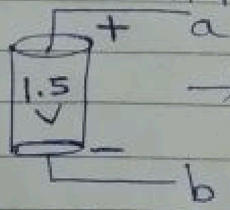
Electrical engineering

Voltage. → unit is J/C or Volt
↓ also can be called potential difference

if a battery rated 1150mAH number of charges
→ $1150 \times 10^{-3} \times \frac{C}{Sec} \times 3600$

$= 4140C$

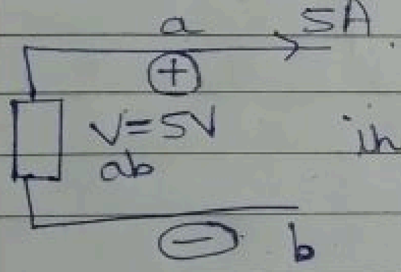


→ $V_{ba} = -1.5V$, $V_{ab} = 1.5V$

$P = VI \rightarrow \frac{J}{C} \times \frac{C}{S} = \frac{J}{S} = W$

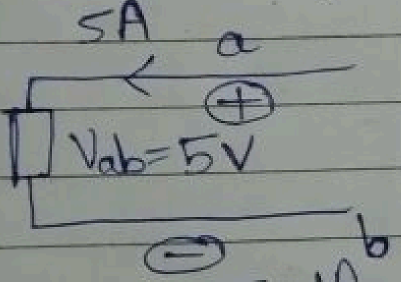
Power unit → $J/S = W$

active sign convention →



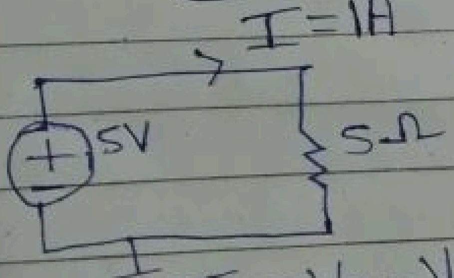
in this power Supplied = 25W

Passive sign convention →



power absorbed = 25W

Q)

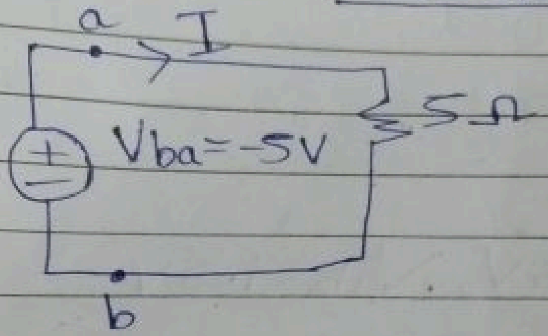


ans) $I = \frac{V_a - V_b}{5\Omega} = 1A$

for Source → active sign convention
so Power <u>supplied</u> = $5 \times 1 = 5W$

for Resistor → passive sign convention
so power <u>absorbed</u> = $5 \times 1 = 5W$

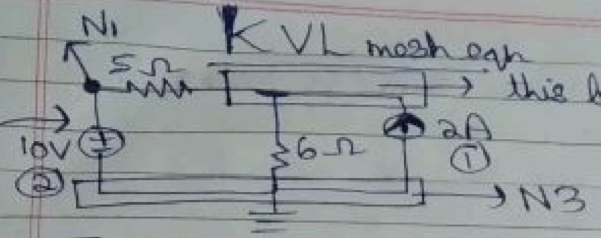
Q)



ans) $V_{ba} = -5$
Power absorbed $= V_{ba} \times I$
$= -5W$.

Basically →
if entering + → passive
if leaving + → active

KVL mesh eqn



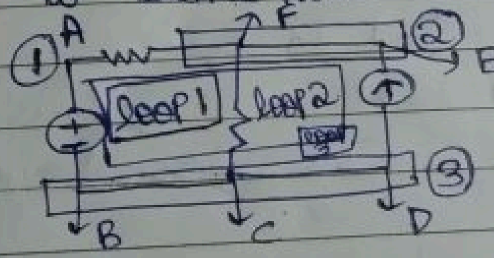
Terms →

① is independant current source
② is independant voltage source
there are 4 branches in this {every element → branch}
{1 with V source, 2 with 5 Ω, 6 Ω resp., 1 with current source}

Nodes → where Braches join.
N1, N2, N3 are nodes

Note – if no components after interaction of two branches → whole area is node

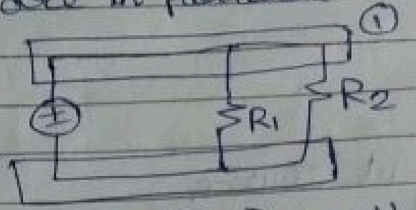
loops → start from one node and come back to same node then loop formed.



AFCB → loop 1
AEDB → loop 2
FCDE → loop 3

independant loop → formula ⇒ $l = b - n + 1$
↓ combinations of 2 loops which covers all branches/elements → independent loop
or
loop which contains atleast 1 branch which isnt present in any other independant loop

