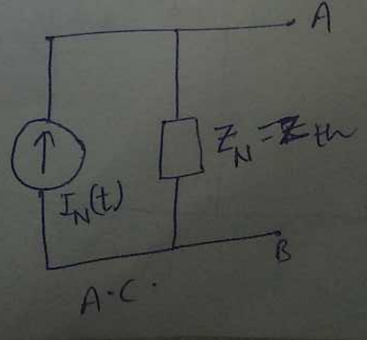


(3) Norton's Theorem :

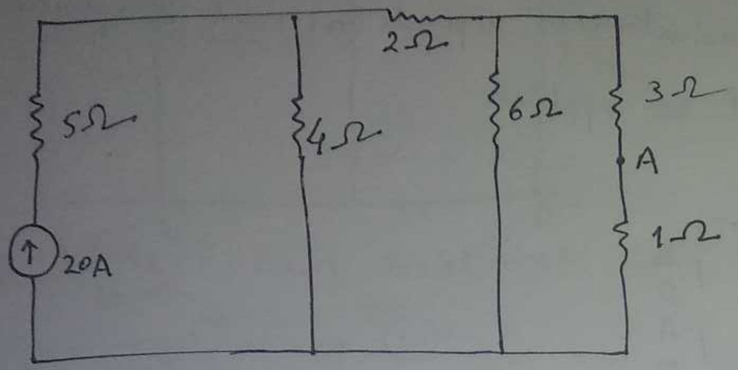
In any Linear Bidirectional circuit having more no. of active & passive elements, it can be replaced by single equivalent circuit consisting of equivalent current source (I_N) in parallel with equivalent resistance (R_N) where, I_{Norton} is a short circuit current w.r.to Load terminal & R_{Norton} is a equivalent resistance w.r.to Load terminals when all the independent sources are deactivated.





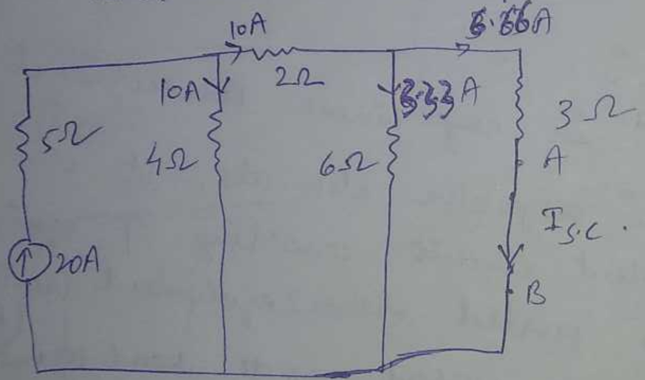


Que.7 Find current in 1Ω resistance by using Norton's Theorem.



Case-1) (I_N) short circuit current.

Load Resistance is Replaced by S.C.



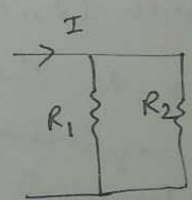
(Current division Rule)

$I_{S.C.}$ by C.D.R.

$I_{S.C.} = 10 \times \frac{\cancel{6}^{2}}{\cancel{9}_{3}}$

$\Rightarrow 6.66$

C.D.R.



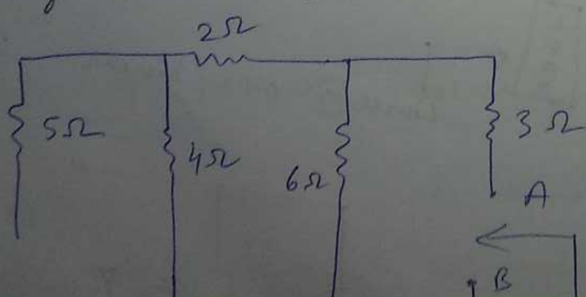
$I_{R_2} = I \times \frac{R_1}{R_1+R_2}$

Case-II) (R_N)

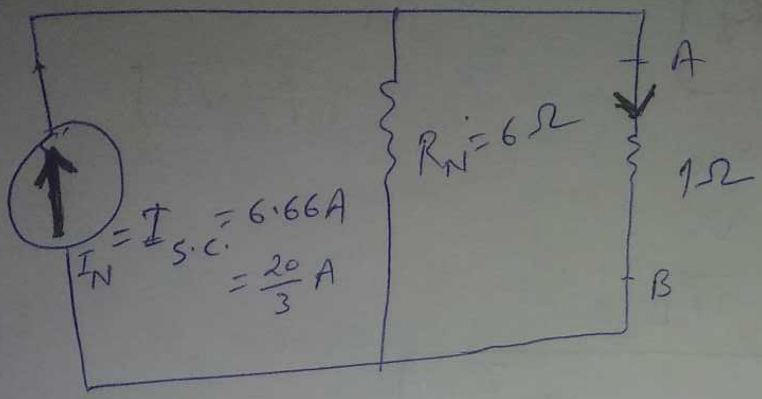
Same procedure as R_{th}.

Current source → Open circuit.

voltage source → short circuit.



