Engr 17 - CSUS Instructor – Russ Tatro

Chapter 4 Techniques of Circuit Analysis – Homework Solutions
James W. Nilsson and Susan A. Riedel, *Electric Circuits*, 6^{th} Edition, 2001

Problems 2, 5, 11, 27, 30 part a only, 33, 34, 51, 52 part a only, 56, 59, 62, 71 & 83

2 P(2 A) = 40 W

5 Vo = 10 V

11 Vo = 1.5 V

27 Σ Pabs = 99 W

30 ia = 9.8 A
ib = -0.2 A
ic = -10 A

33
a) $i\Delta$ = - 1 mA
b) P(2.5mA) = -8.5 mW
c) P(50 $i\Delta$) = 225 μW

34 P(125V) = -1,650 W
P(50V) = 180 W
P(0.2VΔ) = 595.2 W
Σ Pdel = 1,650 W Now check this versus Σ Pabs

51 a) io = 3 mA
b) P(75 V) = -105 mW

52 a) io = -1 mA

56 V_{TH} = 48 V
R_{TH} = 16 Ω

59 V_{TH} = 52 V
R_{TH} = 6 Ω

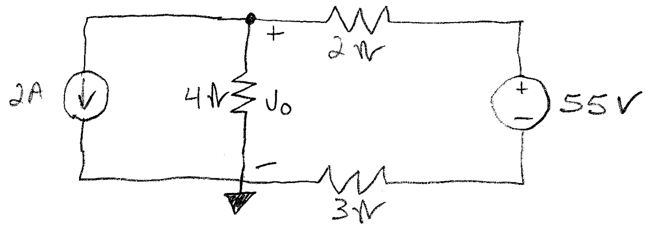
62 I_{Norton} = -8 mA
R_{TH} = 10 kΩ

71 a) Ro = 0 Ω
b) Pmax = 150 W

83 i(50V) = -3.6 A

Chapter 4 | Homework

4.2



Note
$P_{2A} = V_o i$
so find V_o

use node-voltage - find Power of 2A current source.

$$2A + \frac{V_o}{4\Omega} + \frac{V_o - 55V}{(2\Omega + 3\Omega)} = 0$$

note the 55V source is not connected to the reference node - it connects thru the 2Ω and the 3Ω resistors

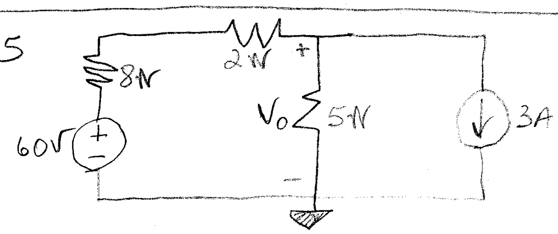
multiply by 20Ω

$$40V + 5V_o + 4V_o - 220V = 0$$

$$9V_o = 180V \Rightarrow V_o = 20V$$

$$P_{2A} = V_o i = (20V)(2A) = \underline{40W} \text{ (absorbing)}$$

4.5

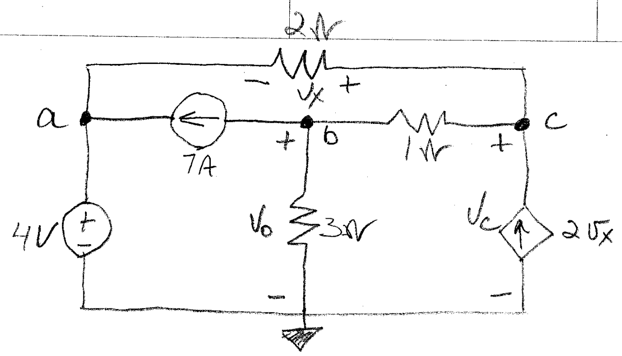


find V_o

$$\frac{V_o - 60V}{10\Omega} + \frac{V_o}{5\Omega} + 3A = 0 \Rightarrow 3V_o = 30V$$

$$\underline{V_o = 10V}$$

4.11



at node a) $v_a = 4V$

at node b) $v_b = v_o$

$$7A + \frac{v_b}{3\Omega} + \frac{v_b - v_c}{1\Omega} = 0$$

at node c)

current!