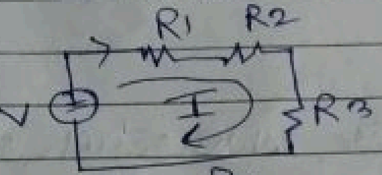
if any 2 element between same 2 nodes they are in parallel



so $R_1, R_2 \rightarrow ||$

KVL mesh equation

ΣV in Circuit $= 0 \rightarrow$ KVL

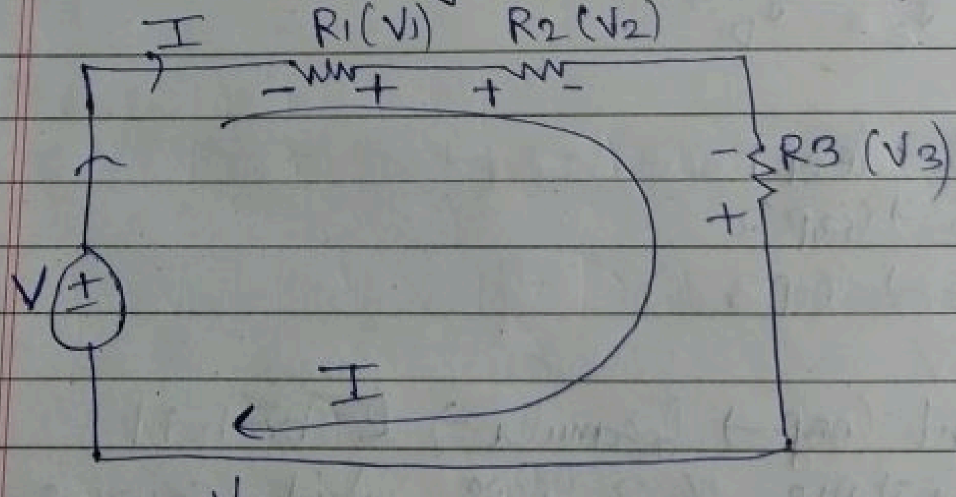


This I is mesh current

Current through $R1 \rightarrow I_1$

through $R_2 \rightarrow I_2$

current through $R_2 \rightarrow I_1 - I_2$ {Branch current}

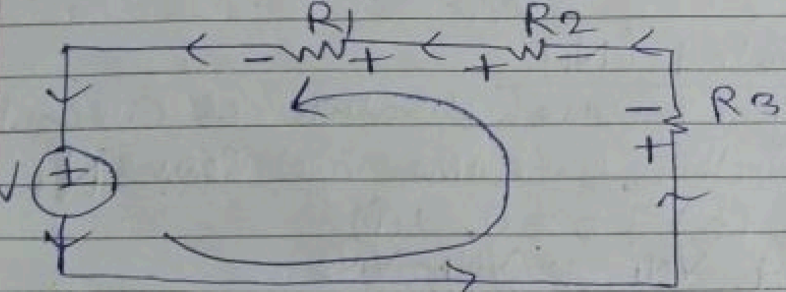


$\Sigma V_{active} = \Sigma V_{passive}$.

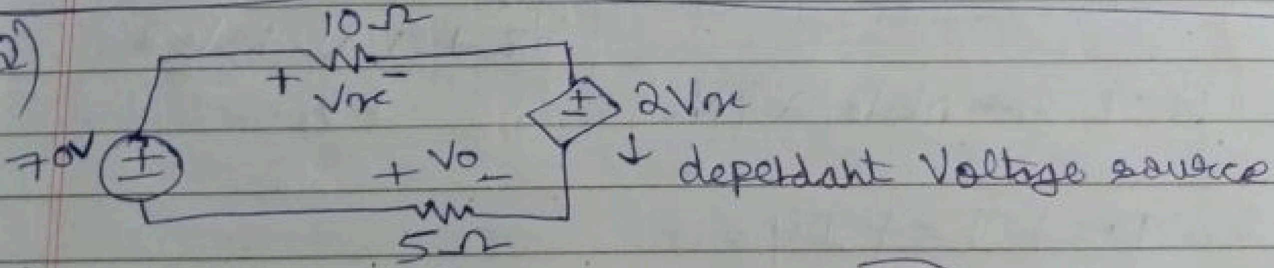
$V + V_1 + V_3 = V_2$.

If current entering + of Resistor → IR
if current leaving + of Resistor → $-IR$
or
Resistor is in active sign → $-IR$
Resistor is in passive sign → IR.

so $V - IR_1 - IR_3 = IR_2$
or $V = I(R_1 + R_2 + R_3)$



in this →
ΣV passive $= \Sigma V$ active.
$V_3 + V_1 + V = V_2$
or $V = I(R_1 + R_2 + R_3)$

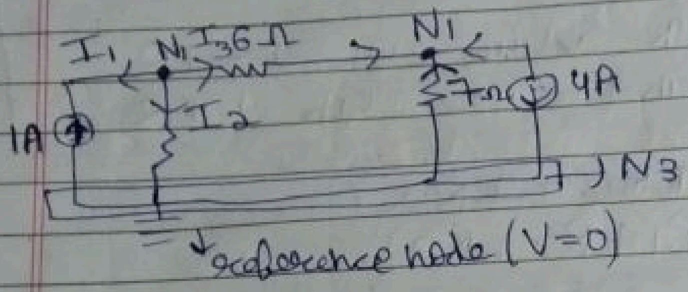
Q)


ans) assume direction as ↺

ΣV active $= \Sigma V$ passive
$70 + V_o = V_x + 2V_x$
$70 + V_o = 3V_x$
now $V_x = 10I$, $V_o = -5I$
so
$70 - 5I = 30I$
$\boxed{I = 2A}$
$V_o = -10V$, $V_x = 20V$.

KCL | Nodal analysis

$\sum I_{entering} = \sum I_{leaving}$



→ KCL for node 1 (N_1)

(arbitrarily assume direction of current from N1. in this i assume all leaves N_1

so $I_1 + I_2 + I_3 = 0$ → (1)

$0 = -1 + \frac{V_{N_1}}{2} + \frac{V_{N_1} - V_{N_2}}{6}$

{ $I_1 = -1A$ as opposing 1A of current source }

{ V_{N_1} → V at Node 1
V_{N_2} → V at Node 2 }

$\boxed{6 = 4V_1 - V_2}$ → (2) { V_1 → V at node 1
V_2 → V at node 2 }

→ KCL for Node 2 (N_2)

