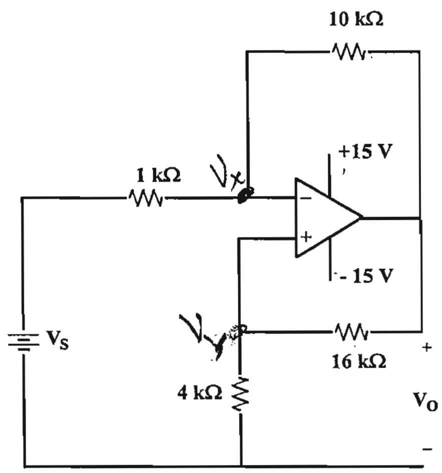
Desk Copy

ECE 300
Fall Semester, 2007
Test #2

wlg Test B **Name** wlg
Print (last, first)

Work the exam on the paper provided.

(1) You are given the op amp circuit shown in Figure 1.
  (a) What is the rail-to-rail voltage of the circuit?
  (b) If $V_S = 2.2$ V, what is the value of V_O?



(a) rail to rail
−15 to +15 Volts

Figure 1: Circuit for problem 1.

At V_x

$$\frac{V_x - V_s}{1K} + \frac{V_x - V_o}{10K} = 0 \qquad (1)$$

but

$$V_Y = V_x = \frac{4 V_o}{4+16} = 0.2 V_o$$

substitute into (1)

$$\frac{.2V_o - V_s}{1} + \frac{0.2V_s - V_o}{10} = 0$$

$$2V_o - 10V_s + 0.2V_s - V_o = 0$$

$$1.2 V_o = 10 V_s$$

$$V_o = 8.33 V_s \Big|_{V_s = 2.2} = 18.33 V$$

but limited to 15V

$$\boxed{V_o = 15V.}$$

(2) You are given the circuit of Figure 2. Determine the relationship between V_o and I_o. Circle the correct answer from the following list.

(a) $V_o = 24 - 5I_o$ (c) $V_o = 14 + 3I_o$ (e) $V_o = 40I_o$

(b) $V_o = 18I_o$ (d) $V_o = 30 - 7I_o$ (f) $V_o = 40I_o - 4$

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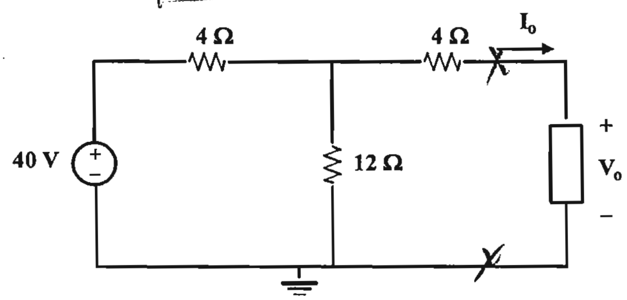
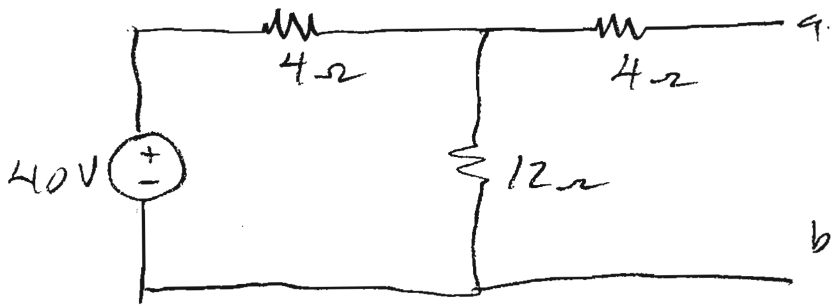
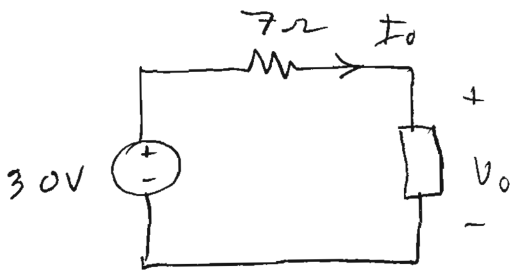


Figure 2: Circuit for problem 2.



