__Power__ = rate of doing work i.e. rate of transfer of energy.

$$P = \frac{dw}{dt} \quad J/s \text{ or Watt } (W) \quad [\text{Instaneous power}]$$

$$W = \int_{t_1}^{t_2} P\,dt \quad \text{then} \quad P_{av.} = \frac{\text{total Workdone}}{\text{total time}}$$

$$\text{i.e.} \quad P_{av.} = \frac{1}{(t_2 - t_1)} \int_{t_1}^{t_2} P\,dt$$

__Energy__ = Ability of doing work.

workdone per unit time is power and workdone for a 'time-interval' is equivalent to energy.

$$\text{i.e.} \quad E = \int_{t_1}^{t_2} P\,dt = P \times t \quad \text{Joule } (J)$$

__Potential difference__ = work done when a unit '+' charge is moved from point 'a' to 'b' in presence of field of 'b'.

Electric potential difference doesn't depend on path choosen.

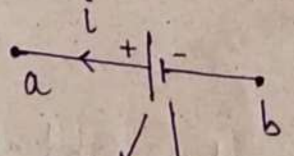
$V_{ab} = V_a - V_b \rightarrow$ 'b' at lower potential

V_a ↓ Point 'a' at higher potential

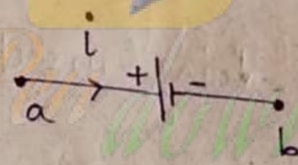
V_{ab} ↓ Potential difference or voltage across a & b

ofcourse, $V_{ab} = -V_{ba}$

<u>Voltage gain and drop</u> –



High potential   Low potential

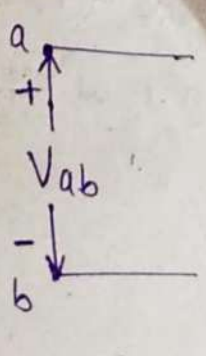


∴ Remember!

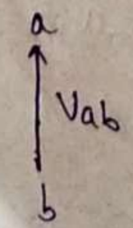
① Low potential → High potential – Voltage Gain

② High potential → Low potential – Voltage drop

Representation –



or



where

$V_a > V_b$

<u>current</u> - rate of flow of charge through a closed conducting path.

$$i_{av.} = \frac{\Delta q}{\Delta t} \quad \text{Amperes (A)}$$

$i = \frac{dq}{dt}$ and $q = \int_{t_1}^{t_2} i\,dt$ (charge transferred b/w t_1 & t_2)

DC - unidirectional.

AC - cyclic ⊕ half → ⊖ half → ⊕ half → ⊖ half ...

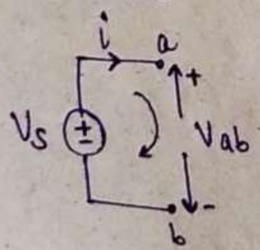
In both AC, DC magnitude may or may not be constant.

* unless stated otherwise we consider constant magnitude

Sources

- Dependent
  - current controlled
  - voltage controlled
    - voltage source
    - current source
- Independent
  - ideal
  - Practical
    - voltage source
    - current source

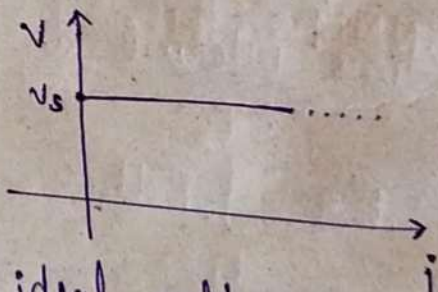
* Ideal and Practical voltage source -



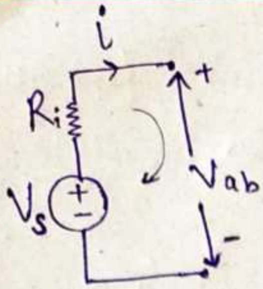
using KVL,

$V_s - V_{ab} = 0$

$V_s = V_{ab}$



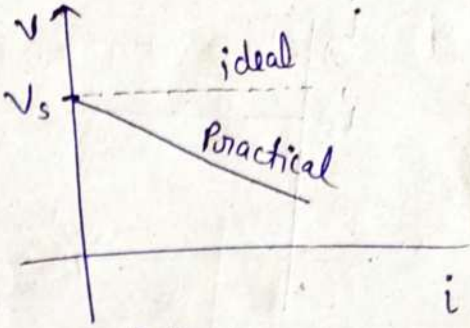
• No internal resistance ∴ ideal voltage source delivers energy at a specified voltage which doesn't depend on current delivered by the source



using KVL;

$$V_s - iR_{int.} - V_{ab} = 0$$

$$V_{ab} = -R_{int}\, i + V_s$$



∴ in practical source, $R_{int} \neq 0$ (finite)

so, it delivers the energy at a specified ~~rate~~ voltage which depends on current delivered by the source.

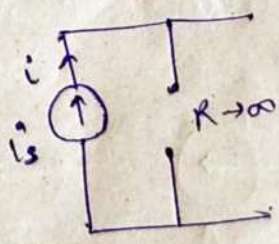
<u>In short</u> : Ideal → Terminal voltage = source voltage

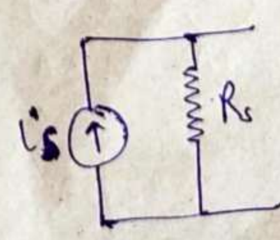
Practical → Terminal voltage < source voltage

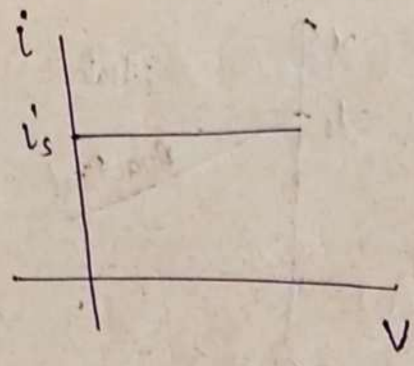
- V_{ab} → terminal voltage

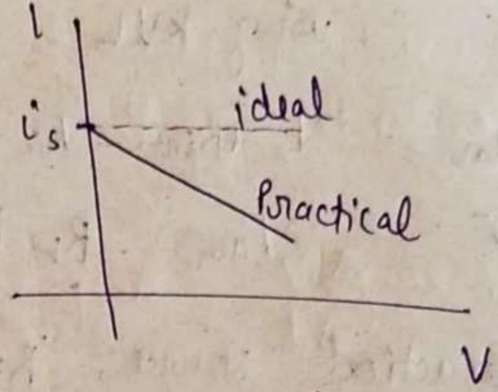
* <u>ideal and Practical current source</u> -

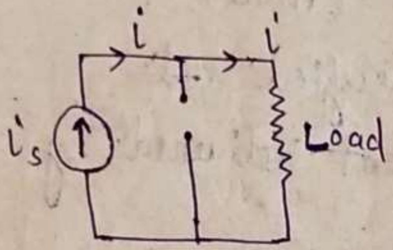
↓	↓
• $R_{int} \to \infty$	$R_{int} \to$ finite
• delivers the energy at a specified current which doesn't depend on voltage source across.	• delivers the energy at a specified current which is dependent on votage across the source