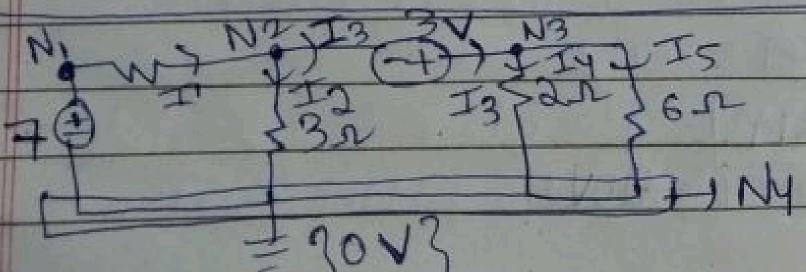
$I_3 + I_5 + I_4 = 0$

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

$\boxed{7V_1 - 13V_2 = 168}$ → (3)

solve (2), (3)

$V_1 = -2, V_2 = -14$ (ans)

Q) 

ans) $V_{N_1} = V_1$, $V_{N_2} = V_2$, $V_{N_3} = V_3$, $V_{N_4} = 0$ {ref node}

now $V_1 = 7V$ {as voltage source of 7V}

now KCL for Node 2:

$I_1 = I_2 + I_3$

$\frac{7 - V_2}{4} = \frac{V_2}{3} + I_3 \rightarrow ①$ {leave I_3 as is}

KCL for Node 3

$I_3 = I_4 + I_5$

$I_3 = \frac{V_3}{2} + \frac{V_3}{6} \rightarrow ②$

now eliminate I_3, {② in ①}

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

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

$\boxed{7V_2 + 8V_3 = 21} \rightarrow ③$

$\boxed{V_3 - V_2 = 3} \rightarrow$ {Voltge source + sign whoever − Voltage source sign = Voltage of source

or

whenever we have a voltage source marked + and − we understand that potential of marked + wrt − terminal is voltage of source.}

solving →

$V_2 = \frac{-1}{5} = -0.2V$

$V_3 = 2.8V$

Note VVV imp

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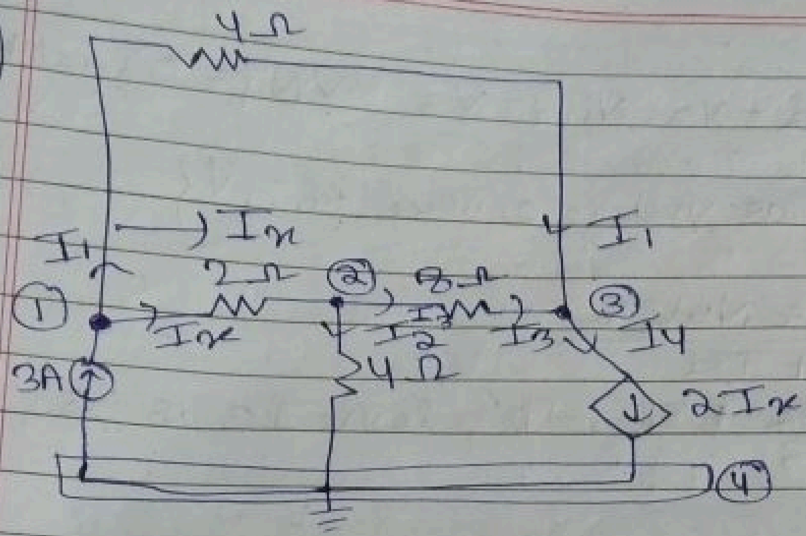
Q)



ans) Node 1 →

$$3 = I_1 + I_x$$

$$\boxed{3 = \frac{V_1 - V_3}{4} + \frac{V_1 - V_2}{2}} \rightarrow (1)$$

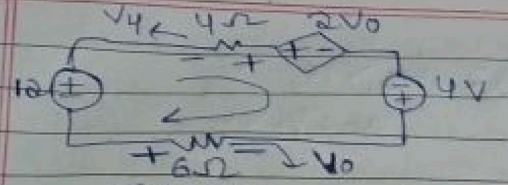
Node 2 → $I_x = I_2 + I_3$

$$\boxed{\frac{V_1 - V_2}{2} = \frac{V_2}{4} + \frac{V_2 - V_3}{8}} \rightarrow (2)$$

Node 3 → $I_3 + I_1 = \underset{(I_4)}{2I_x}$

$$\boxed{\frac{V_2 - V_3}{8} + \frac{V_1 - V_3}{4} = \cancel{2}\left(\frac{V_1 - V_2}{\cancel{2}}\right)} \rightarrow (3)$$

solving → $\boxed{\begin{aligned} V_1 &= 4.8V \\ V_2 &= 2.4V \\ V_3 &= -2.4V \end{aligned}}$ (ans)

Q) 

ans) $\Sigma V_{active} = \Sigma V_{passive}$

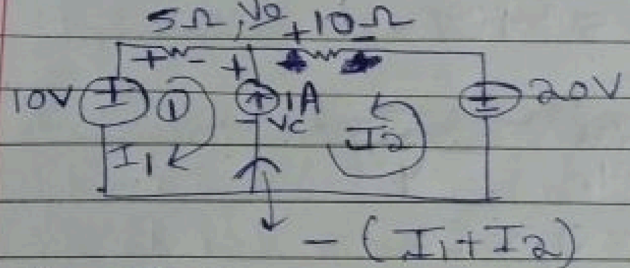
$V_4 + 4 + V_0 + 12 = 2V_0$

$-4I + 4 - 6I + 12 = -12I$

$\boxed{I = -8A}$

$V_0 = -6I = 48V$ (ans), $V_4 = -4I = 32A$

P absorbed by 4V $= 4 \times 8 = 32W$.