$V_{ab} = V_{TH} = \dfrac{40 \times 12}{4+12} = 30V$; $R_{TH} = 4 + 12 \| 4$

$R_{TH} = 7\Omega$



$\boxed{V_o = 30 - 7I_o}$

(3) You are given the circuit of Figure 3.
   (a) Find the Thevenin equivalent circuit to the left of terminals a-b.
   (b) Draw your Thevenin circuit using your V_{TH} and R_{TH}.

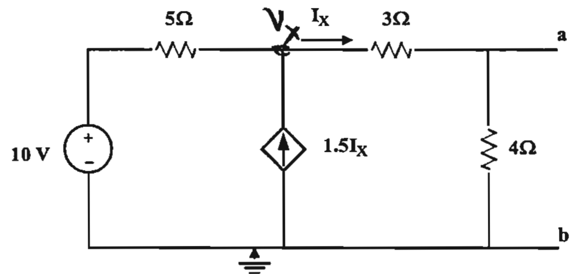


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Figure 3: Circuit for problem 3.

FOR V_{OC}

$$\frac{V_x - 10}{5} + \frac{V_x}{7} - 1.5 I_x = 0$$

but

$$I_x = \frac{V_x}{7}$$

$$35\left(\frac{V_x - 10}{5} + \frac{V_x}{7} - \frac{1.5 V_x}{7} = 0\right)$$

$$7V_x - 70 + 5V_x - 7.5 V_x = 0$$

$$4.5 V_x = 70$$

$$V_x = 15.56 \text{ V}$$

$$V_{oc} = \frac{15.56 \times 4}{4 + 3} = 8.87 V$$

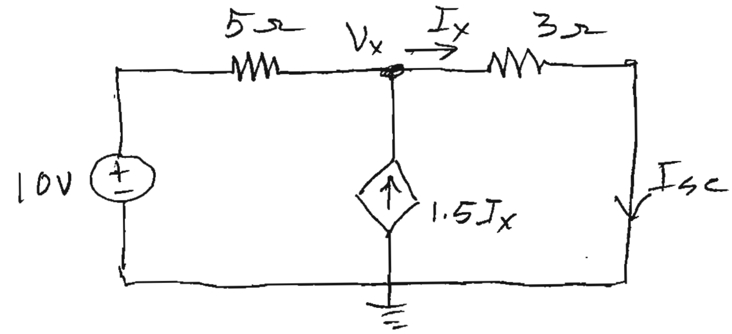
$$\boxed{V_{oc} = V_{TH} = 8.87 \text{ V}}$$

To find R_{TH}, find I_{sc} and use

$$R_{TH} = \frac{V_{oc}}{I_{sc}}$$

Test B
Prob 3

Shorting a-b leaves the following ckt.



$$\frac{V_x - 10}{5} + \frac{V_x}{3} - 1.5 I_x = 0 \qquad I_x = \frac{V_x}{3}$$

$$15\left(\frac{V_x - 10}{5} + \frac{V_x}{3} - \frac{1.5 V_x}{3} = 0\right)$$

$$3V_x - 30 + 5V_x - 7.5V_x = 0$$

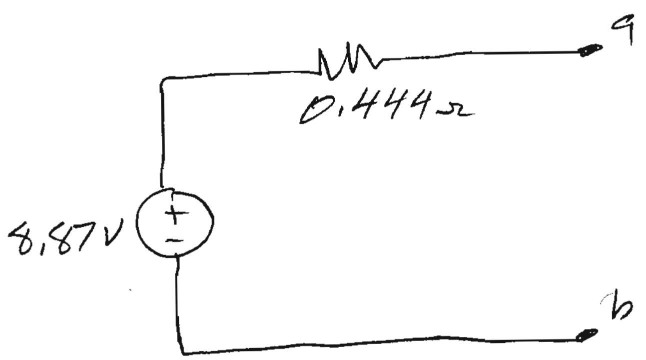
$$0.5 V_x = 30$$

$$V_x = 60$$

$$I_{sc} = \frac{V_x}{3} = 20 \text{ A}$$

$$R_{TH} = \frac{V_{oc}}{I_{sc}} = \frac{8.87}{20} = 0.444\,\Omega$$

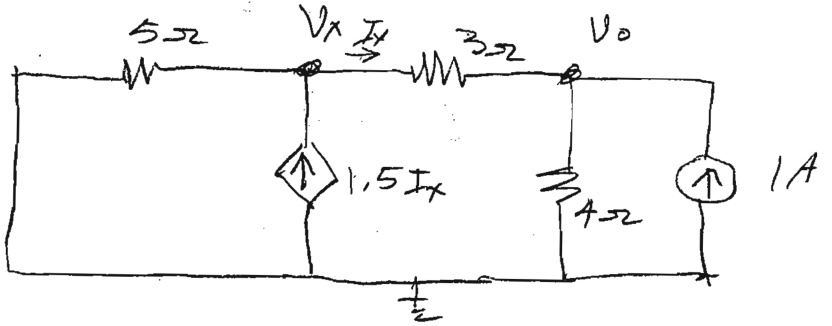
(b)



