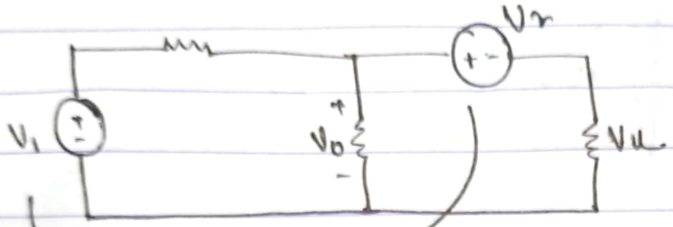
LECTURE 11

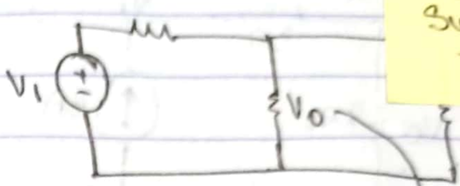
MONDAY DATE: 14/11/22

Slide 8 Superposition Theorem

SUPERPOSITION PRINCIPLE

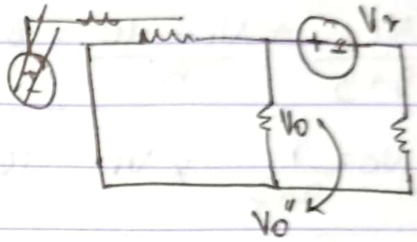


$V_o = V_o' + V_o''$



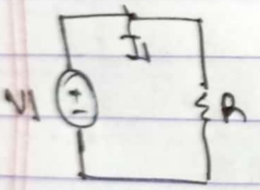
(V_2 is shorted)

V_o'

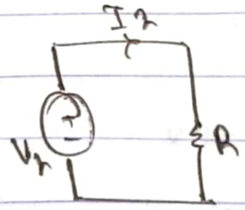


(V_1 is shorted)

* Independant ~~components~~ variables can be shorted.
* Dependant variables can't be shorted.



$P' = I_1^2 R$ +



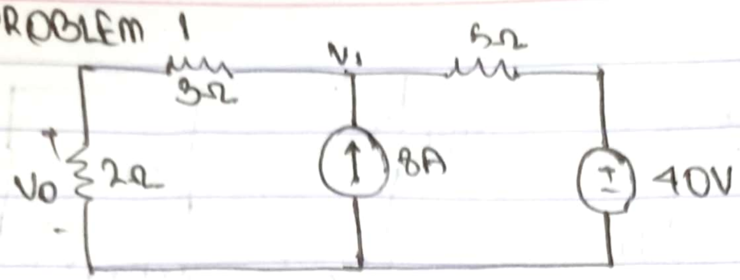
$P'' = I_2^2 R$

$I^2 R = I_1^2 R + I_2^2 R$

$(I_1 + I_2)^2 R \neq I_1^2 R + I_2^2 R$

* Power is not a linear, so superposition is not valid

PROBLEM 1

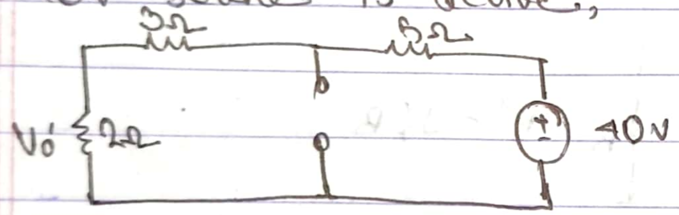


$$\frac{V_1}{2+3} + \frac{V_1 - 40}{5} = 8 \Rightarrow V_1 = 40V$$

$$V_0 = \frac{2}{2+3} \times V_1 = 16V$$

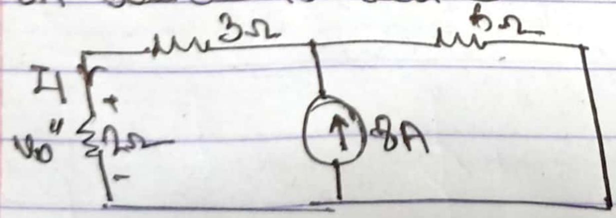
Superposition:-

40V source is active,



$$V_0' = \frac{2}{2+3+5} \times 40 = 8V$$

8A source is active



$$I_1 = \frac{5 \| 5}{2+3} \times 8$$

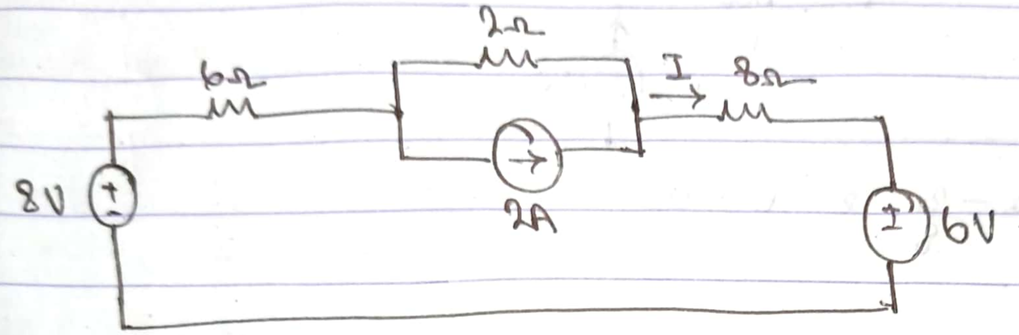
$$I_1 = 4A$$

$$\cancel{V_1 =}\ V_0'' = 4 \times 2 = \cancel{8AV}\ 8V$$

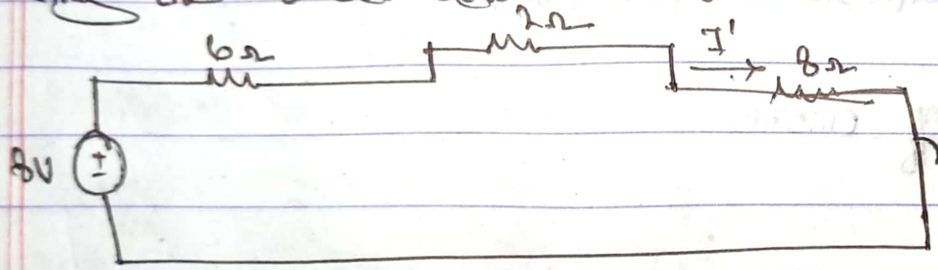
According to the superposition principle,

$$V_0 = V_0' + V_0''$$
$$= 8 + 8$$
$$= 16V$$

PROBLEM 2

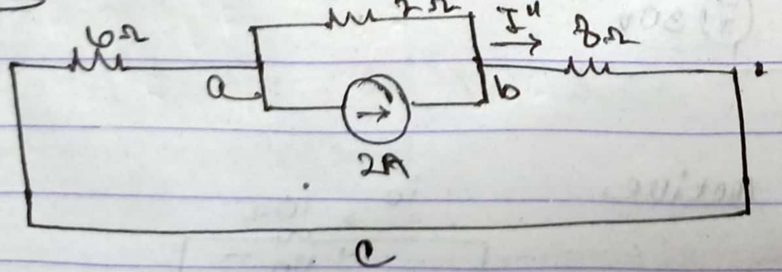


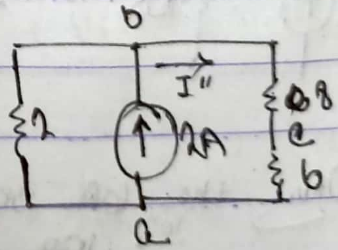
Only the 8V sou source is active



$$I' = \frac{8}{6+2+8} = 0.5A$$

Only the 2A source is active

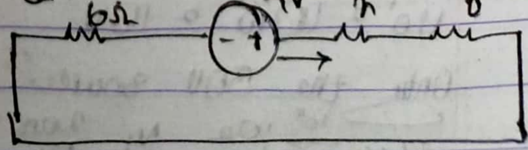




$$I'' = \frac{14\|2}{(8+6)} \times 2$$

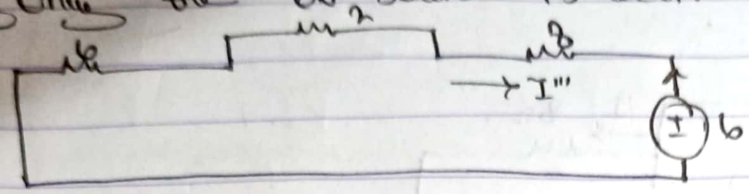
$= 0.25A$

OR



$$I'' = \frac{4}{6+2+8} = 0.25A$$

~~Att~~ Only the 6V source is active.