Q) 

use KVL not KCL.
find V_0

ans) loop ① → $\Sigma V_{active} = \Sigma V_{passive}$

$10 = V_0 + V_C$

$10 = 5I_1 + V_C$

$\boxed{V_C = 10 - 5I_1}$ → ①

loop ② → $\Sigma V_{active} = \Sigma V_{passive}$

$20 + V_{10} = V_C$

$\boxed{20 - 10I_2 = V_C}$ → ②

and $-(I_1 + I_2) = 1$

$\boxed{I_1 + I_2 = -1}$ → ③

from ① and ②

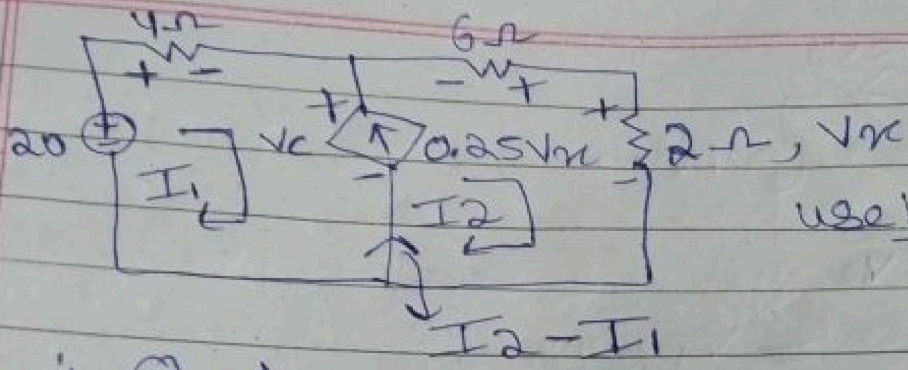
$10 - 5I_1 = 20 - I_2 10$

→ $\boxed{5I_1 - 10I_2 = -10}$ → ④

so $I_2 = \frac{1}{3}A$, $I_1 = \frac{-4}{3}A$.

so $V_0 = 5I_1$
$= \frac{-20}{3}V$ (ans)

Q)



use KVL

ans) in (1) →

$$20 = V_4 + V_c$$

$$\boxed{20 - 4I_1 = V_c} \rightarrow (1)$$

in (2) → $V_c + V_6 = V_x$

$$\boxed{V_c = 8I_2} \rightarrow (2)$$

$$20 - 4I_1 = 8I_2$$

$$\rightarrow \boxed{I_1 + 2I_2 = 5} \rightarrow (3)$$

so $I_2 - I_1 = \frac{V_x}{4} = \frac{2I_2}{4}$

so $I_2 - I_1 = 0.5I_2$

$$\boxed{0.5I_2 = I_1}$$

$\boxed{I_1 = 1A,\ I_2 = 2A}$ (ans)

so $V_x = 4V$.

Superposition Theorem

Linear system → obeys superposition and homogeneity

Homogeneity - if input is changed by a factor a output also changes by a.

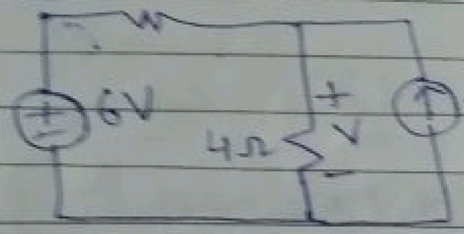
ex - if $V=1 \rightarrow i=1$ } assuming $R=1\Omega$

$V=5 \rightarrow i=5$ }

Superposition → for all linear systems net response by 2 or inputs is sum of responses/outputs caused by each input individually.

Replace voltage source with wire and current with open.

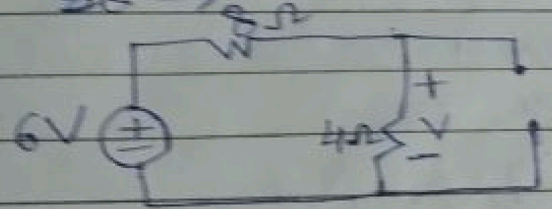
Q)



using superposition solve for V

ans) (i) $V=6V,\ I=0A$

so →

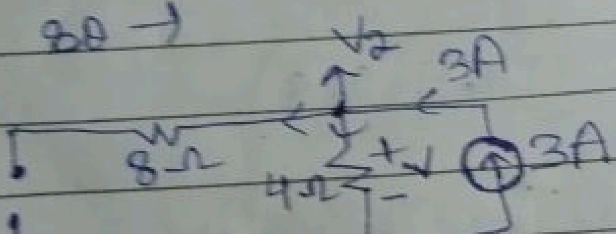


$$I = \frac{6}{12} = 0.5A$$

$$\text{so } V_1 = 0.5 \times 4 = 2V$$

(ii) $V=0V,\ i=3A$

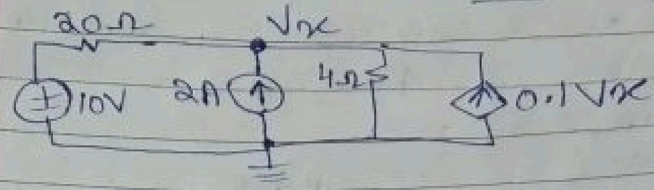
so →



$$3 = \frac{V_2 - 0}{4} + \frac{V_2 - 0}{8} \quad \text{so } \boxed{V_2 = 8V}$$

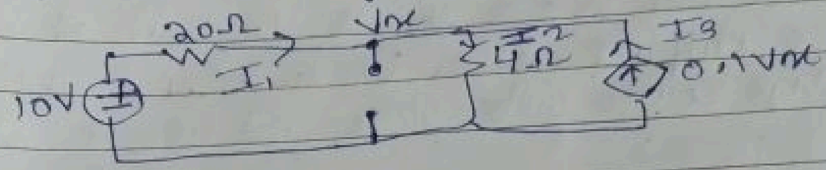
so $V_{4\Omega} = 2V + 8V = \underline{10V}$ (ans)