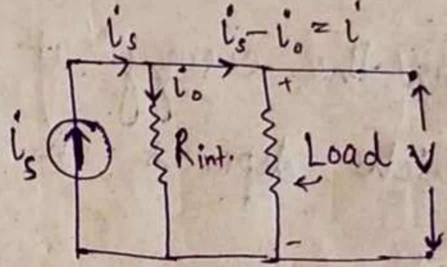








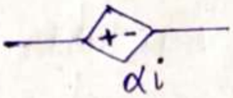


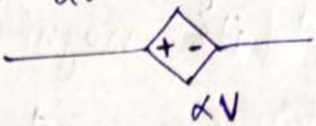


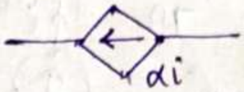
$$i = i_s$$

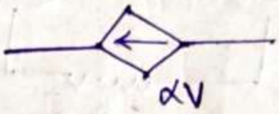
$$i = i_s - i_o$$

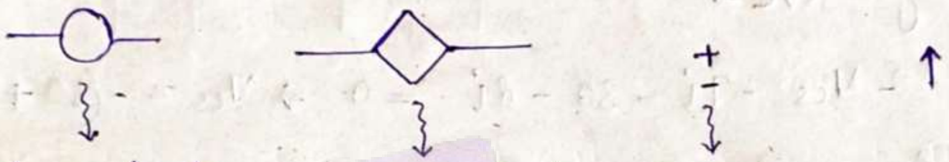
$$i = i_s - \frac{V}{R_{int}}$$

current controlled volt. src. 

voltage " " " 

current " current " 

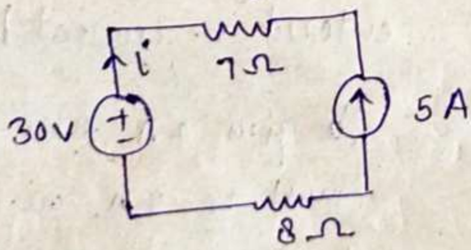
voltage " " " 

Note: ① 

independent dependent voltage current

② $\alpha \rightarrow$ constant and the current or voltage involved in deciding voltage / current source is given in problem.

③ Irrespective of voltage source, current remains same for one closed path.

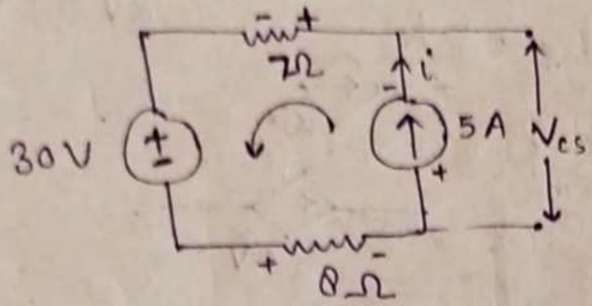
ex: 

$i = -5A$

If no current source is present in series with ideal indep. current source then current can't change in the circuit.

④ voltage across current source is never zero, and its magnitude is decided by external elements.

ex:



say V_{cs} is voltage across current source.

using KVL →

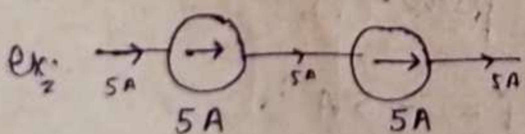
$$-V_{cs} - 7i - 30 - 8i = 0 \rightarrow V_{cs} = -(30 + 15i)$$

⑤ For // comb^n of voltage sources, they must be same in order to obey KVL.

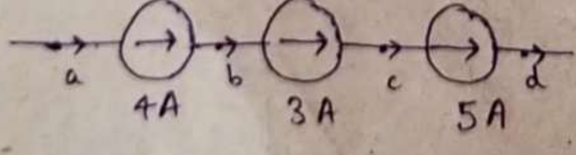
⑥ For series combination of current sources, they should be in <u>same direc^n</u> to obey KCL.

If different magnitudes then, minimum will effictively flow.

ex:



KCL obeyed, current entered = current left



b gives 4A then c must be 4A acc. to KCL but 3A src. can't give 4A

∴ C = 3A

Now, 3A enters so at d we should get 3A (For KCL) & yes it can be possible becoz

5A src. can give 3A easily.

now, at 'a' 3A enters so, 'b' must be 3A.

which is again possible.

$\therefore$ overall current in the circuit = $\underline{\underline{3A}}$

(7) voltage src. in series and current srcs in parallel can be present without any restriction;

* $\underline{\text{KCL}}$ and $\underline{\text{KVL}}$ $\rightarrow$ within any loop, Σ(voltage rise) = Σ(voltage drop)

or Σ(P.D across each component) = 0

• Based on law of energy conservation

KCL $\downarrow$

Σ(All the currents at the junction) = 0 — using this $\rightarrow$ consider incoming currents $\ominus$ and outgoing currents $\oplus$.

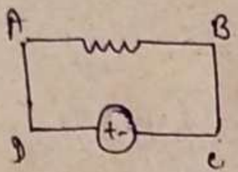
or Σ(incoming currents) = Σ(Outgoing currents) — using this $\rightarrow$ use as it is, as currents are given.

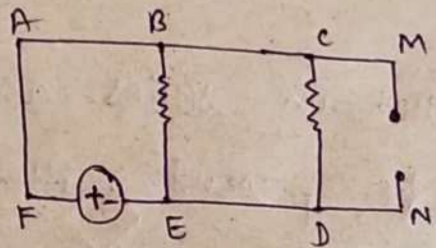
• Based on law of conservation of charges.

- <u>circuit</u> v/s <u>Network</u>

↓ Always closed path

↓ May be closed or open or combination of both





ABCDA → circuit

ABEFA → circuit

BCDEB → "

ABCDEFA → "

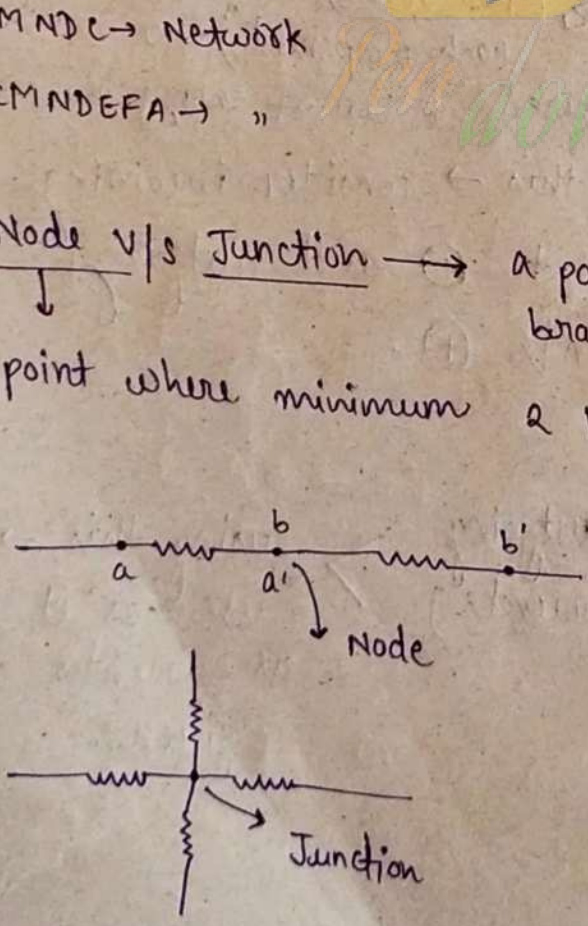
CMNDC → Network

ABCMNDEFA → "

Note: Every circuit is also a Network.