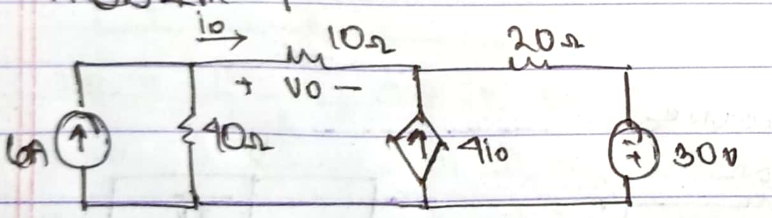


$$I''' = \frac{-6}{6+2+8} = -\frac{3}{8} = -0.375$$

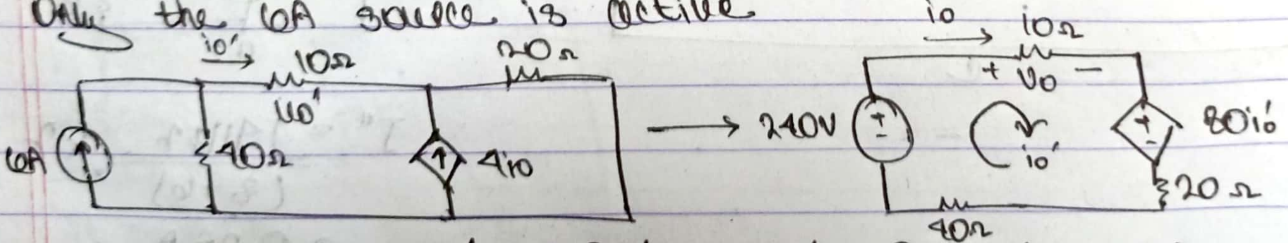
According to the superposition principle,

$$I_0 = I' + I'' + I'''$$
$$= 0.5 + 0.25 - \cancel{\tfrac{3}{8}}\ 0.375$$
$$= 0.375\,A$$

PROBLEM 4



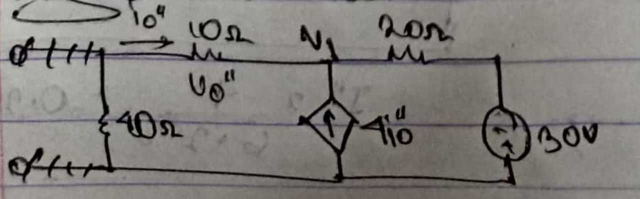
Only the 6A source is active



$$-240 + 40i_0' + 10i_0' + 80i_0' + 20i_0' = 0 \Rightarrow i_0' = 1.6\,A$$

$$v_0' = 10i_0' = 16V$$

Only the 30V source is active.



$$4i_0'' = \frac{v_1}{50} + \frac{v_1+30}{20} \quad \left[i_0'' = -\frac{v_1}{50}\right]$$

$$\Rightarrow 4\left(\frac{-v_1}{50}\right) = \frac{v_1}{50} + \frac{v_1+30}{20}$$

$$v_1 = -10\,V$$

$i_0'' = -\frac{(-10)}{50} = 0.2A$

$V_0'' = i_0'' \times 10 = 0.2 \times 10 = 2V$

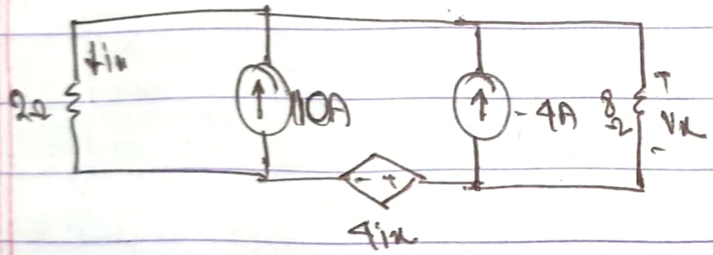
$V_0 = V_0' + V_0''$

$= 16 + 2 = 18V$

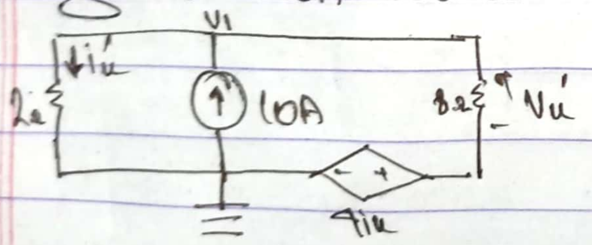
$i_0 = i_0' + i_0''$

$= 1.6 + 1.2 = 1.8A$

PROBLEM 6



Only the 10A source is active



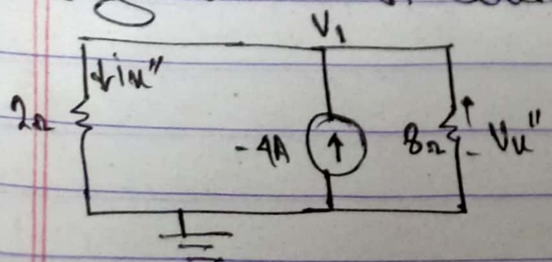
$10 = \frac{V_1}{2} + \frac{V_1 - 4i_x'}{8}$ $\quad [i_x = \frac{V_1}{2}$

$80 = \frac{5V_1}{\cancel{\ }} - 4\left(\frac{V_1}{2}\right)$ $\quad i_x = \frac{\frac{80}{3}}{2} = \frac{40}{3}$

$V_1 = \frac{80}{3} = 26.67V$

$V_x' = \frac{V_1 - 4i_x'}{8} \times 8 \Rightarrow \frac{\frac{80}{3} - 4\left(\frac{40}{3}\right)}{8} \times 8 = -\frac{80}{3}V$

Only the $-4A$ source is active



$i_x'' = \frac{V_1 - 0}{2}$

$-4 = \frac{V_1}{2} + \frac{V_1 - 4i_x''}{8}$

$-4 = \frac{V_1}{2} + \frac{V_1 - \frac{8V_1}{2}}{8}$

$\Rightarrow -32 = 6V_1 - 2V_1$

$V_1 = -\frac{32}{?}V$

$$\frac{V_1 - 4i_x''}{8} \times 8 = V_x''$$

$$V_x'' = \frac{32}{3} \text{ V}$$

~~Acc.~~ $V_x = V_x' + V_x'' = -\frac{80}{3} + \frac{32}{3} = -16 \text{ V}$

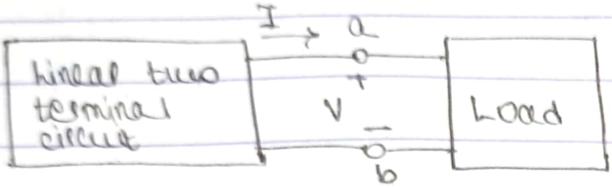
LECTURE 12

WEDNESDAY DATE: 17/11/22

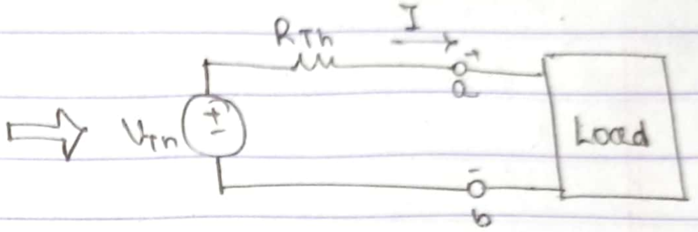
THEVENIN'S THEOREM & NORTON'S THEOREM

Slide 9
Thevenin's and Norton's Theorem

THEVENIN'S THEOREM



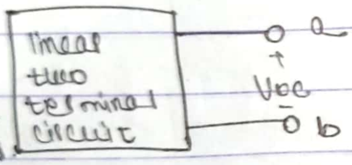
Original circuit

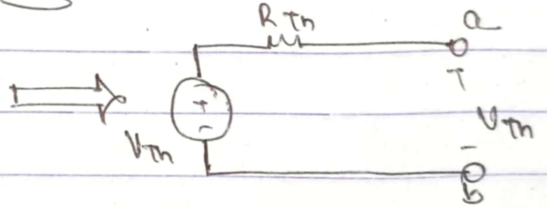


The Thevenin equivalent circuit

To check whether the original circuit = Thevenin equivalent circuit :—

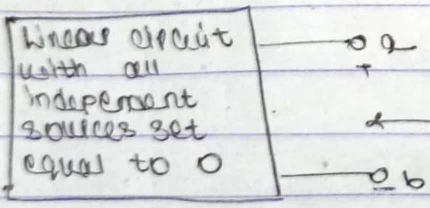
* load is removed and voltage is measured