Q)



find Vx

ans) (i) consider only voltage source →



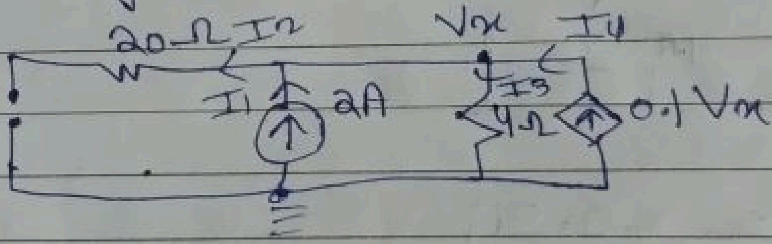
KCL at Vx →

$\rightarrow I_1 + I_3 = I_2$

$$\rightarrow \frac{10 - V_x}{20} + 0.1\,V_x = \frac{V_x}{4}$$

$V_x = 2.5V$

(ii) only current source →



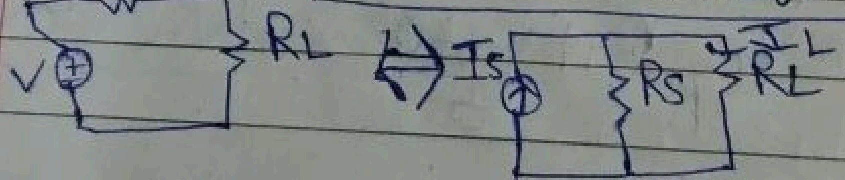
$I_1 + I_4 = I_2 + I_3$

$$2 + 0.1\,V_x = \frac{V_x}{20} + \frac{V_x}{4}$$

$V_x = 10V$

so $V_x = 10 + 2.5 = \underline{12.5}$ (ans)

Source Transformation



to do this $V_{L_{voltage}} = V_{L_{current}}$.

so →

$$V_{L_{voltage}} = \frac{V R_L}{R_S + R_L} \rightarrow ①$$

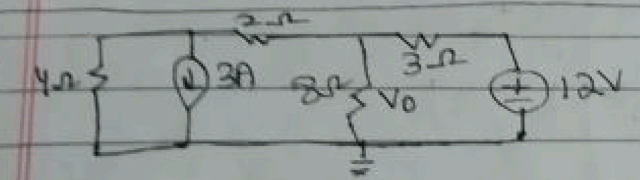
$$I_L = \frac{I_S R_S}{R_L + R_S}$$

so $V_{L_{current}} = \frac{I_S R_S}{R_L + R_S} \times R_L \rightarrow ②$

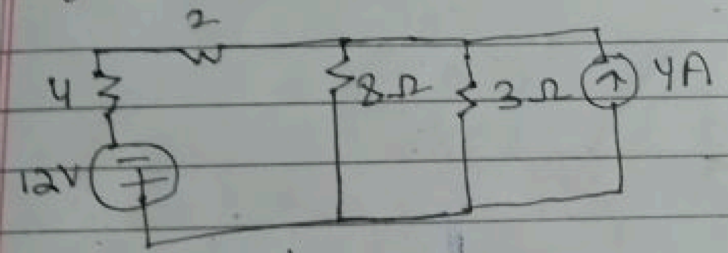
comparing ① and ②

we get $\boxed{V = I_S R_S}$

so $\boxed{I_S = \frac{V}{R_S}}$

Q) 

ans) find Vo →



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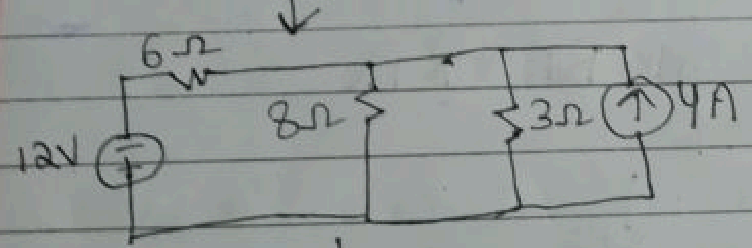

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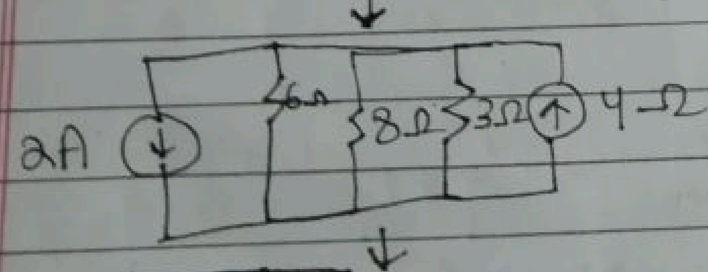

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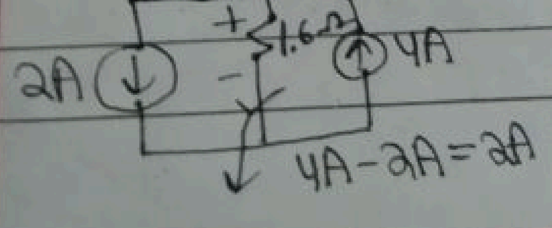
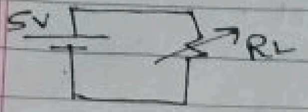
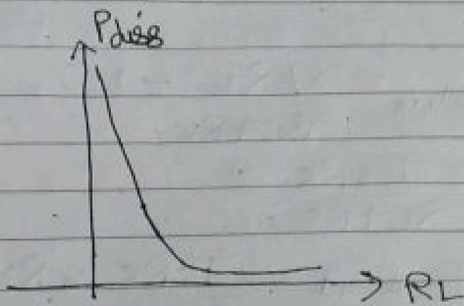


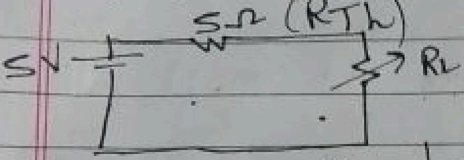
so $V_0 = 2 \times 1.6 = 3.2V$ (ans)