Thevenin Equivalent Circuit

Test B
Prob 3
Alternate solution
For R_{TH}

Apply 1 Amp



At V_x

$$\frac{V_x}{5} + \frac{V_x - V_o}{3} - 1.5 I_x \quad ; \quad I_x = \frac{V_x - V_o}{3}$$

$$\left(\frac{V_x}{5} + \frac{V_x - V_o}{3} - \frac{1.5(V_x - V_o)}{3} = 0\right)$$

$$30\left(\frac{V_x}{5} - \frac{V_x}{6} + \frac{V_o}{6} = 0\right.$$

$$6V_x - 5V_x + 5V_o = 0$$

$$\boxed{V_x + 5V_o = 0}$$

At V_o

$$12\left(\frac{V_o - V_x}{3} + \frac{V_o}{4} = 1\right.$$

$$4V_o - 4V_x + 3V_o = 12$$

$$\boxed{-4V_x + 7V_o = 12}$$

$$V_o = 0.444 \text{ V}$$

$$\boxed{R_{TH} = \frac{V_o}{1} = 0.444\ \Omega}$$

Check

(4) You are given the circuit of Figure 4. Find the value of R that will result in maximum power being delivered to this resistor.

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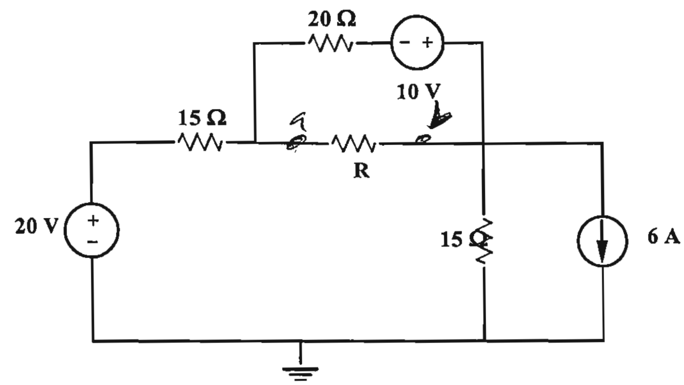
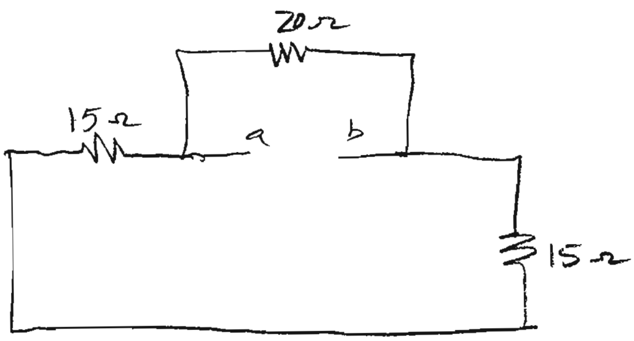


Figure 4: Circuit for problem 4.

For maximum power transfer, R must be R_{TH}. To get R_{TH} look into terminals a-b with R removed and all independent sources deactivated. This gives the circuit below.



$R_{ab} = R_{TH} = 20 \| (15+15) = 12\Omega$

(5) You are given the op amp circuit of Figure 5.

(a) Find the relationship for $\frac{V_o}{i_S}$ in terms of R.

(b) If R = 1 kΩ, what is the maximum value allowable for i_S in order not to saturate the op amp?