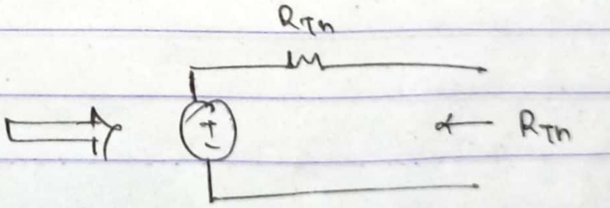




~~* Voc = 0~~
~~Either all the~~

(1) $V_{oc} = V_{Th}$





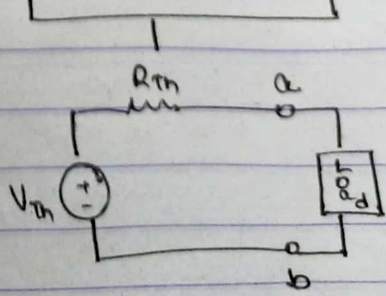
(2) $R_{eq} = R_{Th}$

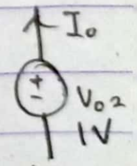
(3) $I_{sc} = \frac{V_{Th}}{R_{Th}}$

$V_{Th} \neq 0$

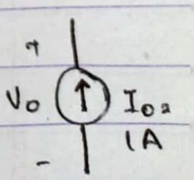
$\frac{V_{Th}}{I_{sc}}$

kill the independent sources





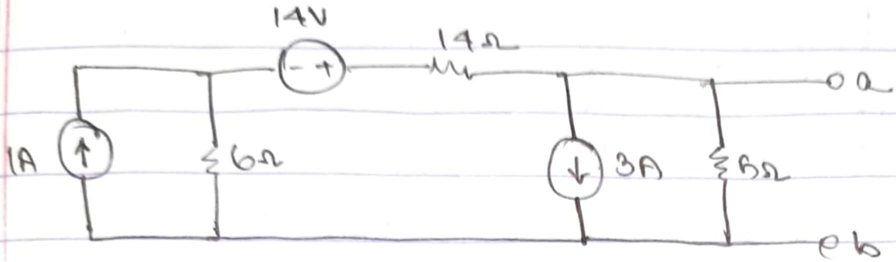
$R_{Th} = \frac{V_o}{I_o}$

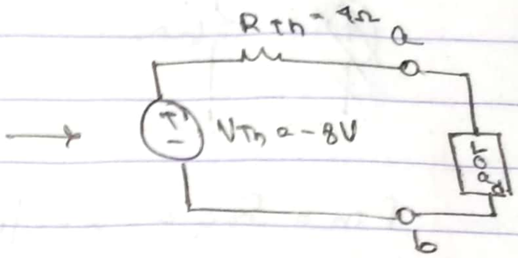


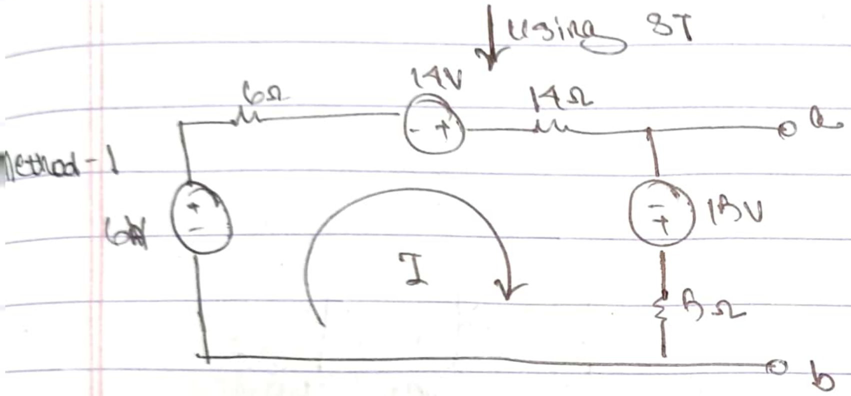
$R_{Th} = \frac{V_o}{I_o}$

special case — { * $V_{oc} = 0$
$I_{sc} = 0$
$R_{Th} = \frac{0}{0}$ = undetermined

Problem 1





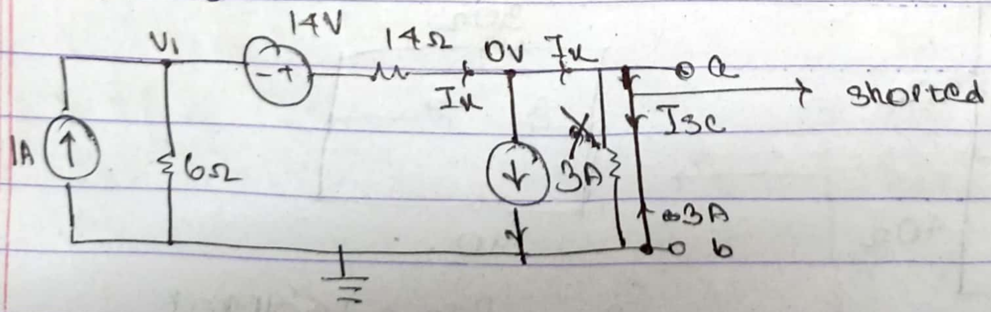


$-6 + 6I - 14 + 14I - 18 + 8I = 0$

$I = \frac{7}{8} = 1.4A$

$-V_{Th} - 18 + 8I = 0$

$V_{Th} = -8V$



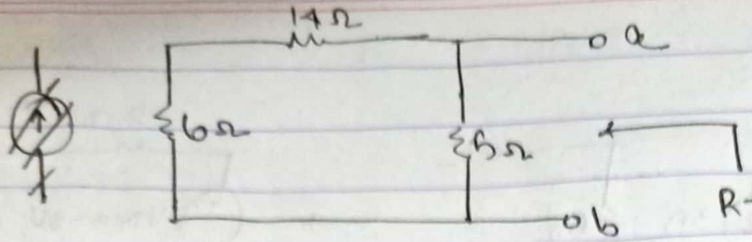
$1 = \frac{V_1}{6} + \frac{V_1 - (-14) - 0}{14} \Rightarrow V_1 = 0V$

$I_x = \frac{V_1 - (-14) - 0}{14} = \frac{0 + 14}{14} = 1A \quad [V_1 = 0]$

$I_{sc} = I_x - 3 = 1 - 3 = -2A$

$R_{Th} = \frac{V_{Th}}{I_{Th}} = \frac{-8}{-2} = 4\Omega$

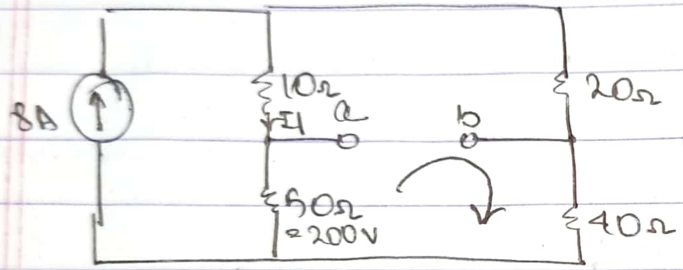
method-2

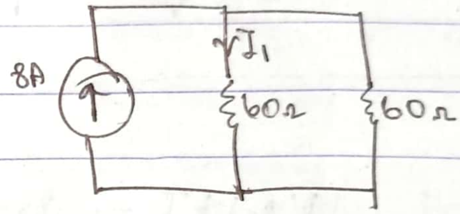


$R_{Th} = R_{eq}$

$R_{Th} = R_{eq} = 20 \| 5 = \left(\frac{1}{20} + \frac{1}{5}\right)^{-1} = 4\,\Omega$