Max power transfer theorem

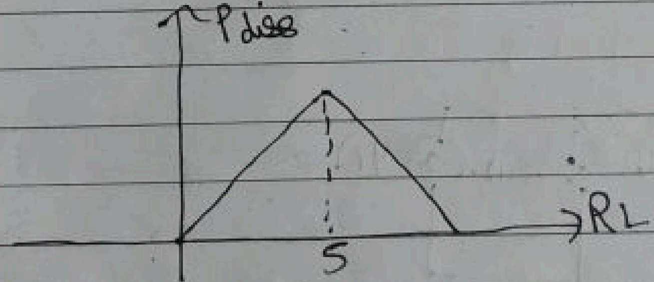


R_L	P
5Ω	5W.W
3Ω	8.33 W
2Ω	12.5 W
1Ω	25 W
0.5Ω	50 W
0.05Ω	100W

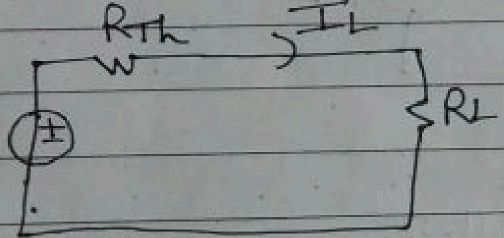




R_L	I	P_{RL}
10	0.66	1.089
6	$\frac{5}{11}$	1.215
5	$\frac{1}{2}$	1.25
2.5	$\frac{5}{7.5}$	1.089
0	1	0



max power at $R_L = R_{Th}$

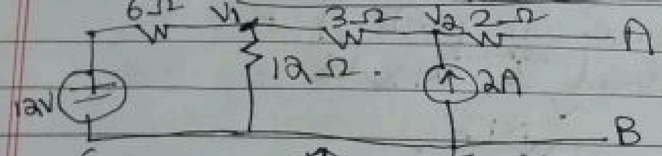


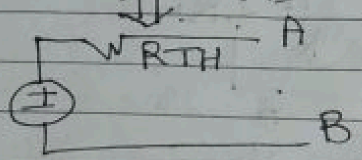
$$I_L = \frac{V_{th}}{R_{TH} + R_L}$$

$$P_{RL} = \frac{V_{TH}^2}{(R_{TH}+R_L)^2} \times R_L$$

how we maximize P_{RL}
and get $\boxed{R_L = R_{TH}}$ ****

Thevenin Theorem





so →

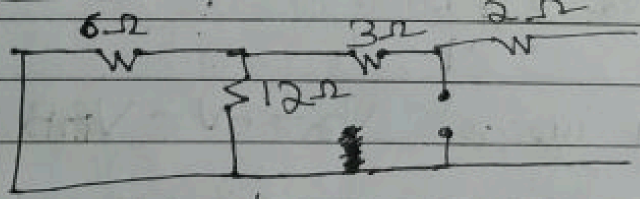
KCL → ① $\boxed{\frac{12-V_1}{6} = \frac{V_1}{12} + \frac{V_1-V_2}{3}}$ → ①

KCL → ② $\frac{V_1-V_2}{3} + 2 = 0 \rightarrow \boxed{V_1 - V_2 = -6}$ → ②

$V_2 = 22V$, $\boxed{V_1 = 16}$

$V_{AB} = V_2 = 22V$

now



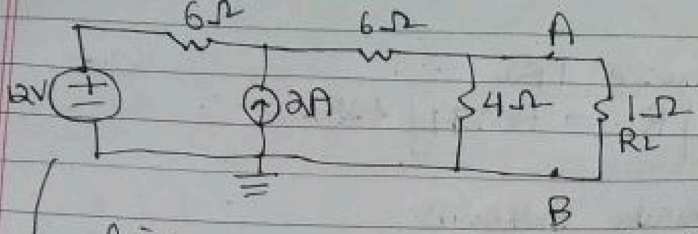
$R_{eq} = R_{th} = 9\Omega$ {6, 12 in ||, 5 in series}

** {as in Rth we need independant voltage source and current source to be 0 so we remove them}

***

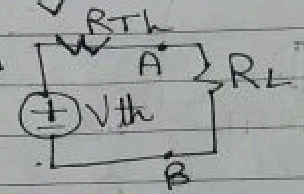
Basically to find Vth → remove load resistor and find open circuit [illegible]. Voltage

Q)

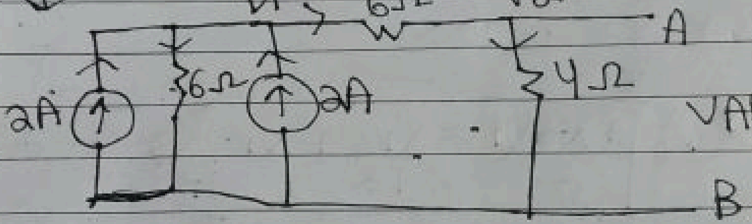


Find max power at port A, B and P transferred when 1Ω is connected

ans) Equivalent to →



so



$V_{AB} = V_2$

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

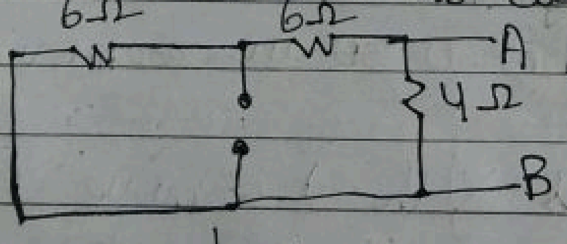
→ $\boxed{2V_1 - V_2 = 24}$

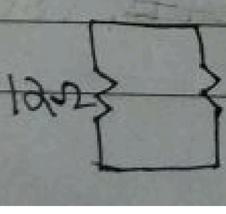
② → $\frac{V_1 - V_2}{6} = \frac{V_2}{4}$

solving we get $V_2 = 6V = V_{AB}$

so open circuit voltage $= 6V = V_{th}$

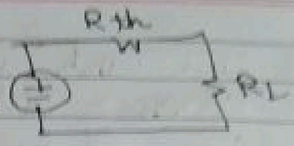
now $R_{eq} = R_{th}$ { No indep Voltage source, no current source }