- <u>Node</u> v/s <u>Junction</u> → a point where minimum 3 branches meet.

↓ A point where minimum 2 branches meet.



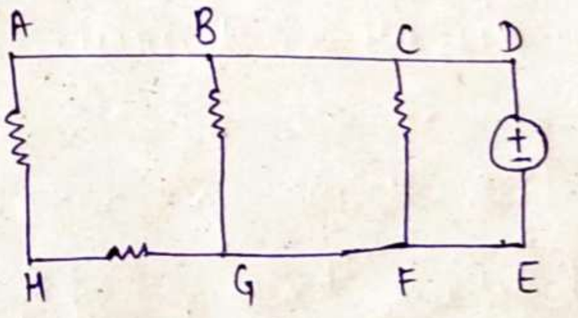
a, a', b, b' are the ends of a component. These are called as terminals

• Loop V/S Mesh → The simplest loop which can't be further reduced.

↓

any closed path in which current can flow

ex:



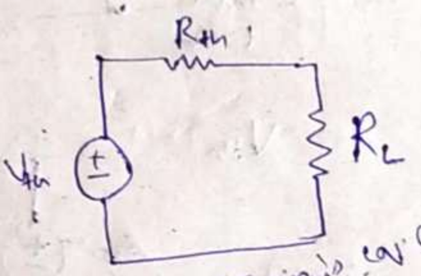
ABGHA, BCFGB, CDEFC → Meshes

ABCFGHA, BCDEFGB, ABCDEFGHA → loops

Q:

(2) Thevenin's theorem :

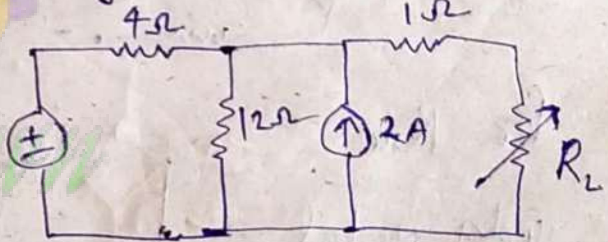
↳ a linear bidirectional 2 terminal network can be replaced by an eq. network consisting of V_{th} connected in series with R_{th}.



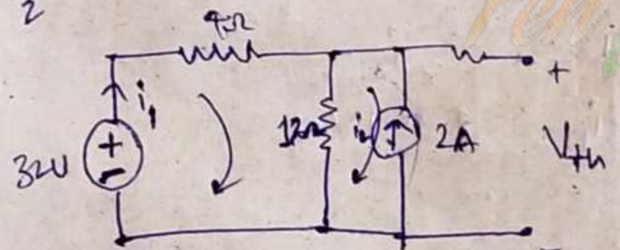
Thevenin's eq. ckt

- depend src → as it is
- V_{th} → open circuit at R_L and find V_{th}.
- R_{th} → Independ. src. are replaced by their int. resistances. and open circuit at R_L.
- ** when dependent src. are present → attach a 1 V indep. src in place of load → draw current 'i' from it then $R_{th} = \frac{1}{i}$ (calculate i using any method)

Q.2



for V_{th},



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

$32 - 16i_1 + 12i_2 = 0$

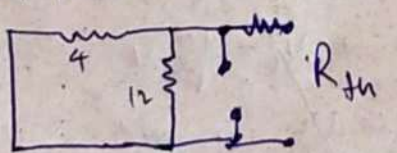
$8 - 4i_1 + 3i_2 = 0$ — (1)

$i_2 = -2A$ — (2)

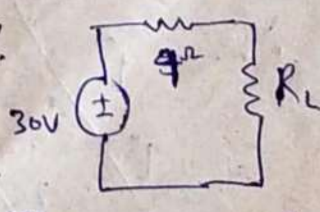
$\therefore 8 - 4i_1 - 6 = 0 \Rightarrow i_1 = 0.5A$

$\therefore V_{th} = V_{12\Omega} = 12(i_1 - i_2) = 12 \times 2.5 \Rightarrow$ $= 30.0V$

For R_{th} ?

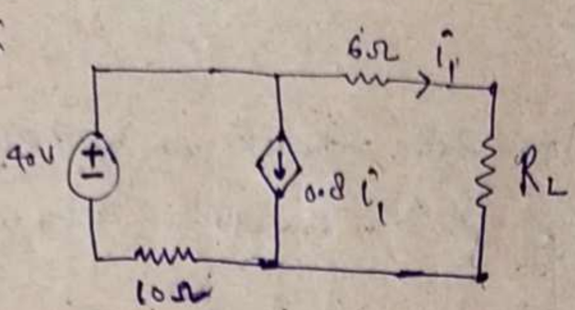


$R_{th} = 1 + \frac{12 \times 4}{16} \Rightarrow 1+3\,\Omega = 4$



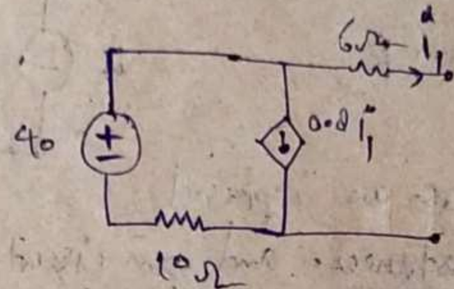
Thevenin's eq. ckt

Q.***



V_{th}, R_{th} ?

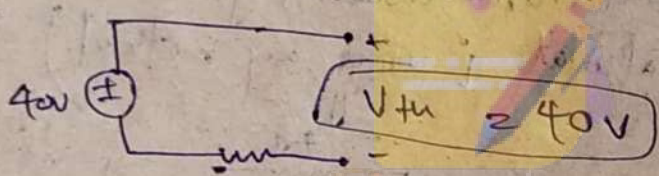
→ for V_{th}



Since, circuit is open so $i_1 = 0$

∴ current through dep. src $= 0$

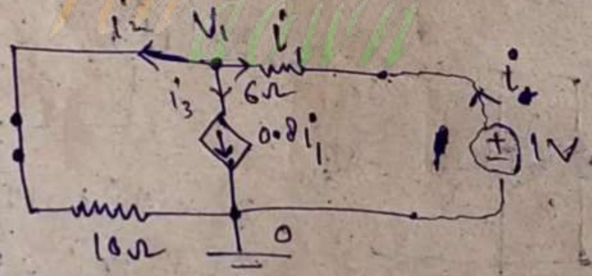
∴



$\boxed{V_{th} = 40\,V}$

for R_{th}

apply Nodal analysis.