Problem 2

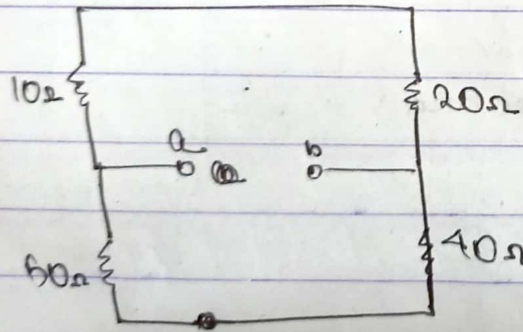


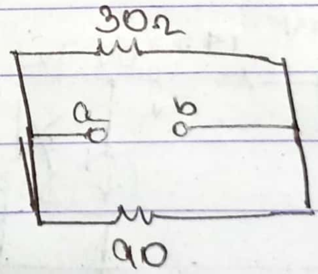


$I_1 = \frac{60 \| 60}{60} \times 8 = 4\,A$

$-200 + V_{Th} + 160 = 0$

$V_{Th} = 40V$



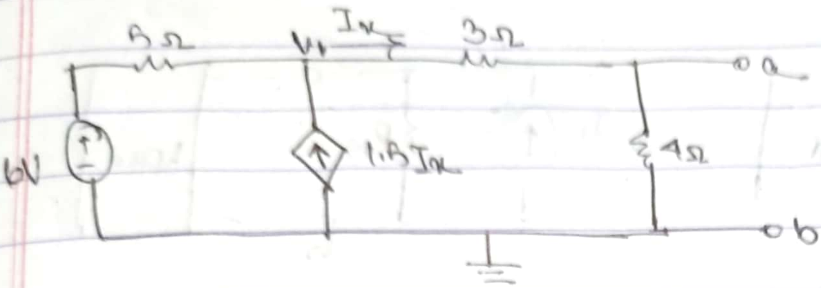


$R_{ab} = R_{Th} = (30 \| 90)$

$= \left(\frac{1}{30} + \frac{1}{90}\right)^{-1}$

$= 22.5\,\Omega$

Problem 4

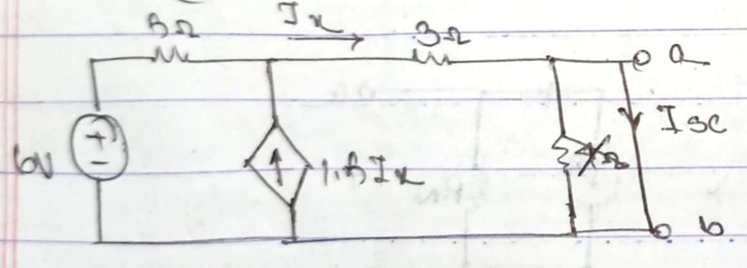


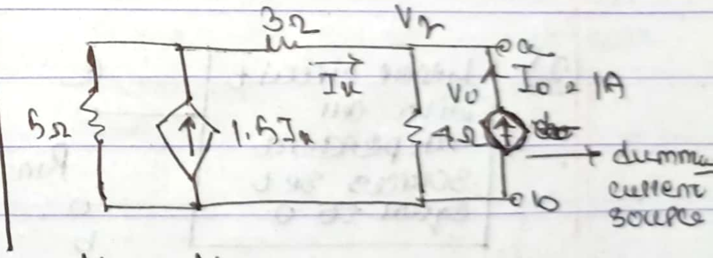
$$\frac{V_1-6}{5} + \frac{V_1}{7} = 1.5\, I_x \qquad \left[I_x = \frac{V_1}{7}\right]$$

$$\frac{V_1-6}{5} + \frac{V_1}{7} = 1.5\left(\frac{V_1}{7}\right)$$

$$V_1 = \frac{28}{3}\ V = 9.33\ V$$

$$V_{Th} = \left(\frac{V_1}{7}\right) \times 4 = 5.33\ V$$





$I_2 = I_{sc}$

$-6 + 5I_1 + 3I_2 = 0$ —— (1)

$I_2 - I_1 = 1.5\, I_x$

$I_2 - I_1 = 1.5\, I_2$

$-I_1 - 0.5\, I_2 = 0$ —— (2)

$I_1 = -6A,\ I_2 = 12\ A$

$I_{sc} = 12\ A$

$$R_{Th} = \frac{V_{Th}}{I_{sc}} = \frac{5.33}{12} = \frac{4}{9}$$

$V_0 = V_r$

OR KCL at V_1,

$$1.5\, I_x = \frac{V_1}{5} + \frac{V_1 - V_r}{3}$$

$$1.5\left(\frac{V_1 - V_r}{3}\right) = \frac{V_1}{5} + \frac{V_1 - V_r}{3} \qquad \left[I_x = \frac{V_1 -}{3}\right.$$

KCL at V_r

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

$V_1 =$

$V_r = \qquad = V_{Th}$

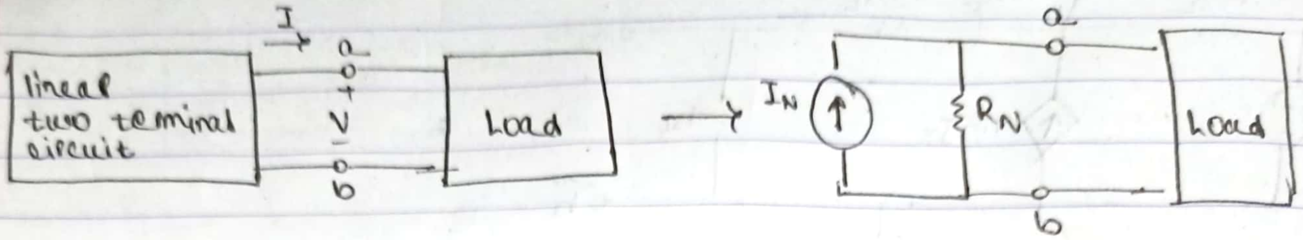
$$R_{Th} = \frac{V_0}{I_0} =$$

LECTURE 13

MONDAY

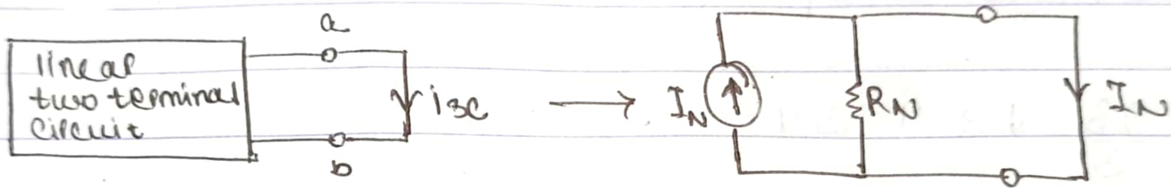
DATE: 21/11/22

NORTON'S THEOREM



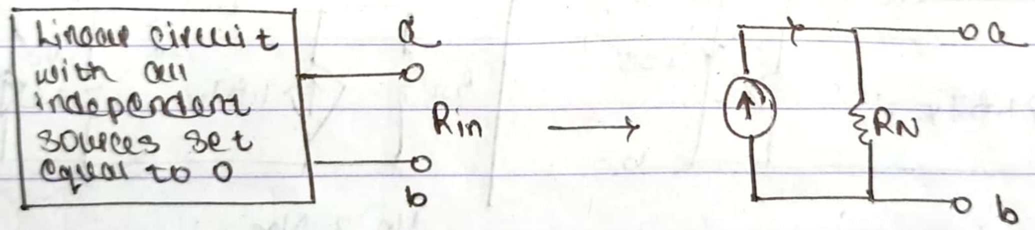
Original circuit

(1)



~~I_{sc}~~ $i_{sc} = I_N$

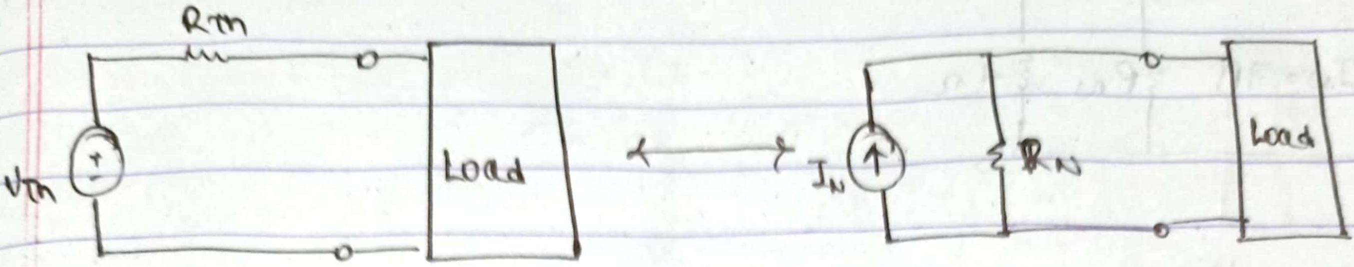
(2)