→ $3\Omega = R_{th}$.

so Thevenised →



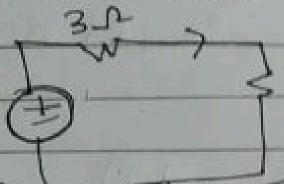
→ $P_{max} = \left(\frac{6V}{6\Omega}\right)^2 \times R_L$

for max power $R_L = R_{Th}$

so → $\boxed{P_{max} = 3W}$

for (b) 1Ω connected

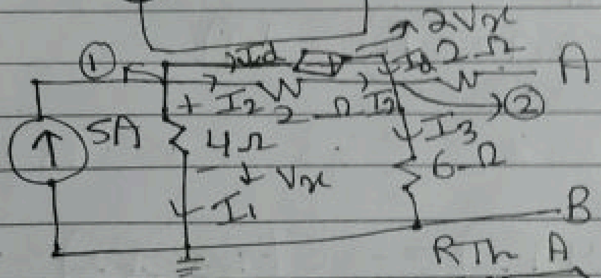
so thevenin circuit →



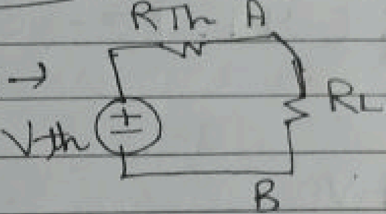
$P_{1\Omega} = (1.5)^2 \times 1$

$= 2.25W$ (ans)

Q)



ans) equivalent to →



$V_{AB} = V_2$

using KCL (1)

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

→ $20 = V_1 + 2V_1 - 2V_2 + I_d \times 4$

→ $\boxed{3V_1 - 2V_2 = 20 - 4I_d}$

for (2)

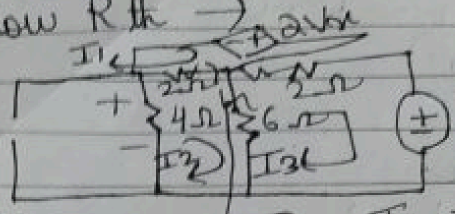
→ $I_d + \frac{V_1 - V_2}{2} = \frac{V_2}{6}$

→ $\boxed{6I_d = -3V_1 + 4V_2}$

eliminate I_d and use
$V_2 - V_1 = 2V_x = 2V_1 \to \boxed{V_2 - 3V_1 = 0} \to (3)$

we got $V_2 = V_{AB} = V_{th} = 20V$

now $R_{th} \to$



↓ added so we can find I and use $V = IR$ to find Req.

$I_t = I_2 - I_1$

using KVL → (1)

$2V_x = V_{21}$

$2(-4I_2) = -2(I_2 - I_1) \to (1)$

for loop (2)

$V_x + V_{21} = V(6\Omega)$

$-2(I_2 - I_1) + (-4I_2) = -6(I_3 - I_2) \to (2)$

In loop 3 →

$V_{6\Omega} = V_{22} + V$

$-6(I_3 - I_2) = 2I_3 + 1 \to (3)$

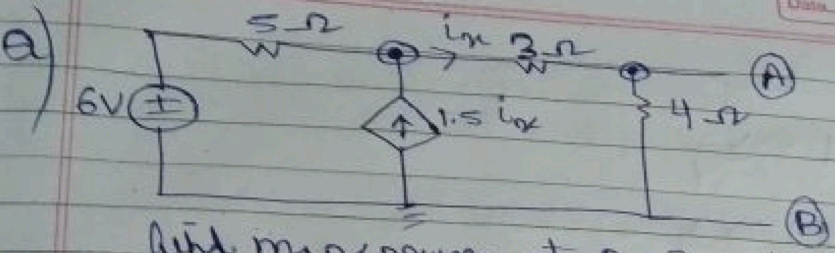
we get $I_3 = \frac{-1}{6}$.

so $I_3 \times R_{th} = 1V$

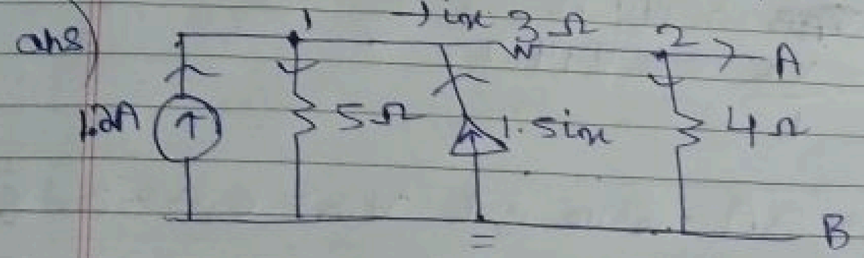
so $\boxed{R_{th} = 6\Omega}$.

so for max power $R_L = 6\Omega$

and max power $= \left(\frac{20}{12}\right)^2 \times 6$ (ans)

a) 

find max power at A-B port

ans) 