$$\frac{v_c - v_b}{1\Omega} + \frac{v_c - v_a}{2\Omega} + (-2v_x) = 0$$

Constraints:

$$v_x = v_c - v_a = v_c - 4V$$

from node b) eqn $4v_b - 3v_c + 21V = 0 \Rightarrow v_c = \frac{4v_b + 21V}{3}$

from node c) eqn

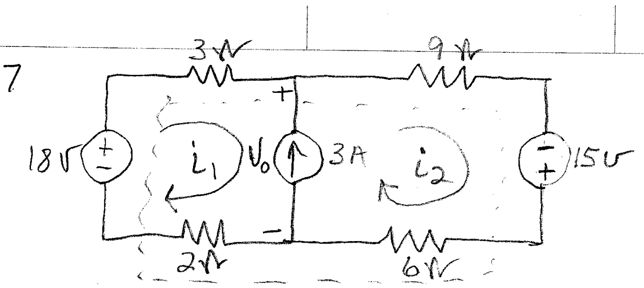
$$2v_c - 2v_b + v_c - v_a - 4(v_c - v_a) = 0$$

$$3v_a - 2v_b - v_c = 0 \Rightarrow 3(4V) - 2v_b - \frac{4}{3}v_b - 7V = 0$$

$$-\frac{10}{3}v_b = -5V$$

$$\underline{v_b = 1.5V = v_o}$$

4.27



use supermesh!

mesh $i_1 \Rightarrow -18V + i_1(3\Omega) + 9i_2 - 15V + 6i_2 + 2i_1 = 0$

constraint (from supermesh) $i_1 - i_2 = -3A \Rightarrow i_2 - i_1 = 3A$

$5i_1 + 15i_2 = 33V$

use constraint $i_1 = i_2 - 3A$

$(5\Omega)(i_2 - 3A) + (15\Omega)i_2 = 33V$

$(20\Omega)i_2 = 48V$

$i_2 = 2.4A$ thus $i_1 = 2.4A - 3A = -0.6A$

For these resistors $\Sigma P = (3+2)\Omega\, i_1^2 + (9+6)\Omega\, i_2^2 = 88.2W$ abs

for the sources

$P_{18V} = vi_1 = (18V)(0.6A) = 10.8W$ absorbed

$P_{3A} = (-)V_0(3A)$ $(V_0 = (9+6)\Omega\, i_2 - 15V = 36V - 15V = 21V)$

$= (-)(21V)(3A) = -63W$ delivered

$P_{15V} = (-)(15V)\, i_2 = -15V \cdot 2.4A = 36W$

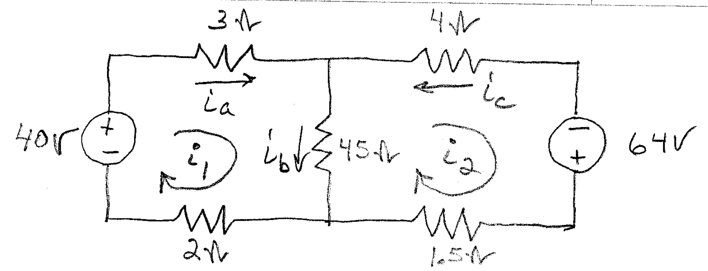
$\Sigma P_{del} = 63 + 36 = 99W$

$\Sigma P_{abs} = 88.2 + 10.8 = 99W$

$\Sigma P_{del} = \Sigma P_{abs}$

Note problem asked for total power dissipate, I check $\Sigma P_{del} = \Sigma P_{abs}$ to verify my work.