$R_{in} = R_N$

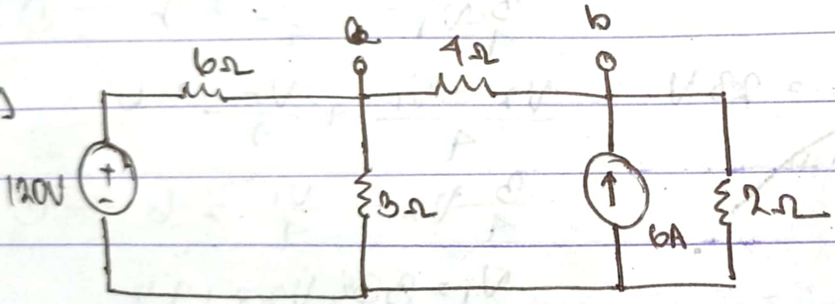
(3) $V_{oc} = I_N R_N$

Thevenin ⟷ Norton

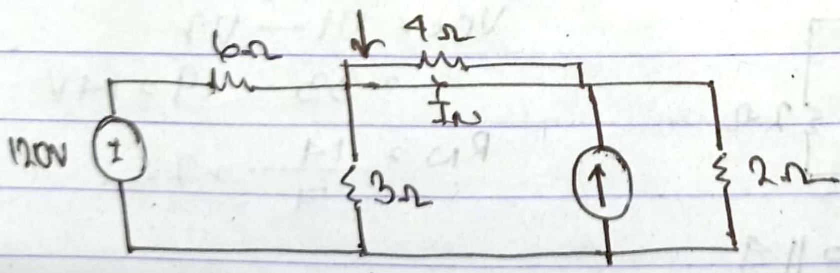


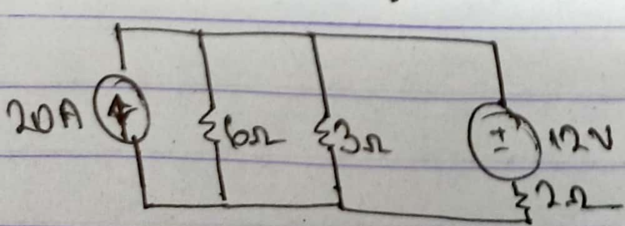
Problem 7

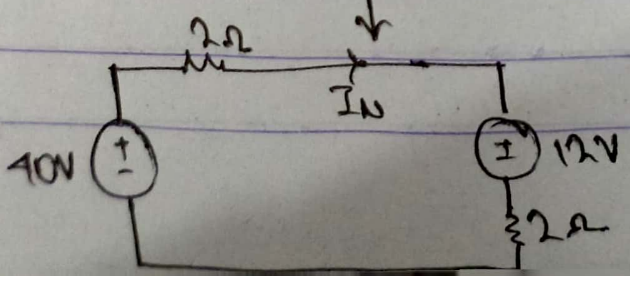
(i)



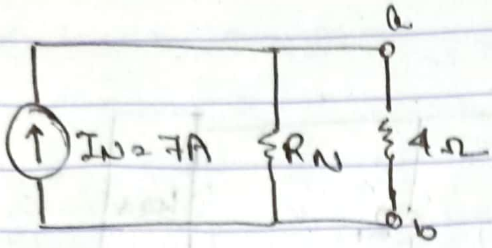
* The components which a
connected to the termina
mentioned in question - a
~~the~~ are load



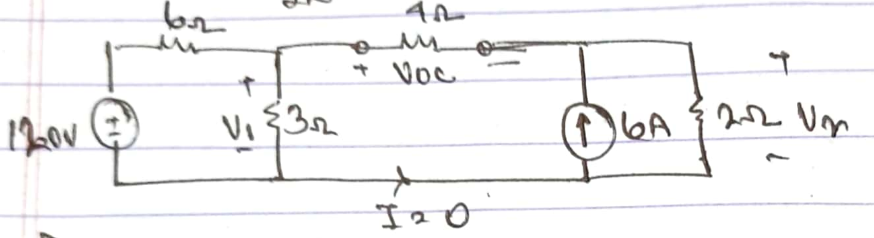




$$I_N = \frac{40-12}{4} = 7A$$



ethod-1 (i) $R_N = \frac{V_{oc}}{I_N}$



$V_1 = \frac{3}{3+6} \times 120 = 40V$

$V_2 = 6 \times 2 = 12 \text{ V}$

$V_{oc} = V_1 - V_2 = 40 - 12 = 28V$

$R_N = \frac{V_{oc}}{I_N} = \frac{28}{7} = 4\Omega$

$\frac{V_1 - 120}{6} + \frac{V_1}{3} + \frac{V_1 - V_2}{4} = 0$

$\frac{3}{4}V_1 - \frac{V_2}{4} = 2$ — (I)

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

$\frac{3}{4}V_2 - \frac{V_1}{4} = 6$ — (II)

$V_1 = 33V, V_2 = 19V$

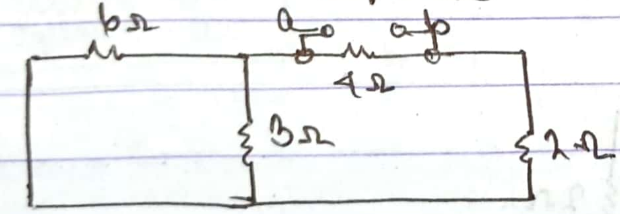
$V_{oc} = V_1 - V_2$

$= 33 - 19 = 14V$

$R_N = \frac{14}{7} = 2\Omega$

$R_{eq} = R_N$

(ii)



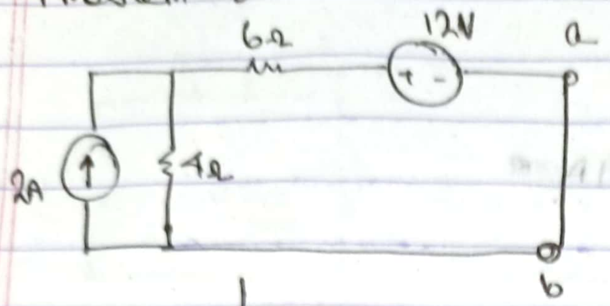
$R_{eq} = ((6 \| 3) + 2) \cancel{= R_N} \| 4$

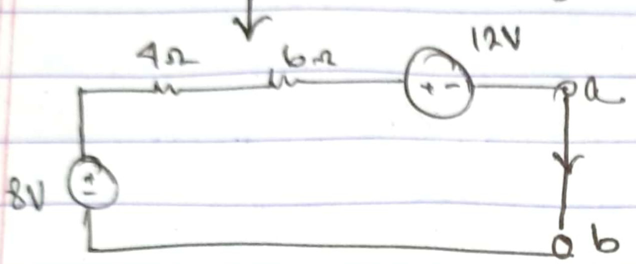
$= (2 + 2) \| 4$

$R_N = 4 \| 4$

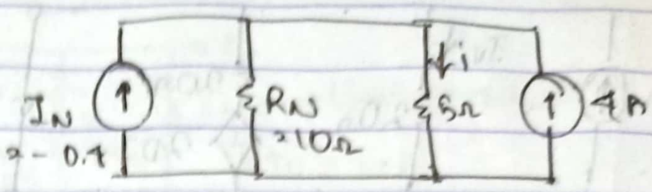
$R_N = 2\ \Omega$

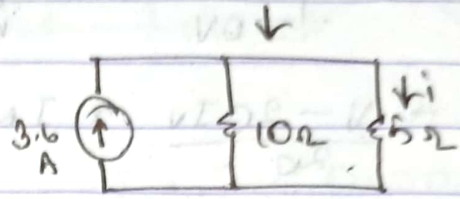
Problem 8



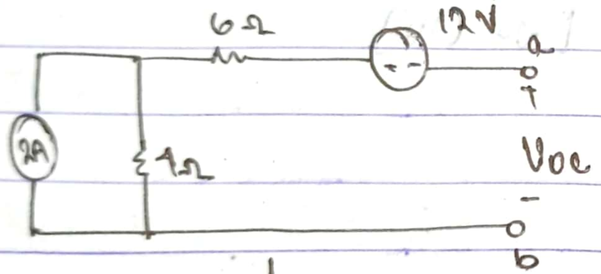


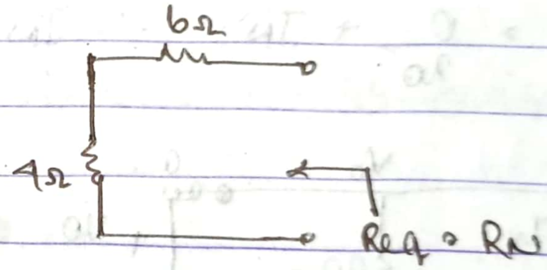
$$I_N = \frac{8-12}{4+6} = -0.4\ A$$





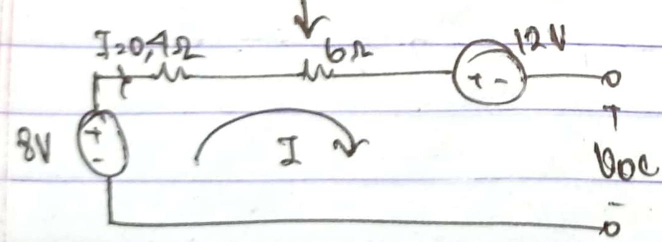
$$i = \frac{(10 \| 5)}{5} * 3.6 = 2.4A$$