$V_{AB} = V_2$

KCL ① $\rightarrow 1.2 + 1.5 I_x = \frac{V_1}{5} + i_x$

$i_x = \frac{V_1 - V_2}{3}$

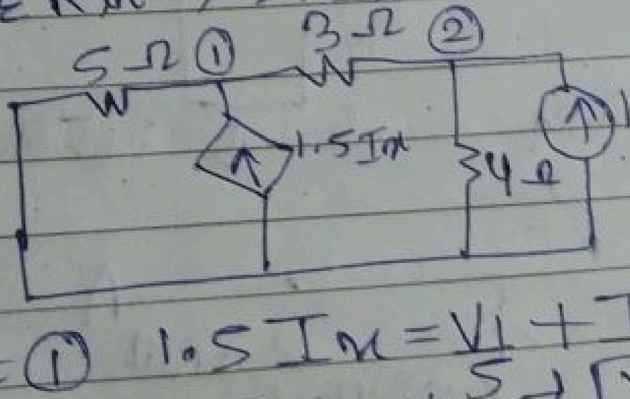
so $1.2 = \frac{V_1}{5} - 0.5\left(\frac{V_1 - V_2}{3}\right) \rightarrow$ ①

KCL ② $\rightarrow \frac{V_1 - V_2}{3} = \frac{V_2}{4}$

$\rightarrow 4V_1 - 7V_2 = 0 \rightarrow$ ②

$\boxed{V_2 = 5.33V} = V_{th}$

for Rth $\rightarrow$ $\rightarrow I_x$



↓ added to find Req

at ① $1.5 I_x = \frac{V_1}{5} + I_x$

$\rightarrow 0.5 I_x = \frac{V_1}{5} \rightarrow \boxed{\frac{V_1 - V_2}{6} = \frac{V_1}{5}} \rightarrow$ ①

at (2)

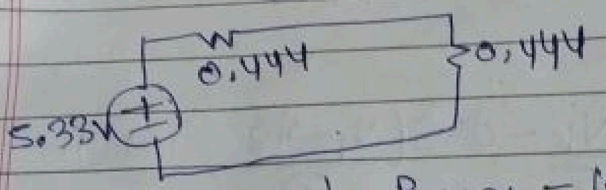
$\rightarrow i_x + 1 = \frac{V_2}{4}$

$\rightarrow \frac{V_1 - V_2}{3} + 1 = \frac{V_2}{4}$

now $V_2 = 0.444\,\Omega$

so $R_{th} = \frac{V_2}{1} = 0.444\,\Omega$.

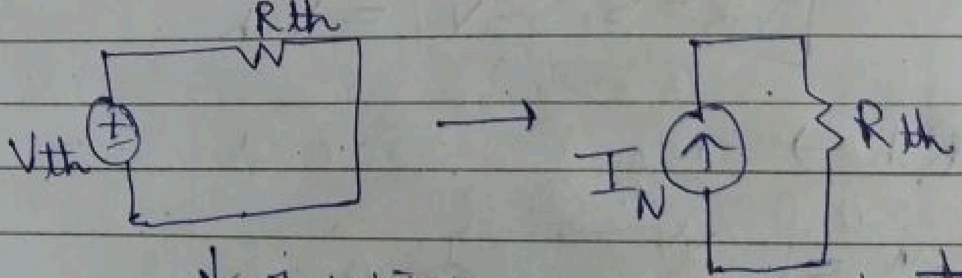
if we took 2A we we get $V_2 = 0.888$ due to linearity



$\downarrow$ $P_{max} = \left(\frac{5.33}{0.888}\right)^2 \times 0.444$

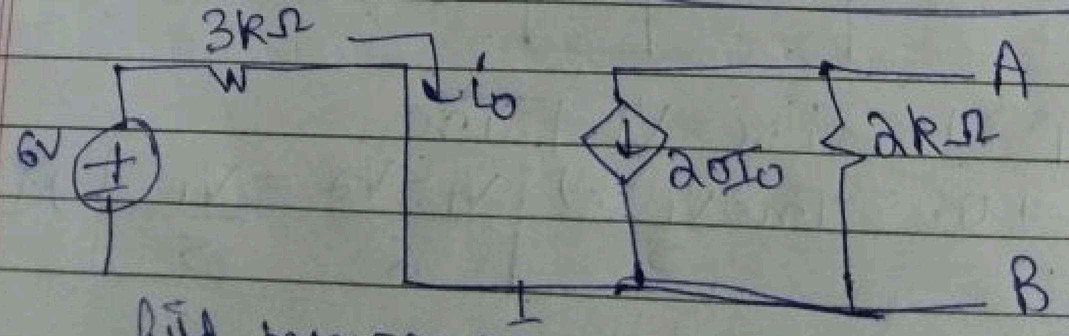
Norton equivalent

convert Vth to a current source, and that is norton equivalent.



$\downarrow$ Thevenin eq $\qquad\qquad$ $\downarrow$ norton eq

Q)



find maxpower = ?

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ans) as open circuit current through $2K = 20I_0$

so $V_{AB} = 20I_0 \times 2K\Omega \times -1$

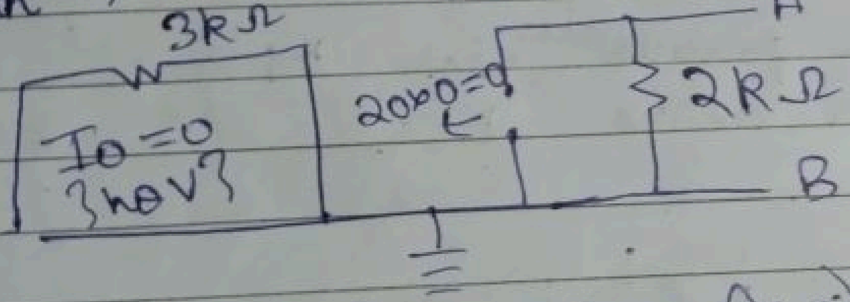
↓ opp direction

$V_{AB} = -40I_0 \times 10^3$

now in (i) $\rightarrow I_0 = \frac{6}{3K\Omega} = 2\times10^{-3}A$

so $V_{AB} = -80V = V_{th}$

$R_{th} \rightarrow$



so $\underline{R_{th} = 2K\Omega}$. (ans)