4.30



Use mesh current & find i_a, i_b, i_c

mesh i_1

$$-40V + i_1(3\Omega) + (i_1 - i_2)(45\Omega) + i_1(2\Omega) = 0$$

$$(50\Omega)i_1 - (45\Omega)i_2 = 40V \qquad i_2 = \frac{(50\Omega)i_1 - 40V}{45\Omega}$$

mesh i_2

$$i_2(4\Omega) - 64V + i_2(1.5\Omega) + (i_2 - i_1)(45\Omega) = 0$$

$$(-45\Omega)i_1 + (50.5\Omega)i_2 = 64V$$

$$(45\Omega)i_1 = (50.5\Omega)i_2 - 64V = (50.5\Omega)\left[\frac{50i_1 - 40V}{45\Omega}\right] - 64V$$

$$\left(\frac{45^2}{45} - \frac{2525}{45}\Omega\right)i_1 = -\frac{2020}{45}V - 64V$$

$$\left(\frac{-500}{45}\Omega\right)i_1 = \left[-\frac{(2020 + 2880)V}{45\Omega}\right]$$

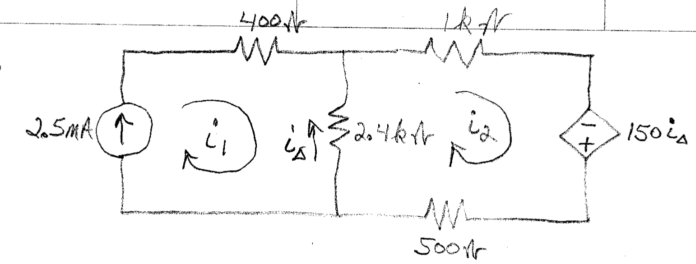
$$i_1 = \left(\frac{-4900V}{-500\Omega}\right) = 9.8A \qquad \text{thus } i_2 = 10A$$

$$i_a = i_1 = \underline{9.8A}$$

$$i_b = i_1 - i_2 = \underline{-0.2A}$$

$$i_c = -i_2 = \underline{-10A}$$

4.33



note $i_2 - i_\Delta = 2.5m$

$i_\Delta = i_2 - 2.5mA$

$i_1 = 2.5\,mA$ so no need for the mesh i_1 equations

<u>mesh i_2</u>

$i_2(1k\Omega) + i_2(500\Omega + i_2(2.4k\Omega) - 2.5mA(2.4k\Omega) - 150\,i_\Delta = 0$

$i_2(3.9k\Omega) - (2.5mA)(2.4k\Omega) - 150(i_2 - 2.5mA) = 0$

$i_2(3.75k\Omega) = 6V - 0.375V = 5.625V$

$i_2 = 1.5\,mA$

a) find i_Δ

$i_\Delta = i_2 - 2.5mA = (1.5 - 2.5)\,mA = \underline{-1mA}$ $(-1\times10^{-3}A)$