$R_N = 10\ \Omega$

OR

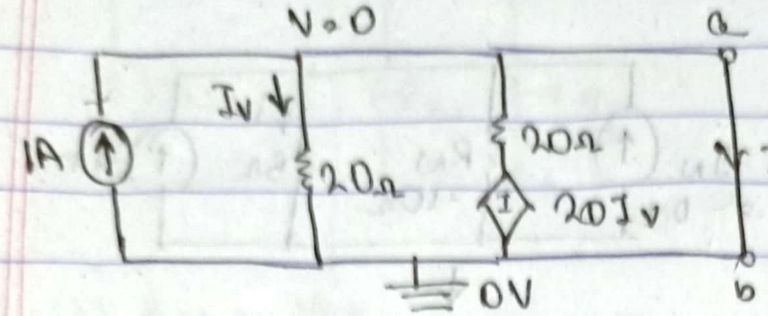


$$-8 + 4I + 6I + 12 + V_{oc} = 0$$

$$V_{oc} = -4$$

$$R_N = \frac{V_{oc}}{I_N} = \frac{-4}{-0.4} = 10\ \Omega$$

Problem 10

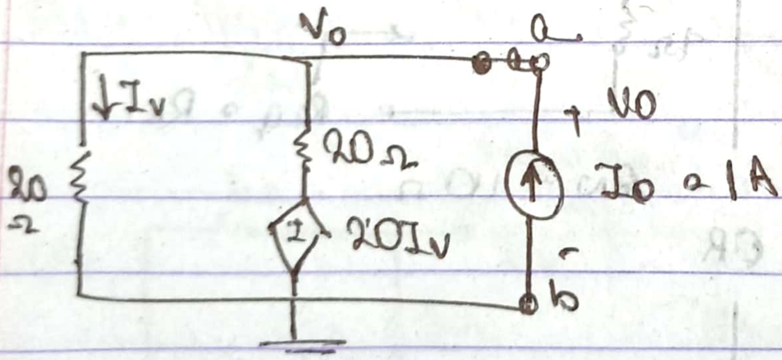


$$1 = \frac{V}{20} + \frac{V - 20I_V}{20} + I_N$$

$$\Rightarrow 1 = \frac{V}{20} + \frac{V - 20\left(\frac{V}{20}\right)}{20} + I_N$$

$$\Rightarrow 1 = \frac{V}{20} + I_N$$

$$\Rightarrow 1 = \frac{0}{20} + I_N \quad \therefore I_N = 1A \quad [V = 0V]$$



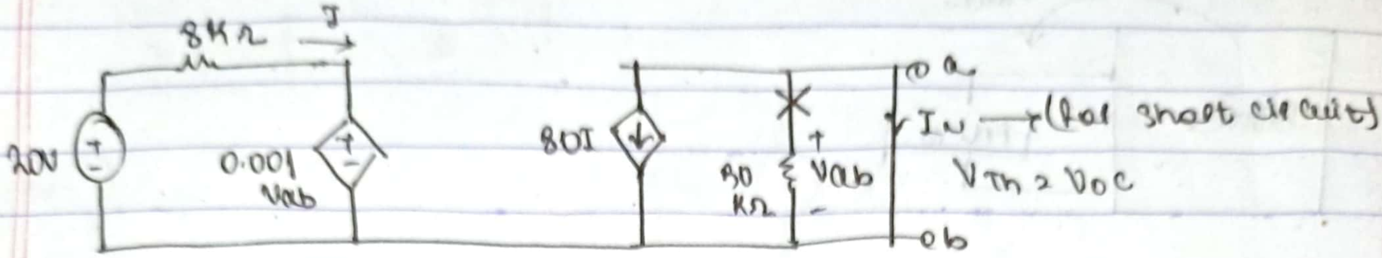
$$\frac{V_0}{20} + \frac{V_0 - 20I_V}{20} = 1$$

$$\frac{V_0}{20} + \frac{V_0 - 20\left(\frac{V_0}{20}\right)}{20} = 1$$

$V_0 = 20V$

$$R_N = \frac{V_0}{I_0} = \frac{20}{1} = 20\Omega$$

Problem 11



$$V_{ab} = V_{Th} = -80I \times 50 \qquad I = \frac{2 - 0.001V_{ab}}{8}$$

$$= -4000I$$

$$= -4000\left(\frac{2 - 0.001V_{ab}}{8}\right)$$

$$V_{ab} = -2000\ V$$

$$I_N = -80I = -80\left(\frac{2 - 0.001(-2000)}{8}\right) = \cancel{-22\ 0.25\ mA}\ -20\ m$$

$$R_N = \frac{V_{oc}}{I_N} = \frac{-2000}{-20} = 100\ k\Omega$$

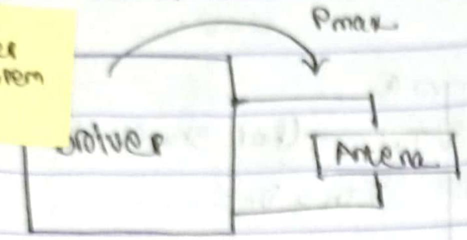
LECTURE 17

DATE: 23/11/22

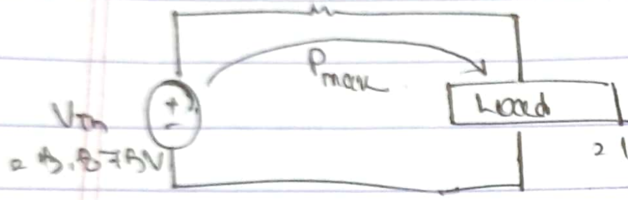
WEDNESDAY

MAXIMUM POWER TRASFER THEOREM

Slide 10
Maximum Power
Transfer Theorem



$$\eta = \frac{P_{out}}{P_{in}} * 100\%$$



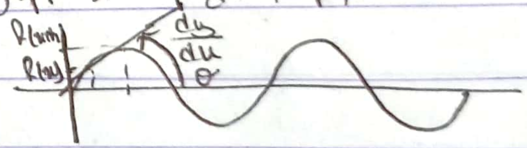
$$P = I^2R = \frac{V^2}{R} = VI$$

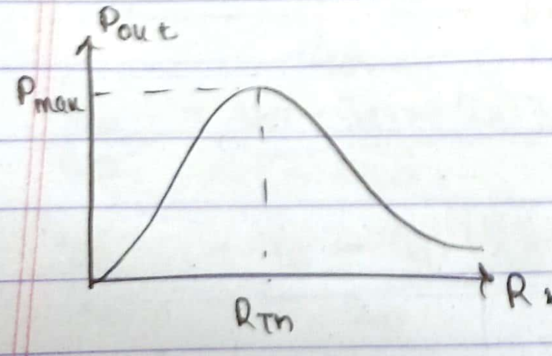
$$I = \frac{5.879}{1.94 + 100} = 0.058 \text{ (mA)}$$

$$P_{out} = I^2R = 0.333 \text{ (mW)}$$

$$P_{in} = -5.875 * 0.058 = -0.34 \text{ (mW)}$$

$$\eta = \frac{P_{out}}{P_{in}} * 100\% = \frac{0.333}{0.341} * 100\% = 98.74\%$$





$$\frac{dy}{dx} = \lim_{\Delta x \to 0} \frac{\Delta y}{\Delta x}$$

$$\frac{dy}{dx} = \lim_{h \to 0} = \frac{f(x+h) - f(x)}{h}$$

$$\frac{dy}{dx} = \tan\theta, \quad \frac{dy}{dx} = 0$$

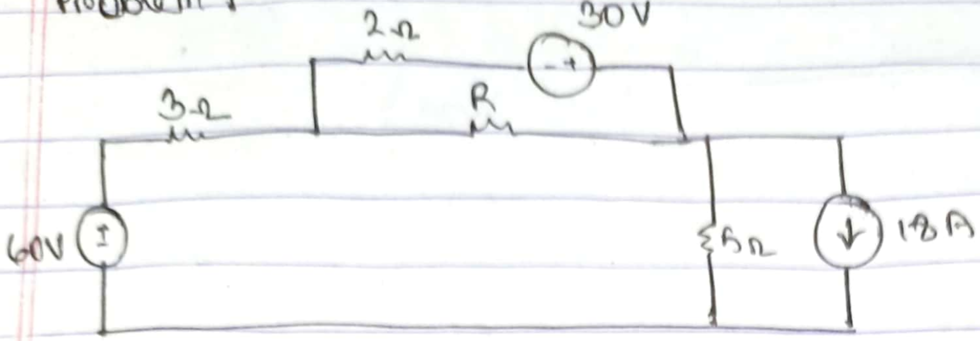
$$P = i^2R = \left(\frac{V_{Th}}{R_{Th} + R_L}\right)^2 R_L = V^2_{Th} \left(\frac{R_L}{R_{Th} + R_L}\right)^2$$