$i_1 + i_2 + i_3 = 0 \Rightarrow \underbrace{\frac{V_1 - 1}{6}}_{i_1} + \frac{V_1 - 0}{10} + 0.8\, i_1 = 0$

$\frac{V_1 - 1}{3} + \frac{V_1}{10} = 0 \Rightarrow 10V_1 - 10 + 3V_1 = 0$

$13V_1 = 10 \Rightarrow V_1 = \frac{10}{13}\,V$

∴ $i = -i_1 = \frac{1 - V_1}{6} = \frac{1 - \frac{10}{13}}{6} = \frac{3}{13 \times 6}$

$i_2 = \frac{1}{26}\,A$

∴ $\boxed{R_{th} = 26\,\Omega}$

$$\frac{v_1}{10} + 1.8 i_1 = 0$$

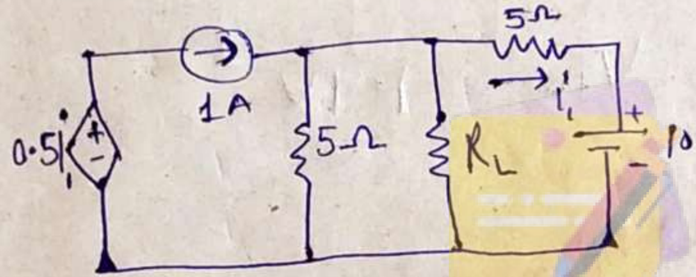
$$\frac{v_1}{10} + \frac{\cancel{18}^{3}}{10} \times \left(\frac{v_1 - 1}{\cancel{6}}\right) = 0 \Rightarrow 4v_1 = 3 \Rightarrow v_1 = 3/4 \text{ V}$$

$$\therefore i_1 = \frac{\frac{3}{4} - 1}{6} \Rightarrow -\frac{1}{24} \text{ A}$$

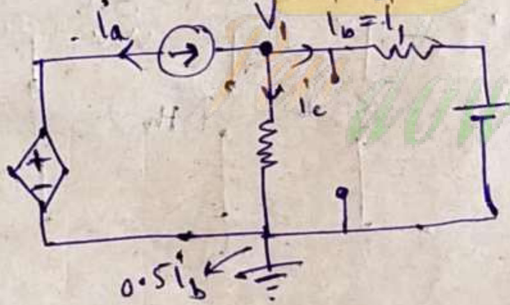
$$i = -i_1 = \frac{1}{24} \text{ A}$$

$$\therefore \boxed{R_{th} = 24\,\Omega}$$

Q2: Find V_{th} & R_{th}



For V_{th} :



KCL at node ①

$$i_a + i_b + i_c = 0$$

$$\cancel{-1 + \frac{V_1 - 10}{5} + \frac{V_1}{5} = 0}$$

$$\cancel{V_1 = 7.5 \text{ V}}$$

$$\therefore \cancel{V_{5\Omega} = \frac{15 \cdot 3}{2 \times 5} \Rightarrow 1.8 \text{ V}} \qquad \therefore \boxed{\cancel{V_{th} = 1.8 \text{ V}}}$$

$$\cancel{i_c = V_1}$$

$$-1 + \underbrace{\left(\frac{V_1 - 10}{5}\right)}_{i_b} + \frac{V_1 - 0.5 i_b}{5} = 0$$

$$i_b + \frac{V_1 - \frac{i_b}{2}}{5} = 1 \Rightarrow \frac{2V_1 - i_b}{10} + i_b = 1$$

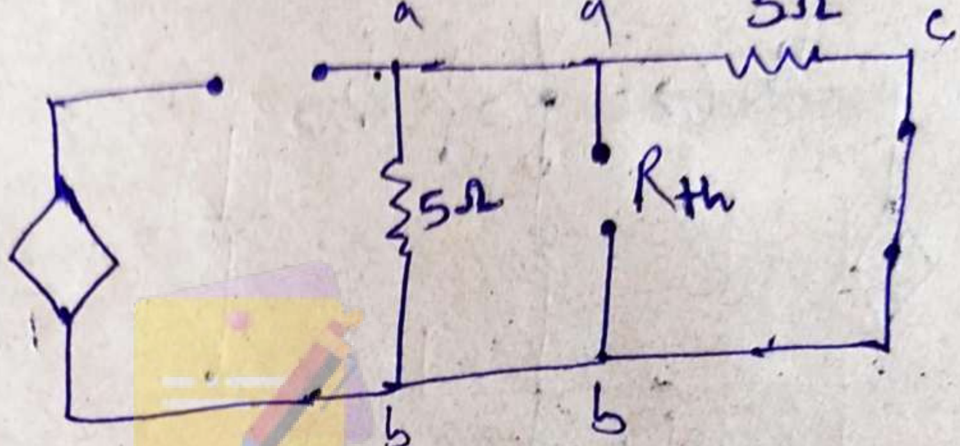
$$2V_1 + 9 i_b = 10 \Rightarrow 2V_1 + 9 \times \left(\frac{V_1 - 10}{5}\right) = 10$$

$$10 V_1 + 9V_1 - 90 = 50$$

$$19 V_1 = 140 \Rightarrow V_1 = \frac{140}{19} \text{ V} \quad \therefore V_{th} = 5 \times i_c$$

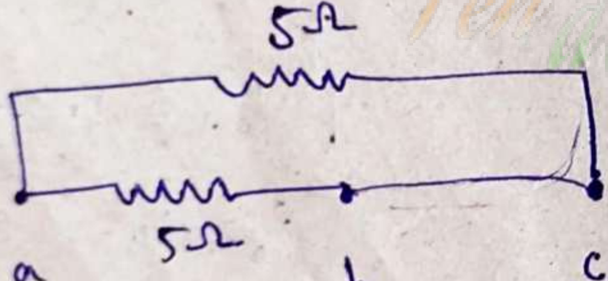
from Q. $V_1 = V_{th} = 7.4V$

for R_{th} ?



clearly $R_{th} = \frac{5\Omega}{2}$

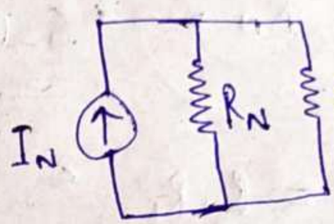
$R_{th} = 2.5\Omega$



Norton's theorem : {same as thevenin only diff. in I_N & V_{th}}

a linear & bidirectional 2 terminal network can be replaced by an equivalent circuit consisting of a current source I_N in parallel with a resistor R_N.

- $R_N \rightarrow$ same as R_{th}
- $I_N \rightarrow$ short circuit load branch
  solve for currents. I_N = current in load branch

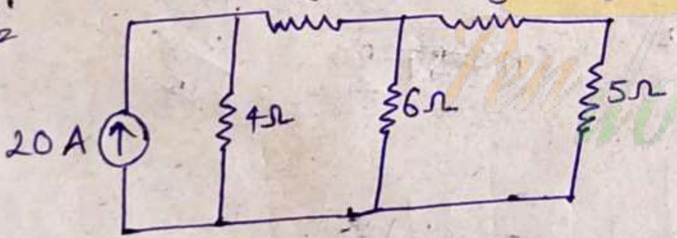


as $R_N = R_{th}$, $I_N = \frac{V_{th}}{R_{th}}$ or $R_{th} = R_N = \frac{V_{th}}{I_N}$