b) find Power in indep current source

$P_{2.5mA} = (-)\,v\,i$ $v = i_1(400\Omega) - i_\Delta(2.4k\Omega) = 3.4V$

$= (-)(3.4V)(2.5mA) = \underline{-8.5mW}$ delivered $(8.5\times10^{-3}\,W)$

c) find Power in the dep volt source

$P_{150i_\Delta} = (-)\,v\,i = (-)\,v\,i_2 = (-)(150\,i_\Delta)\,i_2$

$= (-)\,[150\cdot(-1mA)]\,(1.5mA)$

$= \underline{0.225\,mW\text{ absorbed}} = 225\,\mu W = 225\times10^{-6}\,W$

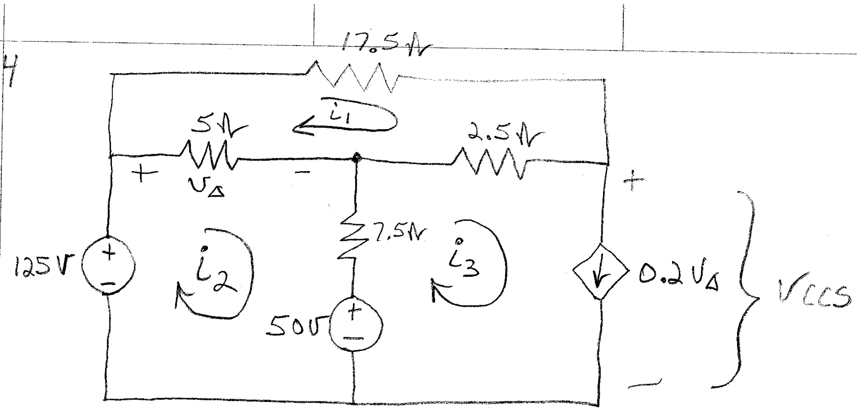
note that the textbook mis-lead you.

$\Sigma P_{absorbed} = P_{400\Omega} + P_{2.4k\Omega} + P_{1k\Omega} + P_{500\Omega} + P_{150i_\Delta}$

$= (2.5 + 2.4 + 3.375 + 0.225)\,mW = 8.5\,mW$

$= \Sigma P_{delivered}$

4.34



<u>mesh i_1</u>

$$i_1(17.5 + 2.5 + 5\Omega) - i_2(5\Omega) - i_3(2.5\Omega) = 0$$
$$i_1(25\Omega) - i_2(5\Omega) - i_3(2.5\Omega) = 0$$

<u>mesh i_2</u>

$$-125V + i_2(5 + 7.5\Omega) - i_1(5\Omega) - i_3(7.5\Omega) + 50V = 0$$
$$-i_1(5\Omega) + i_2(12.5\Omega) - i_3(7.5\Omega) = 75V$$

<u>constraints</u>

$i_3 = 0.2 V_\Delta$ from the V.C.C.S. → volt controlled current source

$V_\Delta = (i_2 - i_1)(5\Omega)$

so $i_3 = (0.2)(5\Omega)(i_2 - i_1) = i_2 - i_1$

solve for $i_1 \Rightarrow i_1 = 3.6$ A (you also do the algebra on your own)
" " $i_2 \Rightarrow i_2 = 13.2$A
$i_3 = i_2 - i_1 \Rightarrow i_3 = 9.6$A

Now I know the currents, but must still find the voltage across the dependent current source.

4.34 cont.

solve KVL for loop i_3

$$-50V + (i_3 - i_2)(7.5\Omega) + (i_3 - i_1)(2.5\Omega) + V_{CCS} = 0$$

$$V_{CCS} = 50V + i_1(2.5\Omega) + i_2(7.5\Omega) - i_3(10\Omega)$$
$$= 62V$$

Now I can calculate the power for each element in the circuit.

$$P_{125V} = (-)\,v\,i_2 = (-)(125V)(13.2A) = -1650W \quad \underline{(\text{delivered} = 1650W)}$$