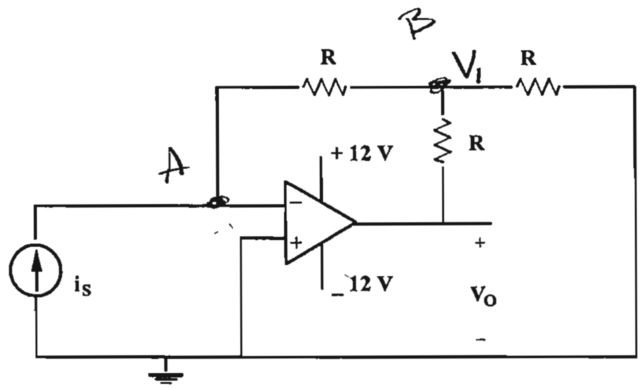


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Figure 5: Circuit for problem 5.

(a)

At A

$$i_s = -\frac{V_1}{R} \quad \text{OR} \quad V_1 = -R i_s \qquad (1)$$

At B

$$\frac{V_1}{R} + \frac{V_1}{R} + \frac{V_1 - V_o}{R} = 0$$

$$V_o = 3V_1$$

substitute from Eq. (1).

$$\boxed{V_o = -3R i_s} \qquad (2)$$

(b) use (2) with $V_o = \pm 12$

$$\boxed{i_s = \mp \frac{12}{1K \times 3} = \mp 4 \text{ mA}}$$

(6) You are given the circuit of Figure 6.

(a) Find the Norton equivalent circuit looking into terminals a-b.

(b) Draw the Norton equivalent circuit using your values of I_N and R_N.

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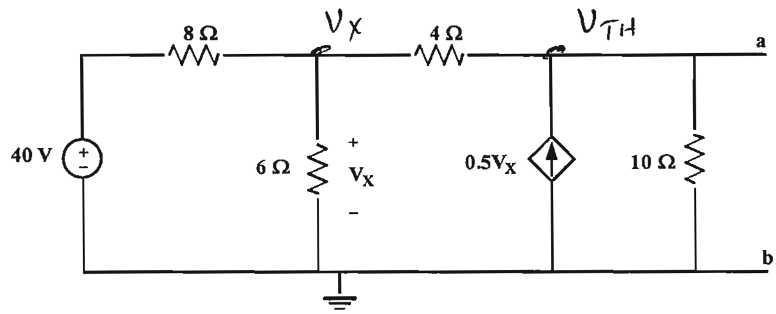


HW problem

Figure 6: Circuit for problem 6.

@ V_X / FIND $V_{OC} = V_{TH}$: FIND I_{SC} ; $R_{TH} = \frac{V_{OC}}{I_{SC}}$

$$24\left(\overset{3}{\frac{V_X - 40}{8}} + \overset{4}{\frac{V_X}{6}} + \overset{6}{\frac{V_X - V_{TH}}{4}} = 0\right)$$

$$3V_X - 120 + 4V_X + 6V_X - 6V_{TH} = 0$$

$$\boxed{13V_X - 6V_{TH} = 120}$$

@ V_{TH}

$$20\left(\overset{5}{\frac{V_{TH} - V_X}{4}} + \overset{2}{\frac{V_{TH}}{10}} - \overset{10}{0.5V_X} = 0\right)$$

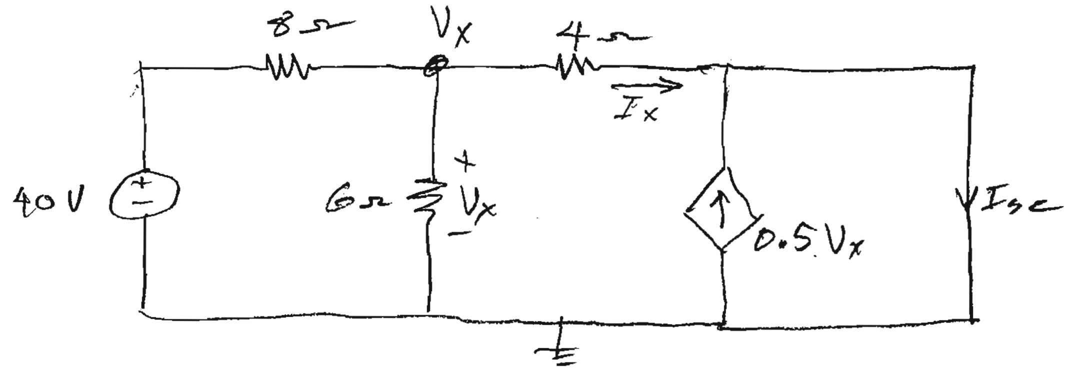
$$5V_{TH} - 5V_X + 2V_{TH} - 10V_X = 0$$

$$\boxed{-15V_X + 7V_{TH} = 0}$$

$$\begin{bmatrix} 13 & -6 \\ -15 & 7 \end{bmatrix} \begin{bmatrix} V_X \\ V_{TH} \end{bmatrix} = \begin{bmatrix} 120 \\ 0 \end{bmatrix}$$