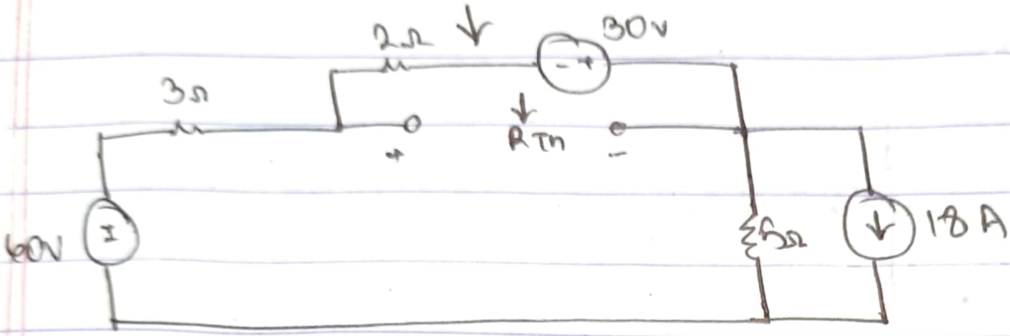
$$\frac{dp}{dR_L} = 0 \rightarrow R_L \text{ at max}$$

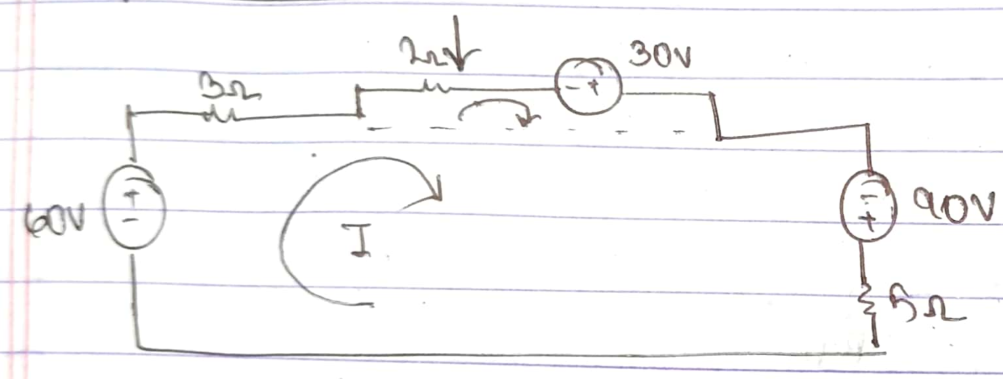
$$P_{max} = \frac{V^2_{Th}}{(2R_{Th})^2} R_{Th} \quad \boxed{R_L = R_{Th}}$$

$$\boxed{P_{max} = \frac{V^2_{Th}}{4R_{Th}}}$$

Problem 1







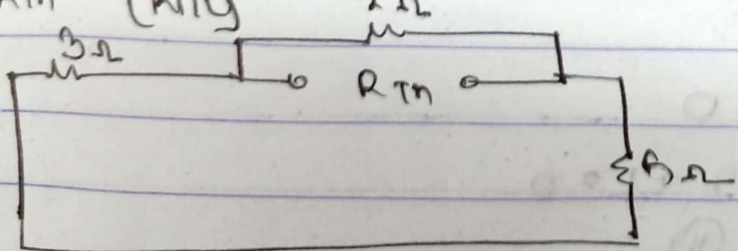
$$-60 + 3I + 2I - 30 - 90 + 5I = 0$$

$$I = 18\,A$$

$$-V_{Th} + 2I - 30 = 0$$

$$\Rightarrow V_{Th} = 6V$$

R_{Th} (Kill)

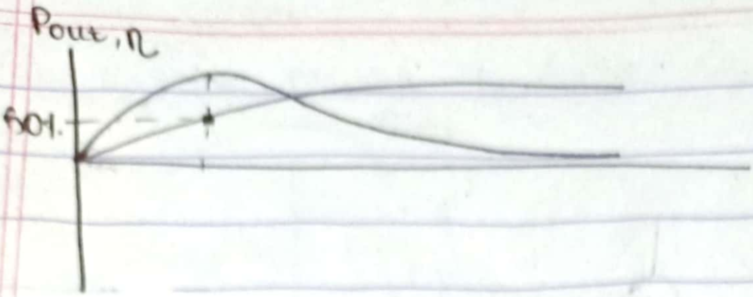


$$R_{Th} = (3+5) \,||\, 2$$

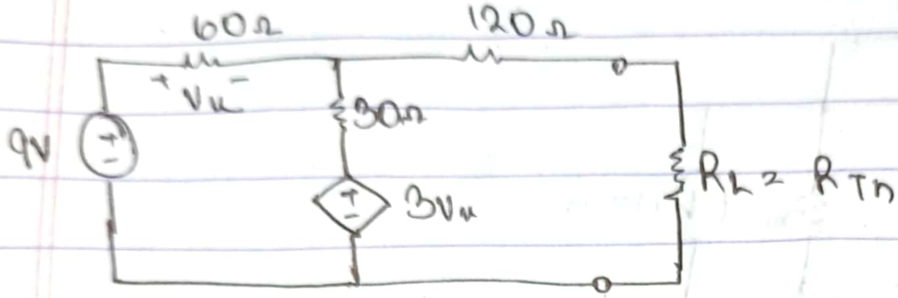
$$R_{Th} = 1.6\,\Omega$$

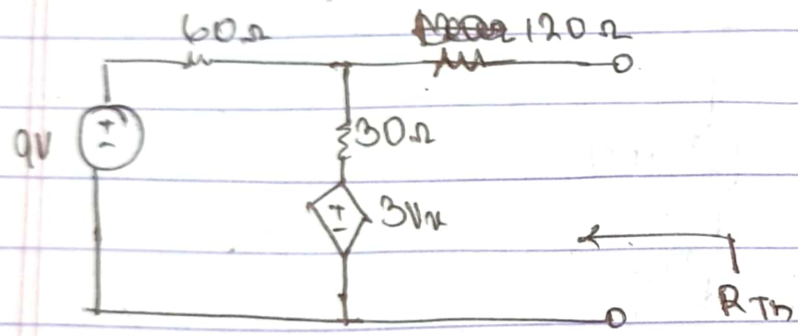
$$P_{max} = \frac{V_{Th}^2}{4R_{Th}} = 5.625 (W)$$

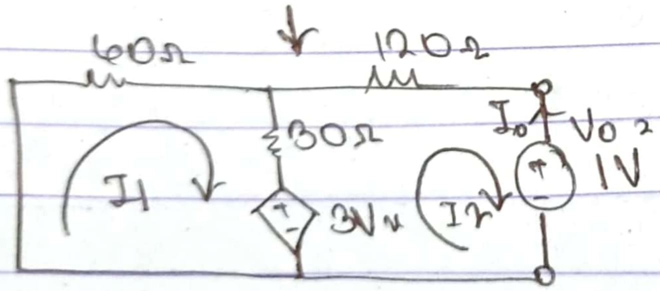
$$\eta = \frac{P_{RL}}{P_{RTh}+P_{RL}} = \frac{\frac{P_{in}}{2}}{P_{in}} = 50\%$$



Problem 3







$\Rightarrow 60I_1 + 30(I_1 - I_2) + 3V_x = 0$ $\quad (V_x = 60I_1)$

$\Rightarrow \cancel{180I_1}\ 270I_1 - 30I_2 = 0$ —— (i)