$$P_{50V} = (+)\,v(i_2 - i_3) = (50V)(13.2 - 9.6) = 180W \text{ absorbed}$$

$$P_{0.2v_\Delta} = (+)(V_{CCS})(i_3) = (62V)(9.6A) = 595.2W \text{ absorbed}$$

Do Power check

$$P_{17.5\Omega} = i_1^2(17.5\Omega) = 226.8W$$

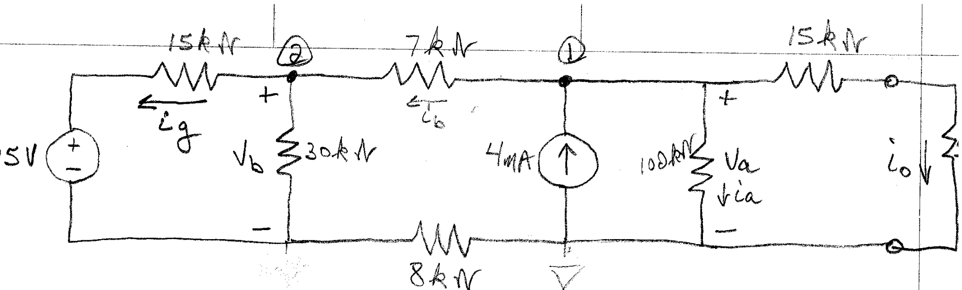
$$P_{5\Omega} = (i_2 - i_1)^2(5\Omega) = 460.8W$$

$$P_{7.5\Omega} = (i_2 - i_3)^2(7.5\Omega) = 97.2W$$

$$P_{2.5\Omega} = (i_3 - i_1)^2(2.5\Omega) = 90W$$

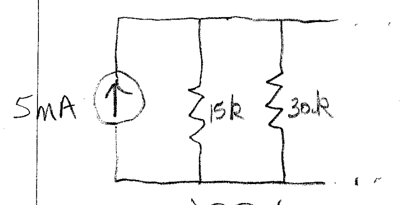
$$\sum P_{absorbed} = 180 + 595.2 + 226.8 + 460.8 + 97.2 + 90$$
$$= 1650W$$
$$= \underline{\sum P_{delivered}} \;!!$$

4.51



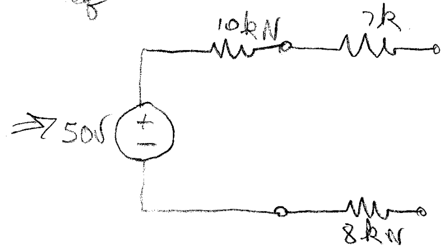
use source Transforms

$$V_s = i_s R_{eq} \Leftrightarrow i_s = \frac{V_s}{R_{eq}}$$



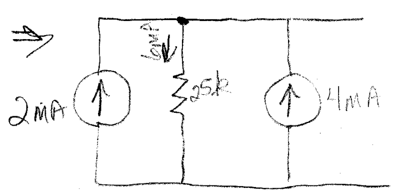
$15k \| 30k = 10k\Omega$

$\Rightarrow$

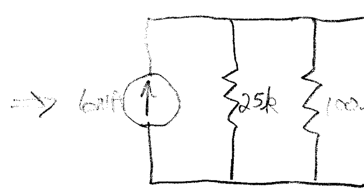


$10k + 7k + 8k = 25k$

$\Rightarrow$

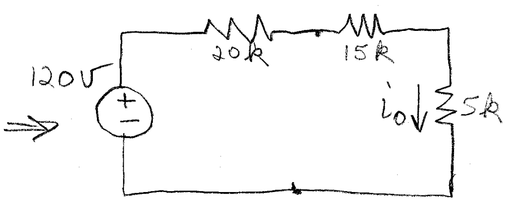


$\Rightarrow$



$25k \| 100k = 20k\Omega$

$\Rightarrow$



a) find current i_o

$$i_o = \frac{120V}{(20+15+5)k\Omega} = \underline{3\,mA}$$

4.51 continued

b) Find Power in the 75 V source

$$V_a = i_o(15k\Omega + 5k\Omega) = (3mA)(20k\Omega) = 60V$$

at node ① $i_b - 4mA + i_a + i_o = 0$

$$i_b = 4mA - \frac{V_a}{100k\Omega} - 3mA = (4 - 0.6 - 3)mA = 0.4mA$$

$$V_b = 60V - i_b(7+8)k\Omega \quad 60V - (0.4mA)(15k\Omega) = 54V$$

at node ②

$$i_g + \frac{V_b}{30k\Omega} - i_b = 0 \Rightarrow i_g = i_b - \frac{54V}{30k\Omega} = (0.4 - 1.8)mA$$