$V_X = 840\text{ V}$; $V_{TH} = 1800\text{ V}$

Now Find I_{sc}



$$24\left(\frac{V_x - 40}{8} + \frac{V_x}{6} + \frac{V_x}{4} = 0\right)$$

$$3V_x - 120 + 4V_x + 6V_x = 0$$

$$13V_x = 120$$

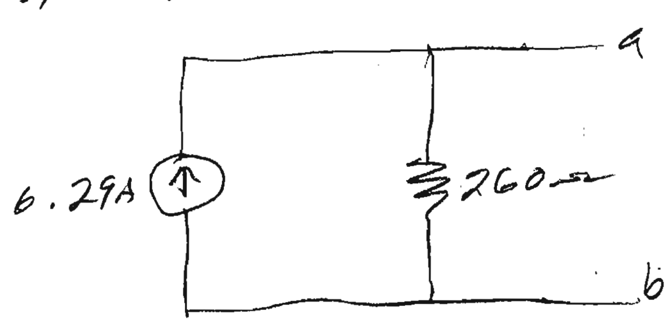
$$V_x = \frac{120}{13}$$

$$I_x = \frac{V_x}{4} = \frac{30}{13}$$

$$I_{sc} = I_x + 0.5V_x = \frac{30}{13} + \frac{60}{13} = \frac{90}{13} = 6.92A$$

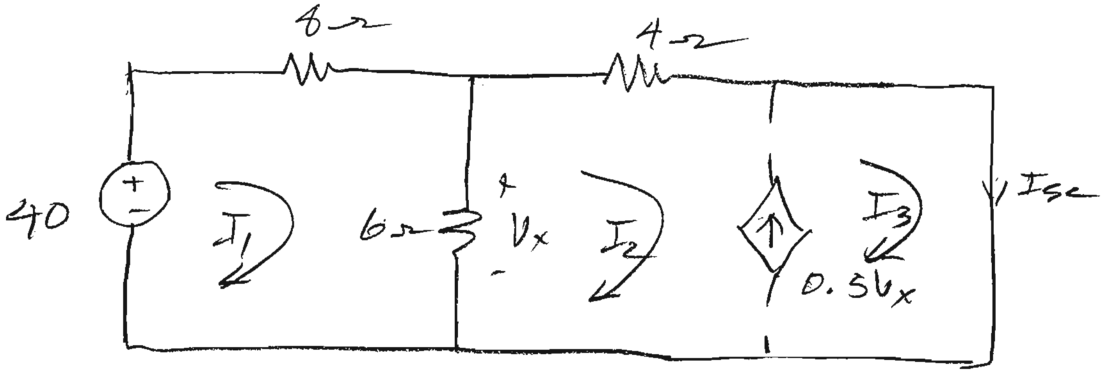
$$R_{TH} = \frac{V_{oc}}{I_{sc}} = \frac{1800}{6.92} = 260\,\Omega$$