{this is source transformation technique}

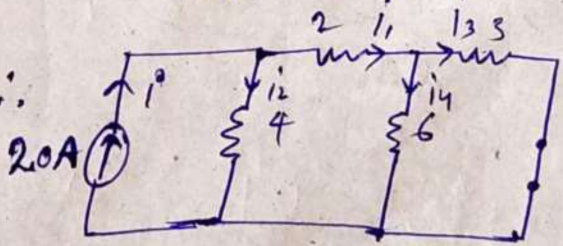
-

Q. find current through 5 Ω using Norton's theorem

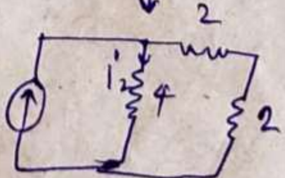


→ so, let $R_L = 5\Omega$

∴



↓



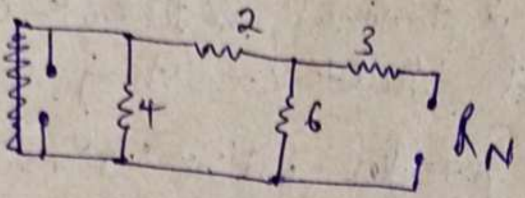
using current div. rule,

$i_2 = 10\,A = i_1$

$i_3 = \frac{10 \times \cancel{6}^{2}}{\cancel{9}_{3}} = \frac{20}{3} \Rightarrow 6.67A$

$i_3 = \boxed{I_N = 6.67\,A}$

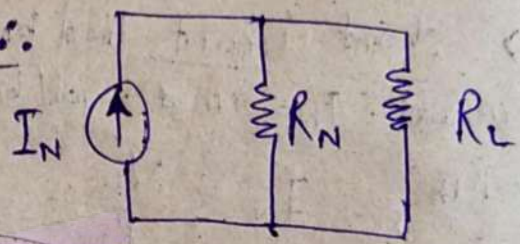
for Norton's resistance ie. R_N.



$R_1 = 6\Omega$

$$R_N = 6\,\Omega$$

$\therefore$



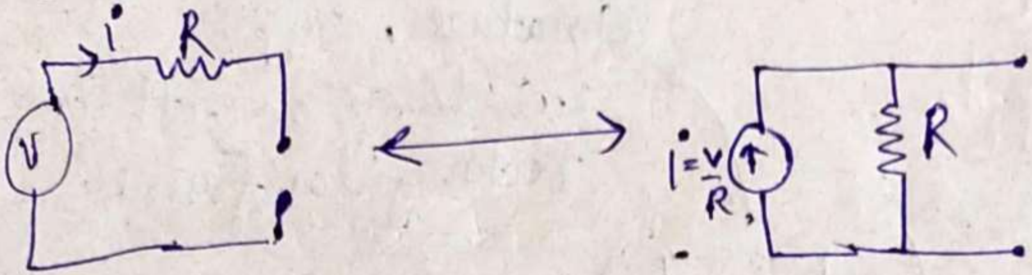
No need

$$R_{eq} = \frac{R_N R_L}{R_N + R_L} = \frac{6\times 5}{11} = \frac{30}{11}\,\Omega$$

$$\therefore \; i_{Load} = \frac{R_N \times I_N}{R_N + R_L} = \frac{6\times\frac{20}{3}}{11} = \frac{\cancel{120}}{\cancel{33}}$$

$$\boxed{i_{5\Omega} = \frac{40}{11}\,A}$$

Note: Source transformation technique :

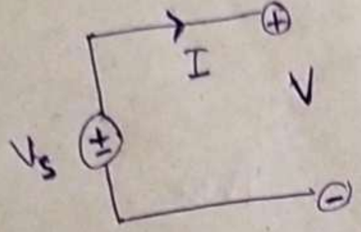


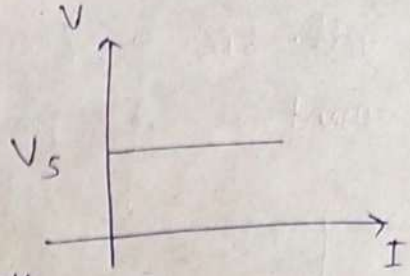
Maximum Power theorem :

maximum power from a network is delivered from a network then resistance of load must be equal to the thevenin's resistance of network.

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

ideal volt. source → $R_{int} = 0$

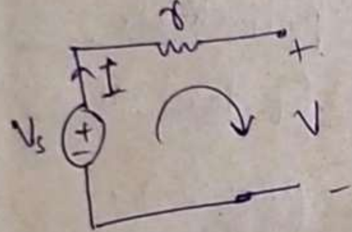




delivers energy at specific constant voltage which doesn't depend on current I produced from 'V_s'.

Practical volt. source

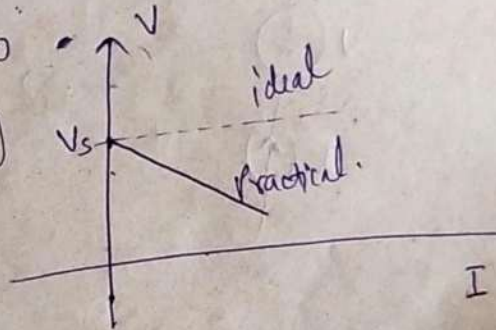
R_{int} = finite = r



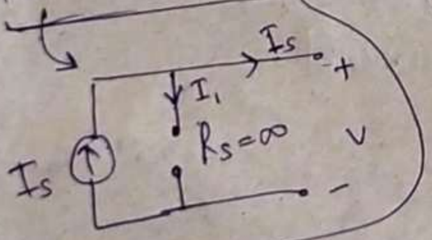
$\Sigma \Delta V = 0$

$V_s - Ir - V = 0$

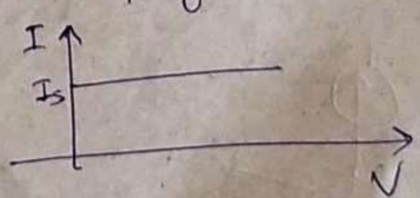
$\boxed{V = -Ir + V_s}$

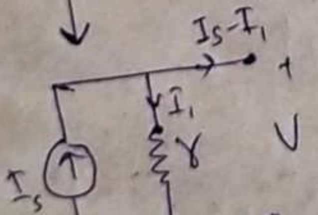


ideal & Practical current .src.



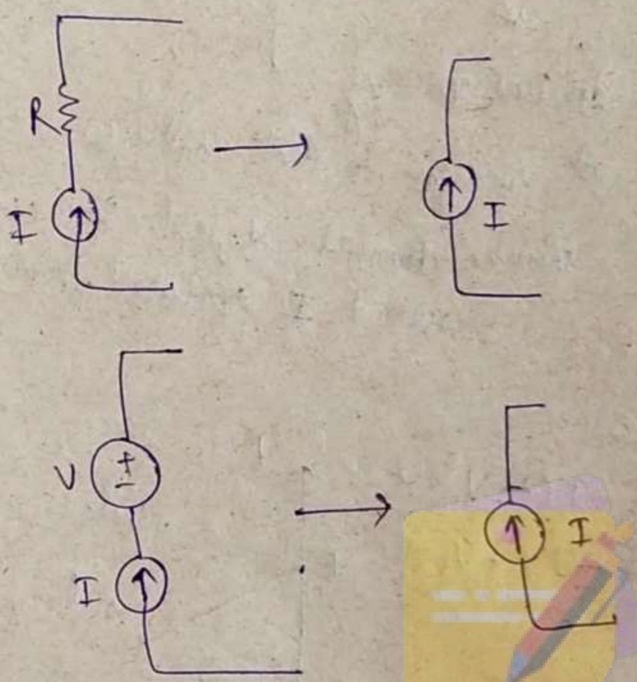
$I = I_s$ delivers eng at a specific current indep. of. volt. across source





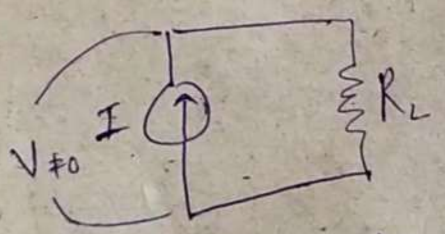
$I = I_s - \frac{V}{R_s}$

* volt. src → series → add kr sakte hain.
* current " → parallel → ______ .