$$= -1.4\ mA$$

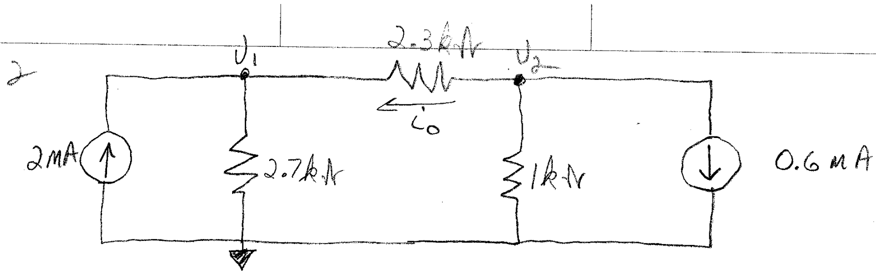
thus

$$P_{75V} = (+)\, v\, i_g = (75V)(-1.4mA) = -105\,mW$$

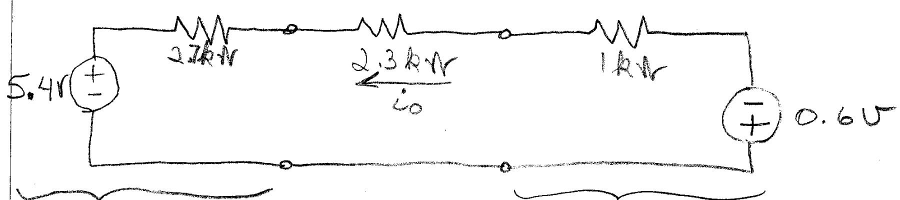
$$= \underline{105 \times 10^{-3}\,W \text{ Delivered}}$$

you should check $\Sigma P_{del} = \Sigma P_{abs}$ on your own.

4.52



a) Use source transforms to find i_o



$v_s = i_s R$ $\qquad\qquad$ $v_s = i_s R$

Now write KVL for this loop

$-5.4V - i_o(2.7+2.3+1)k\Omega - 0.6V = 0$

$(6k\Omega)\, i_o = -6V$

$\underline{i_o = -1.0mA}$

b) (not part of homework - I've included part b) here to give you another example)

<u>at node v_1</u>

$$-2mA + \frac{v_1}{2.7k\Omega} + \frac{v_1 - v_2}{2.3k\Omega} = 0$$

<u>at node v_2</u>

$$0.6mA + \frac{v_2}{1k\Omega} + \frac{v_2 - v_1}{2.3k\Omega} = 0$$

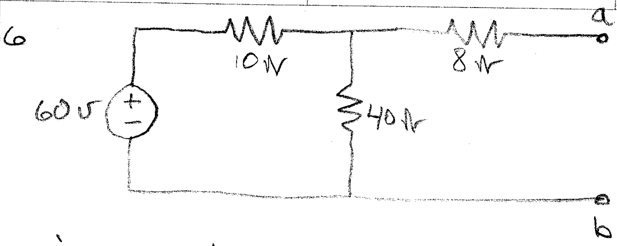
solve for v_1 & v_2

$v_1 = 2.7V$

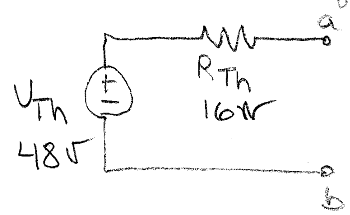
$v_2 = 0.4V$

thus $i_o = \dfrac{v_2 - v_1}{2.3k\Omega} = \dfrac{0.4V - 2.7V}{2.3k\Omega} = \dfrac{-2.3V}{2.3k\Omega} = \underline{-1mA}$

4.56



find the Thévenin equiv.



find open circuit voltage a $\overline{ab}$ (recall no current thru 8Ω resistor when "open circuit")