(b) $I_N = I_{sc}$



#6

Finding I_{sc} another way



$I_{sc} = I_3$

$-40 + 14I_1 - 6I_2 + 0I_3 = 0$

$$\boxed{14I_1 - 6I_2 + 0I_3 = 40}$$

$$\boxed{-6I_1 + 10I_2 + 0I_3 = 0}$$

$0.5V_x = I_3 - I_2$

$0.5(6(I_1 - I_2)) = I_3 - I_2$

$3I_1 - 3I_2 = I_3 - I_2$

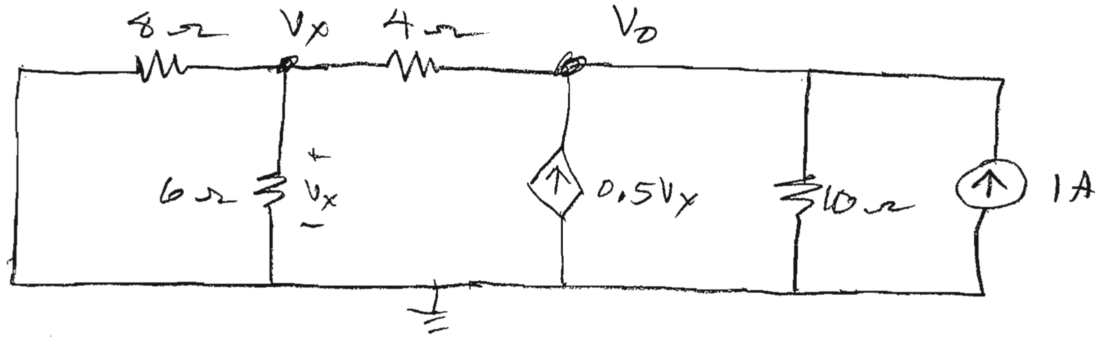
$$\boxed{3I_1 - 2I_2 - I_3 = 0}$$

$$\begin{bmatrix} 14 & -6 & 0 \\ -6 & 10 & 0 \\ 3 & -2 & -1 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 40 \\ 0 \\ 0 \end{bmatrix}$$

$I_3 = I_{sc} = 6.923\ A$ check

Test B

#6 Verify R_{TH}, second method



$$R_{TH} = \frac{V_0}{1}$$

At V_x

$$24\left(\frac{\overset{3}{V_x}}{8} + \frac{\overset{4}{V_x}}{6} + \frac{\overset{6}{V_x} - V_0}{4} = 0\right)$$

$$3V_x + 4V_x + 6V_x - 6V_0 = 0$$

$$\boxed{13V_x - 6V_0 = 0}$$

At V_0

$$20\left(\frac{V_0 - V_x}{4} + \frac{V_0}{10}\right) - 0.5V_x = 1$$

$$5V_0 - 5V_x + 2V_0 - 10V_x = 20$$

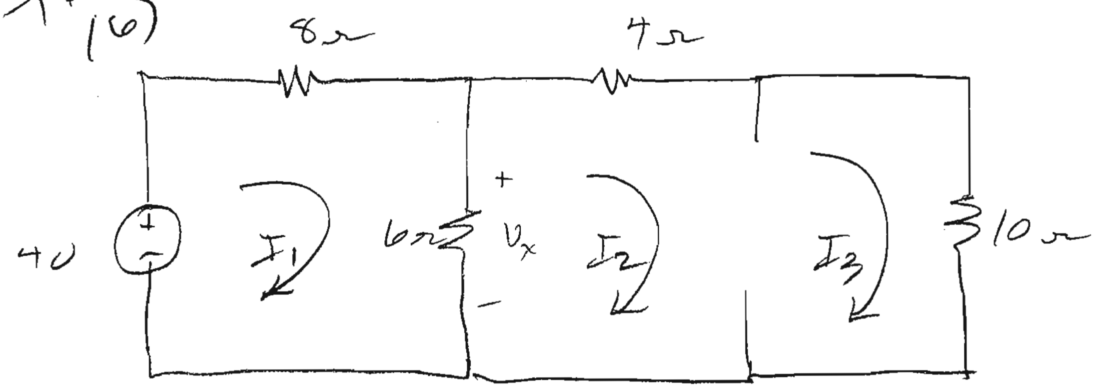
$$\boxed{-15V_x + 7V_0 = 20}$$

$$\begin{bmatrix} 13 & -6 \\ -15 & 7 \end{bmatrix}\begin{bmatrix} V_x \\ V_0 \end{bmatrix} = \begin{bmatrix} 0 \\ 20 \end{bmatrix}$$

$V_0 = 260\ V$

$R_{TH} = \frac{260}{1} = 260\ \Omega$ check

Test B
(6)



Constraint: $0.5 V_x = I_3 - I_2$

OR $V_x = 2I_3 - 2I_2$

$14 I_1 - 6 I_2 + 0 I_3 = 40$

$-6 I_1 + 10 I_2 + 10 I_3 = 0$

$V_x = 6I_1 - 6I_2 = 2I_3 - 2I_2$

$+6I_1 - 4I_2 - 2I_3 = 0$

$$\begin{bmatrix} 14 & -6 & 0 \\ -6 & 10 & 10 \\ 6 & -4 & -2 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 40 \\ 0 \\ 0 \end{bmatrix}$$

$I_3 = 180$

$V_{TH} = 1800V$ check