$-3V_x + 30(I_2 - I_1) + 120I_2 + 1 = 0$

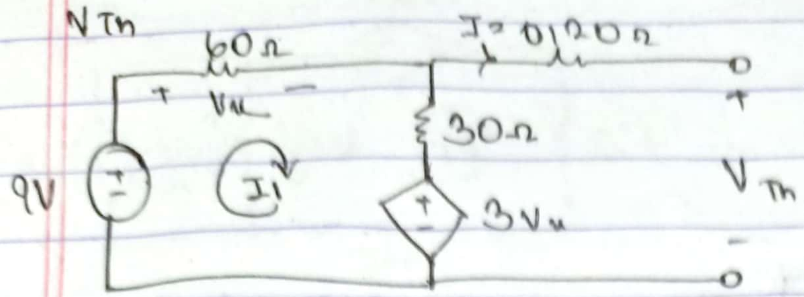
$-3(60I_1) + 30(I_2 - I_1) + 120I_2 + 1 = 0$

$-210I_1 + 150I_2 = -1$ —— (ii)

$I_2 = -7.89 \times 10^{-3}$ A $\qquad \cancel{P_{max} = 4}$

$I_o = -I_2 = 7.89 \times 10^{-3}$ A

$R_{Th} = \dfrac{V_o}{I_o} = \dfrac{1}{7.89 \times 10^{-3}} = 126.7\,\Omega$



$-9 + 60I1 + 30I1 + 3V_x = 0 \qquad V_x = 60I1$

$-9 + 60I1 + 30I1 + 3(60I1) = 0$

$I1 = 0.0333\ A$

$V_{Th} = \cancel{30 \times 0.0333} \; 30I1 + 3V_x$

$= 30(0.0333) + 3(60 \times 0.0333)$

$= \cancel{6.93V} \; 6.993V$

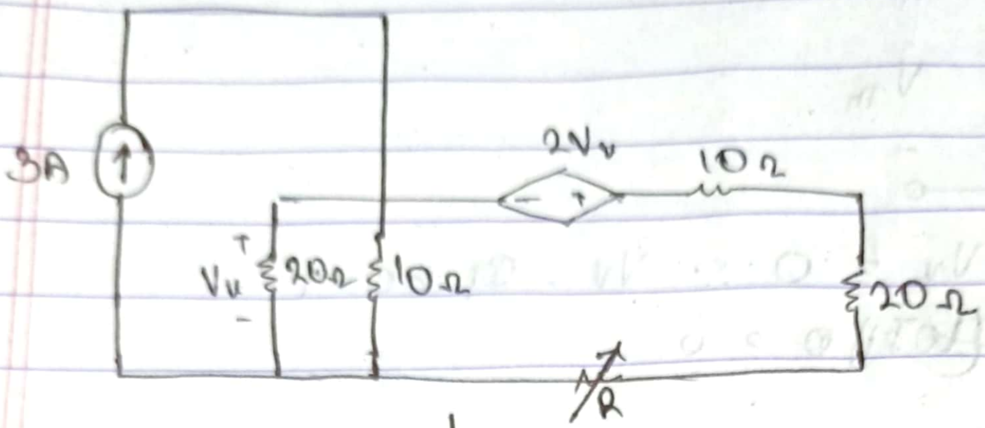
$$P_{max} = \frac{V_{Th}^2}{4R_{Th}} = \frac{(6.993)^2}{4(126.7)} \cancel{\times 100} = 0.0963\ W$$

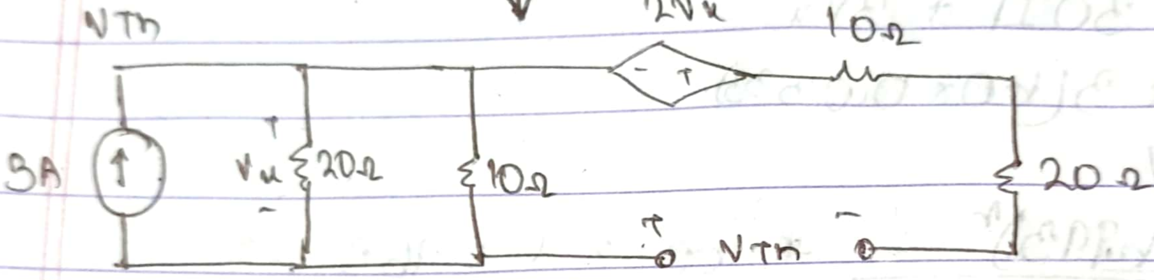
$$I_N = \frac{V_{Th}}{R_{Th}}$$

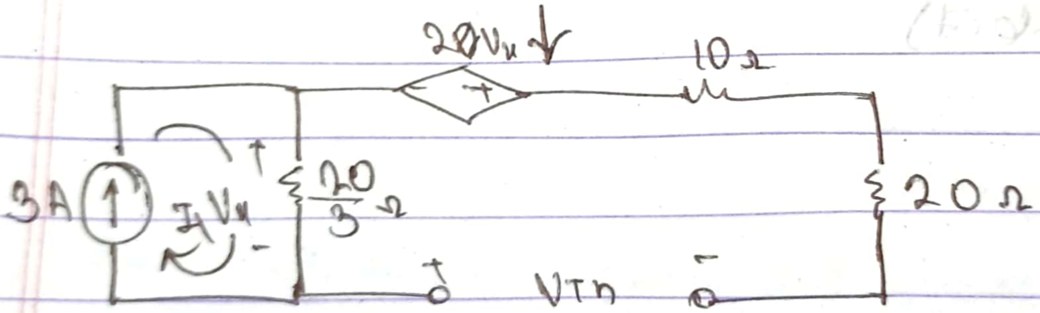
$$P_{max} = \frac{V_{Th}^2}{4R_{Th}}$$

$$= \frac{I_N^2 R_{Th}^2}{4R_{Th}} = \frac{I_N^2 R_{Th}}{4} = \frac{I_N^2 R_N}{4}$$

Problem 5







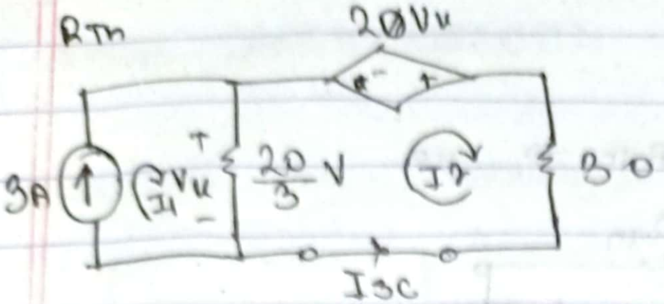
$\cancel{V_x} = I_1 = 3A$

$V_x = \frac{20}{3}(3) = 20V$

KVL at loop 1

$-V_x - 2V_x + 0 + 0 - V_{Th} = 0$

$V_{Th} = -60V$



$I1 = 3A$

KVL at loop 2

$\frac{20}{3}(I2 - I1) - 2Vx + 30I2 = 0 \quad [Vx = (I_1 - I2)(\frac{20}{3})]$

$\frac{20}{3}(I2 - I1) - 2[(I1 - I2)(\frac{20}{3})] + 30I2 = 0$

$\frac{20}{3}(I2 - 3) - 2[(3 - I2)(\frac{20}{3})] + 30I2 = 0$

$I2 = 1.2A$

$Isc = -I2 = -1.2A$

$RTh = \frac{VTh}{RTh} = \frac{-60}{-12} = 50\Omega$

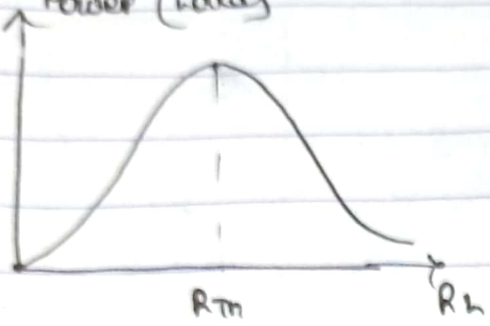
$Pmax = \frac{V^2 Th}{4RTh} = \frac{(-60)^2}{4(50)} = 18 \ W$

LECTURE 15

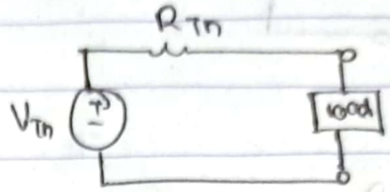
MONDAY

DATE: 28/11/22

FIRST ORDER CIRCUITS



R_N — R_{Th} → $-ve$



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

Maxima

Minima

$R_L = -R_{Th}$

* when load supplies to R_{Th} instead of voltage source, then R_{Th} comes in $-ve$.