$R_N = 6\Omega$



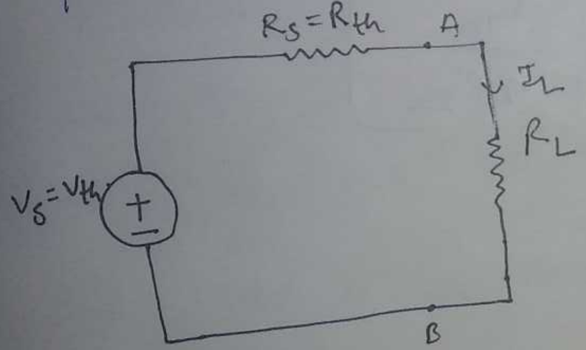
$$I_L = I_{s.c.} \cdot \frac{R_N}{R_L + R_N}$$

$$= \frac{20}{3} \times \frac{6^2}{7}$$

$$= \frac{40}{7} = 5.706 \text{ Amp.}$$

(4) Maximum Power Transfer Theorem:

Power delivered (Transferred) to Load is maximum when load resistance is equals to Thevenin resistance of the source. is known as maximum power transfer thm.



$$\boxed{R_L = R_S / R_{th}}$$

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

$$P_L = I_L^2 R_L.$$

$$\boxed{P_L = \left(\frac{V_{Th}}{R_L + R_{Th}}\right)^2 \cdot R_L} \quad \text{---} \ (1)$$

Differentiating eqn (1) w.r. to R_L and equate to zero:

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

$$\left(\frac{V_{Th}}{R_L + R_{Th}}\right)^2 + 2R_L\left(\frac{V_{Th}}{R_L + R_{Th}}\right)\frac{(-V_{Th})}{(R_L + R_{Th})^2} = 0$$

$$\left(\frac{V_{Th}}{R_L + R_{Th}}\right)^2 \left[1 - \frac{2R_L}{R_L + R_{Th}}\right] = 0$$

$$1 = \frac{+2R_L}{R_L + R_{Th}}$$

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

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

$$\boxed{R_L = R_{Th} = R_S}$$

$\boxed{P = VI}$

Power o/p by source.

$$P_S = V_S \cdot \frac{V_S}{2R_L}$$

$$\boxed{P_S = \frac{V_S^2}{2R_L} = \frac{V_{Th}^2}{2R_L}}$$

$P = I^2R$

$$P_L = \left(\frac{V_S}{2R_L}\right)^2 \cdot R_L$$

$$\boxed{P_L = \frac{V_S^2}{4R_L} = \frac{V_{Th}^2}{4R_L}}$$

max power across Load resistance.

* Efficiency (η) :

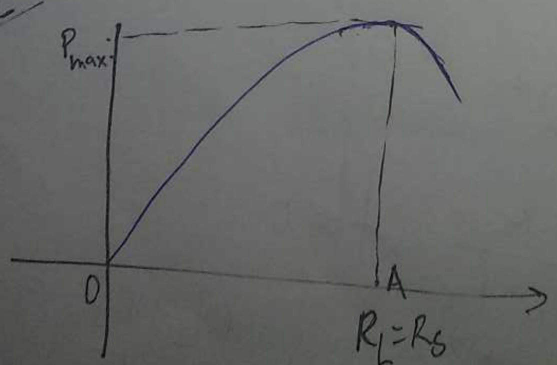
$$\eta = \frac{\text{o/p power}}{\text{I/p power}} \times 100$$

$\boxed{\eta = 50\%}$

$$\eta = \frac{I_L^2 R_L}{I_L^2 (R_S + R_L)} \times 100 = \frac{R_L}{2R_L} \times 100 = 50\%$$

Graph:

~~Case-1~~



Case-1)

OA ⇒ $\boxed{R_S > R_L}$

$\boxed{\eta < 50\%}$

Case-2

At A $\boxed{R_L = R_S}$

$\boxed{\eta = 50\%}$

Case - III $R_L > R_S$

$\boxed{\eta > 50\%}$

<u>Que.]</u> $R_L = 10\,\Omega$, $R_S = 8\,\Omega$ Find η.

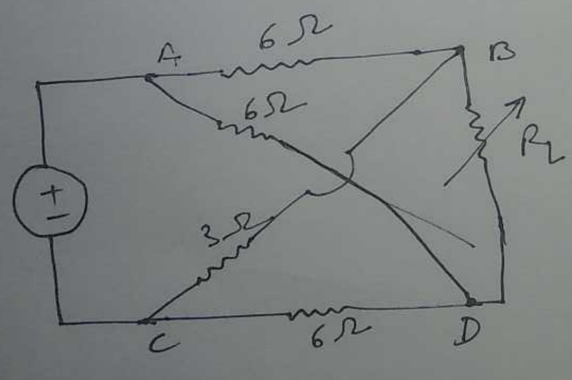
$$\eta = \frac{R_L}{R_L + R_S} \times 100 = \frac{\cancel{10}^{\,5}}{\cancel{18}_{\,9}} \times 100 = \frac{500}{9} = 55.55$$ <u>Ans</u>

To obtain high efficiency network is designed with Low ~~load~~ resistance. (Internal)

w.r. to electrical application case - III is desirable,

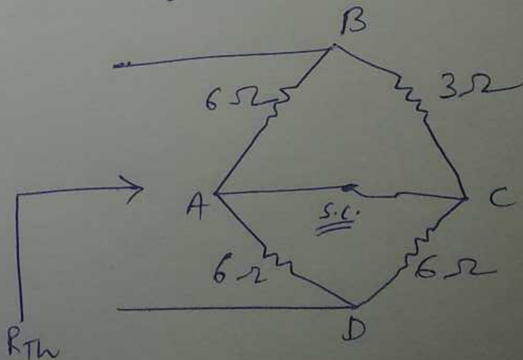
w.r. to electronic circuit case - II is desirable.

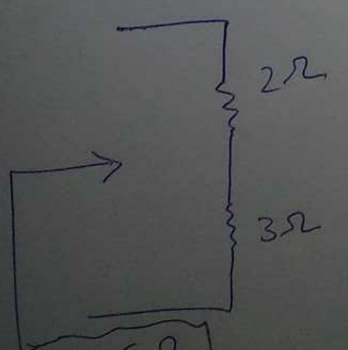
<u>Que.]</u> Find R_L to obtain max. power from source to Load.



$R_L \to$ O.C.

$V_S \to$ S.C.





$\boxed{R_{Th} = 5\,\Omega}$