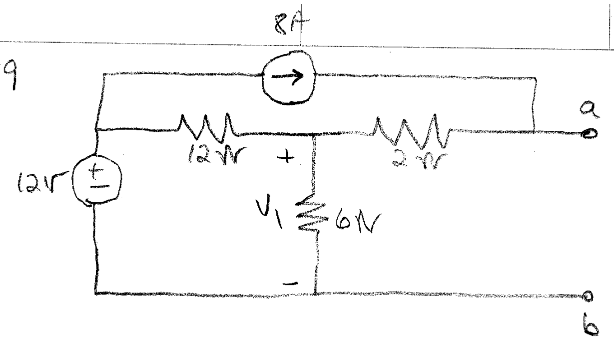
$V_{oc} = 60V\left(\frac{40\Omega}{10+40\Omega}\right) = 48V = \underline{V_{Th}}$ I use the voltage divider rule across the 40Ω resistor

now either find short circuit current or find R_{eq} (easier here)

(recall you short volt source & open current source. To calc R_{eq}

$R_{eq} = 10 \| 40 + 8 = 8 + 8 = \underline{16\Omega = R_{Th}}$

4.59



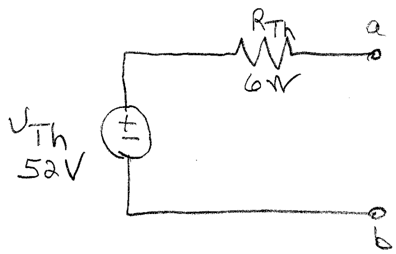
find Thévenin Equiv.

use node analysis to find v_1

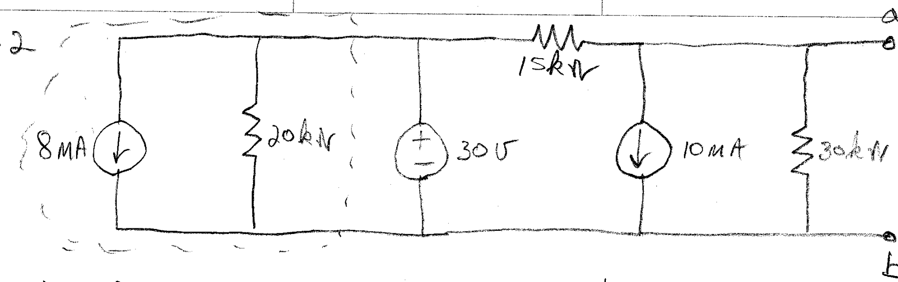
$$\frac{v_1 - 12V}{12\Omega} + \frac{v_1}{6\Omega} + (-8A) = 0 \Rightarrow v_1 = 36V$$

$$v_{Th} = 36V + (2\Omega)(8A) = \underline{\underline{52V}}$$

$$R_{Th} = R_{eq} = 12 \| 6 + 2 = 4 + 2 = \underline{\underline{6\,\Omega}}$$

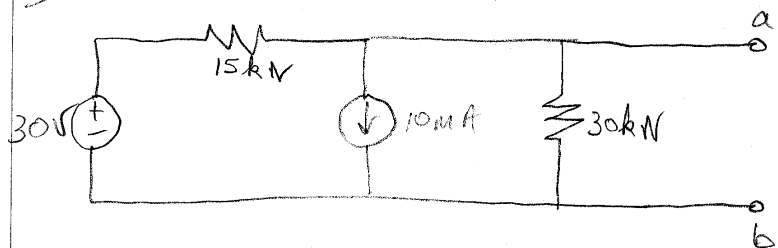


4.62

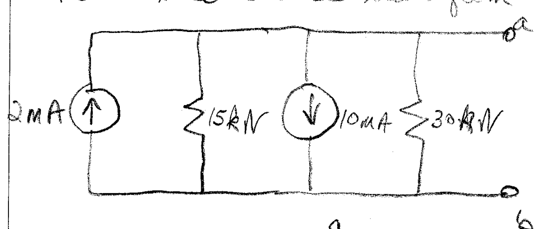


This circuit needs a careful look before jumping in.
The 8mA current source & the 20kΩ resistor are in parallel with an ideal voltage source of 30V.
Thus the behavior of the circuit W.R.T. (with respect to) Terminals a&b does not depend on these two elements.