These conversions are only applicatable for load side parameters.

① current src. doesn't have zero voltage across its terminals while providing fixed current.



② indep. & dep. sources are handled in same manner, except:

(i) Sup. thm
(ii) Thevenin's
(iii) Norton

indep. → Replace by Rint { ideally, for V, $R_{in} \to 0$; I, $R_{in} \to \infty$

dep. ✓ (No change)

KCL

entering = +ve
outgoing = −ve then $\Sigma I = 0$.

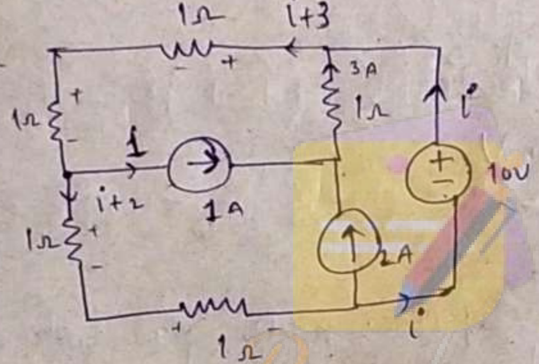
K.VL

$\ominus \rightarrow \oplus$
low to high (Rise)

$\oplus \rightarrow \ominus$ (drop.)

$\Sigma \Delta V = 0$.

Q. ***



to avoid dealing with current sources, becoz we don't know volt. across them, we choose outer loop. & apply KVL→

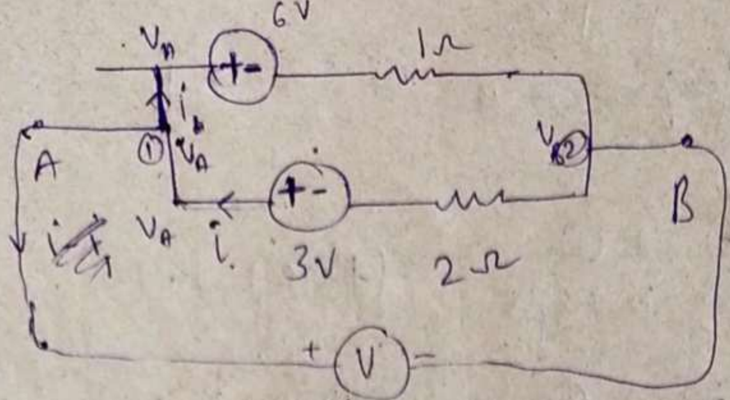
$$\Sigma \Delta V = 0$$

$$+10 - (i+3) - (i+3) - (i+2) - (i+2) = 0$$

$$10 - 2[i+3] - 2[i+2] = 0$$

$$10 - 2(2i+5) = 0 \Rightarrow i = 0\text{ A}$$

Q. 2



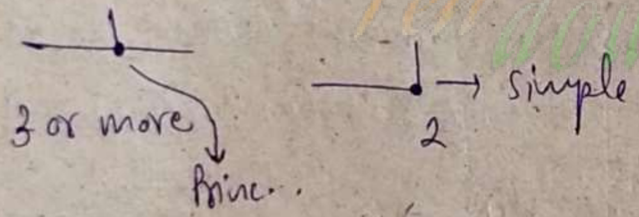
$V_{AB} = ?$

$\cancel{3 - 2i - V = 0}$

$\cancel{-6 - i_1 - 2i + 3 = 0}$

$\cancel{(6 + i_1) = V}$

#. current div. keval princ. node par hota hai



in above circuit ①, ② are simple nodes

∴ $\cancel{x \sqrt{7} x}$

$-6 - i - 2i + 3 = 0$

$-3 = 3i \Rightarrow \boxed{i = 1A}$

Now. $V_A - 6 - i = V_B$

open path me potential drop kabhi zero nahi hoga ∴ A → B mey drop. hote hue eqn ye banegi

$\{ V_A - V_B = 6 + i \Rightarrow 6 - 1 \Rightarrow 5V \}$

• mesh analysis :

→ not applicable in non-planar networks.

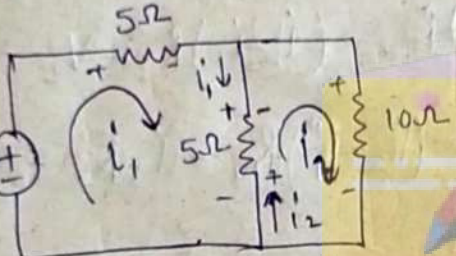
→ No. of eqn. to solve a network

$$\underbrace{e}_{\text{no. of eqn}} = \underbrace{M}_{\text{no. of meshes}} = \underbrace{b}_{\text{No. of branches}} - (\overbrace{n}^{\text{no. of nodes}}-1)$$

→ take direc^n always clockwise for simplicity.

$\boxed{\text{For common branch}}$ **

Jis mesh ka analysis kar rahe ho, usi ke current ko greater mano. & uski direc^n ke according eqn likho.



Mesh (1):

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

$$10 - 5i_1 - 5i_1 + 5i_2 = 0 \Rightarrow \boxed{10 + 5i_2 - 10i_1 = 0} \quad (1)$$

mesh (2):

$$-5(i_2 - i_1) - 10i_2 = 0 \Rightarrow -5i_2 + 5i_1 - 10i_2 = 0$$

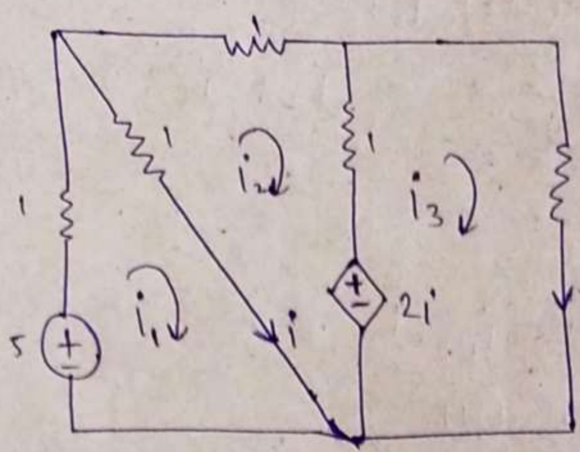
$$5i_1 = 15i_2 \quad (2)$$

$$\boxed{i_1 = 3i_2}$$

using (1) & (2) →

$$10 + 5i_2 - 10(3i_2) = 0 \Rightarrow i_2 = \frac{\cancel{10}^{2}}{\cancel{25}_{5}} \Rightarrow \boxed{0.4A}$$

$$\boxed{i_1 = 1.2A}$$



mesh ①:

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

$$5 - 2i_1 + i_2 = 0 \quad \text{—①}$$

$i = i_1 - i_2$
or
$i_2 - i_1 = -i$

mesh ②:

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

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

$$-3i_2 + i_1 + i_3 - 2i_1 + 2i_2 = 0 \Rightarrow i_3 - i_1 - i_2 = 0 \quad \text{—②}$$

mesh ③:

$$-i_3 + 2i - (i_3 - i_2) = 0$$

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

Here
$i_3 = i$

$i_2 = 0$

$i_3 = i_1$

$$i_1 = \frac{5}{2} \Rightarrow 2.5\text{ A}$$

$$\therefore \; i = 2.5\text{A}$$

Jis Mesh ko solve kar rahe ho uske according dekho dependent parameters ka relation with variables.

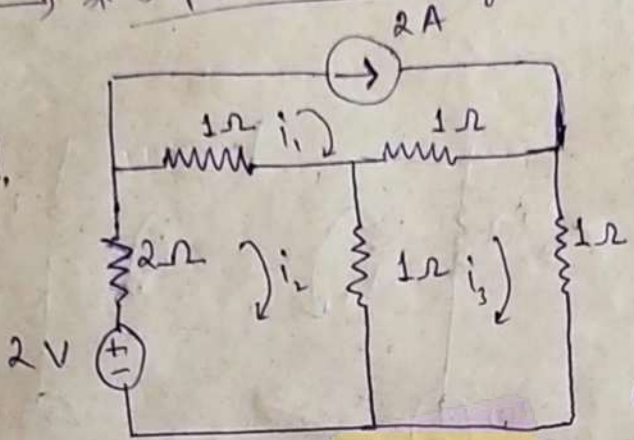
· when current src is present in mesh:

case ①: shared by other meshes in circuit.

case ②: not

→ * super mesh analysis *

Q. find $i_3 = ?$



$i_1 = 2A$ directly

now, $2 - 2i_2 - (i_2 - 2) - (i_2 - i_3) = 0$

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

$i_3 - 4i_2 = -4$ —①

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

$-3i_3 + i_2 + 2 = 0$ —②

②×4 + ①

$-11i_3 = -12 \Rightarrow i_3 = \frac{12}{11} A$

mesh ①: $\cancel{-(i_1 - i_2) - (i_1 - i_3) = 0}$

but $i_1 = 2A$ directly

∴ $\cancel{-2 + i_2 - 2 + i_3 = 0 \Rightarrow i_2 + i_3 = 4}$ ①

mesh ②: $-(i_2 - i_1) - (i_2 - i_3) + 2 - 2i_2 = 0$

$-4i_2 + 4 + i_3 = 0 \Rightarrow i_3 - 4i_2 = -4$ ①

$\cancel{4 \times ① + ② : \quad 5i_3 = 12 \Rightarrow i_3 = 2.4A}$

∴ $\cancel{i_2 = 1.6A}$

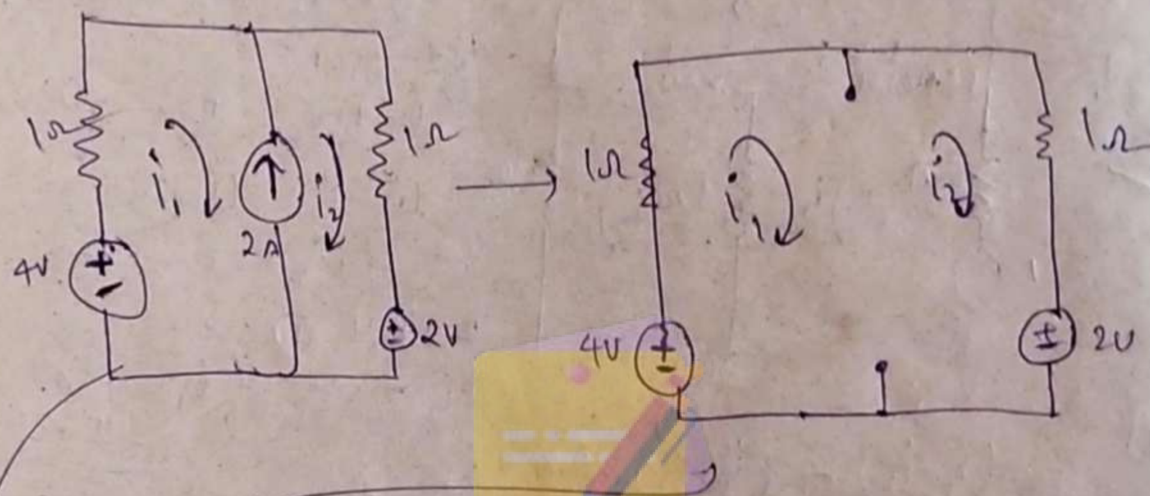
mesh ②:

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

$2 - 4i_2 = -4 \Rightarrow i_2 = \frac{6}{4} = \frac{3}{2} \Rightarrow 1.5A$

∴ $i_3 = -4 + 4 \times 1.5 \Rightarrow 2A.$

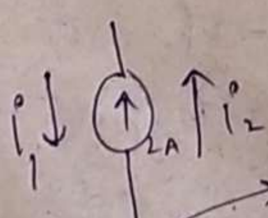
Supermesh: when a current src is present b/w 2 meshes, we remove the brach having current src. and then remaing. loop is known as ~~to~~ supermesh.



Now apply KVL→

$$4 - i_1 - i_2 - 2 = 0 \Rightarrow i_1 + i_2 = 2 \quad -(1)$$

now



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

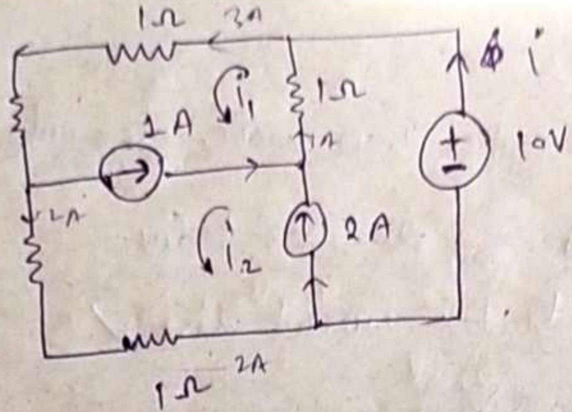
i_2 ki direct me 2A hai so

$$+$$

$$i_2 = 2A$$

$$\therefore i_1 = 1A$$

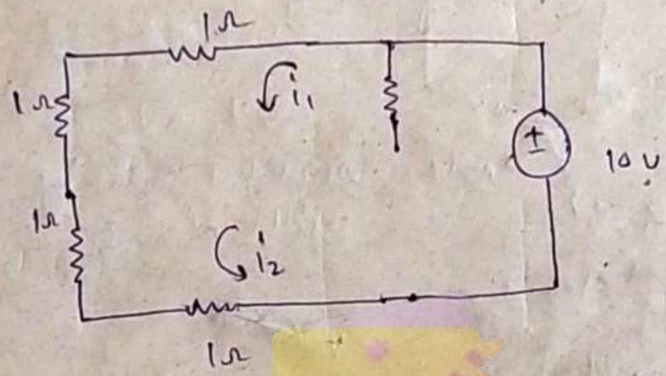
Q. 2



Solve using sup. Mesh analysis

Find i ?