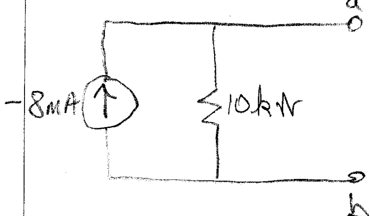
SO Redraw the circuit.



now use Source transform

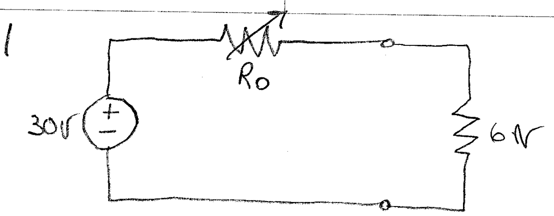


By now this circuit should be obvious



Norton Equiv

4.71

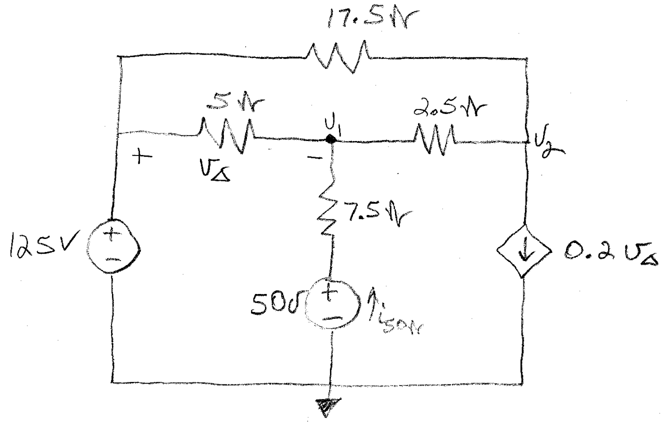


a) R_o is a variable resistor. We assume $0 \le R_o \le \infty$ and that is the "catch" in this problem!
So the source delivers the most power to the 6Ω resistor when $R_o = 0$!! (Any $R_o > 0$ uses power from the source

b) What is the max power?

$$P = \frac{V^2}{R} = \frac{(30V)^2}{6\Omega} = 150W$$

Problem 4.83



Use superposition

① Solve w/ 50V source acting alone → note $v_1' = -v_\Delta$

$$\frac{v_1'}{5} + \frac{v_1' - 50V}{7.5} + \frac{v_1' - v_2'}{2.5} = 0$$

$$\frac{v_2' - v_1'}{2.5} + 0.2v_\Delta + \frac{v_2'}{17.5} = 0 \Rightarrow \frac{v_2' - v_1'}{2.5} + 0.2(-v_1') + \frac{v_2'}{17.5}$$

Plug & Chug $v_1' = 32V$ $\Rightarrow i_{50V}' = \frac{50-32}{7.5} = 2.4A$

② Solve w/ 125V source acting alone

a) $\frac{v_1'' - 125}{5} + \frac{v_1''}{7.5} + \frac{v_1'' - v_2''}{2.5} = 0$

b) $\frac{v_2'' - v_1''}{2.5} + \frac{v_2'' - 125}{17.5} + 0.2v_\Delta'' = 0$

c) $-125 + v_\Delta'' + v_1'' = 0 \Rightarrow v_\Delta'' = 125 - v_1''$

More Plug & Chug $v_1'' = 45V$

$$i''_{50V} = \frac{0 - 45V}{7.5\Omega} = -6\,A$$

thus

$$i_{50V} = i'_{50V} + i''_{50} = 2.4A - 6A = \underline{-3.6A}$$