→



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

$$i_1 + i_2 = 5 \quad — (1)$$

Now, $i_1 - i_2 = 1 \quad — (2)$ ∴ $i_2 = 2A$

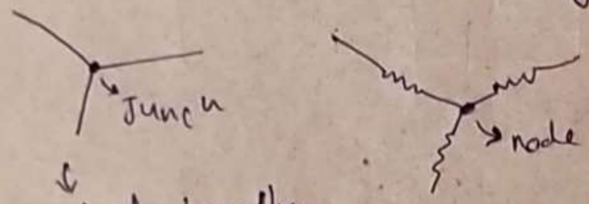
$i_1 = 3 A$

Implies $i_1 = 0 A$

Nodal analysis :

Node → common point when 2 or more elements meet.

- Simple → 2 elements → No current div.
- Principal → >2 elements → current div ✓
  - ↳ considered in analysis.



branches must be with elements

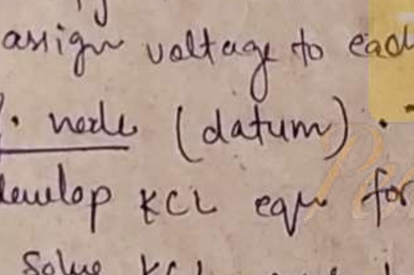
simple branches may or may not have elements.

① identify total nodes
② assign voltage to each node, one node is taken as ref. node (datum). Take $V_{ref.\,node} = 0$ {Bottom node is often taken as ref.}
③ develop KCL eqn for each non-ref. node
④ Solve KCL eqns to get V_{node}.

$\Phi = \frac{E \cdot A}{\varepsilon t}$

Note: ① for both planar & non-planar networks.
② No. of eqns $e = N-1$
↳ no. of nodes (Princ. Nodes)

ex. 2



KCL of non-ref node ①, leaving ← $(i_1+i_2+i_3) = 0$ → entering (sum of leaving current = sum of entering current)

$$\frac{V_x - 4}{1} + \frac{V_x - 2}{1} + (-2) = 0$$

$$V_x = \frac{8}{2} \Rightarrow 4V.$$

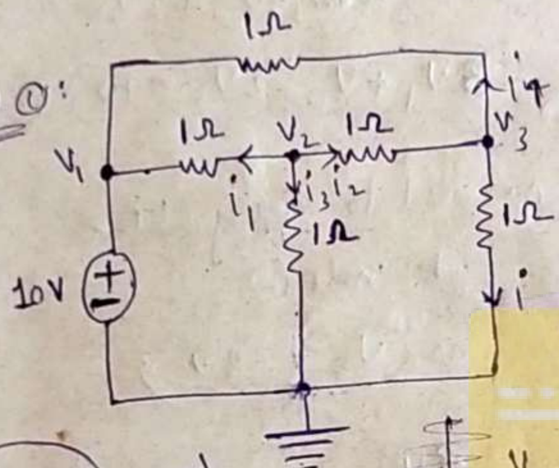
When voltage src. is present :

case ①: voltage src connected b/w the ref. node & non-ref. node.

case ②: volt. ——————— 2 non-ref. nodes.

→ Super node analysis.

case ①:



Find i using nodal analysis

KCL at node ②:

$\underbrace{i_1+i_2+i_3}_{\text{outgoing}} = \underbrace{0}_{\text{incoming}}$

$V_1 = 10V$ → no need to write KCL for node ①

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

$$V_2 - 10 + V_2 + V_2 - V_3 = 0$$

$$\boxed{3V_2 - V_3 = 10} \quad -①$$

KCL at node ③

$$i_2 = i_4 + i$$

$$\frac{V_2 - V_3}{1} = \frac{V_3 - 10}{1} + \frac{V_3 - 0}{1}$$

$$V_2 - V_3 = 2V_3 - 10 \Rightarrow \boxed{3V_3 - V_2 = 10} \quad -②$$

① × 3 + ② : $8V_2 = 40 \Rightarrow V_2 = 5V$

$\therefore V_3 = 5V$

$\therefore \boxed{i = 5A}$

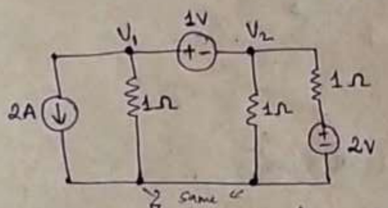
$$\frac{12+2}{2} + \frac{26+2}{1} = i_x$$

$$i_x = 28+7 \Rightarrow 35\,A$$

$$\therefore P_{2V\,source} = 2 \times i_x = \underline{\underline{70\,W}}$$

Q. case ②: supernode analysis:

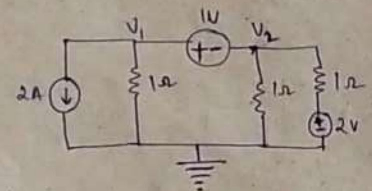
Find V_1 & V_2 ?



we have $\underline{\underline{3}}$ nodes

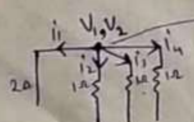
node ① & ② are non-ref. principal nodes so ⓵ b/w them makes it a problem of super nodal analysis.

$\therefore$



Here no need to apply KCL separately at node ①, ②.

but neglect the (1V) src. and make a common node known as super node and apply KCL at this node.



KCL → $i_1+i_2+i_3+i_4=0$

consider V_1 consider V_2

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

$$\boxed{V_1 + 2V_2 = 0} - ①$$

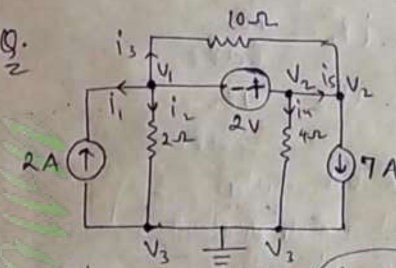
now, by KVL in V_1 —(+ −)— V_2 (1V)

$$V_1 - 1 = V_2 \Rightarrow \boxed{V_1 - V_2 = 1} - ②$$

$$① - ② \quad 3V_2 = -1 \Rightarrow \boxed{V_2 = -\tfrac{1}{3}\,V}$$

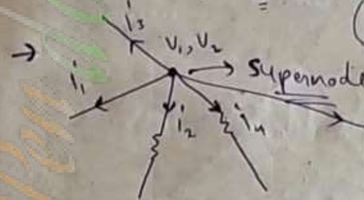
$$\therefore \boxed{V_1 = \tfrac{2}{3}\,V}$$

Q. Find V_1, V_2 ?



clearly we have only 3 nodes.

$$\boxed{i_3 + i_5 = 7}$$



$$i_1+i_2+i_3+i_4+i_5 = 0$$

$$-2 + \frac{V_1-0}{2} + \cancel{\left(\frac{V_1-V_2}{10}\right)} + \frac{V_2-0}{4} + (7-i_3) = 0$$

$$\boxed{2V_1 + V_2 = -20} - ①$$

by KCL,

$$V_1 + 2 = V_2 \Rightarrow \boxed{V_2 - V_1 = 2} - ②$$

$$① - ② \quad 3V_1 = -22 \Rightarrow \boxed{V_1 = -\tfrac{22}{3}\,V}$$

$$\therefore V_2 = 2 - \frac{22}{3} \Rightarrow \boxed{-\frac{16}{3}\,V}$$