Name: ______________________________ (please print)

Signature: ___________________________

ECE 2201 – Final Exam
July 2 2019

Keep this exam closed and face up until you are told to begin.

1. This exam is closed book, closed notes. You may use one 8.5" x 11" crib sheet, or its equivalent.
2. Show all work on these pages. Show all work necessary to complete the problem. A solution without the appropriate work shown will receive no credit. A solution which is not given in a reasonable order will lose credit.
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6. You will have 170 minutes to work on this exam.

1. _______________/25

2. _______________/25

3. _______________/35

4. _______________/35

5. _______________/40

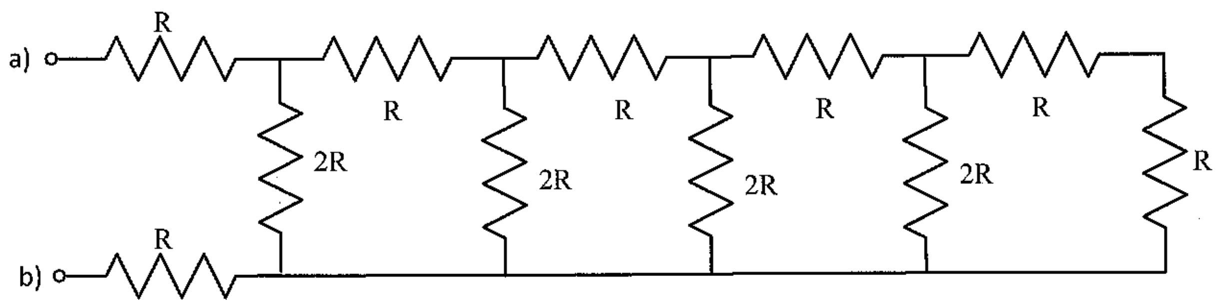
6. _______________/40

Total = 200

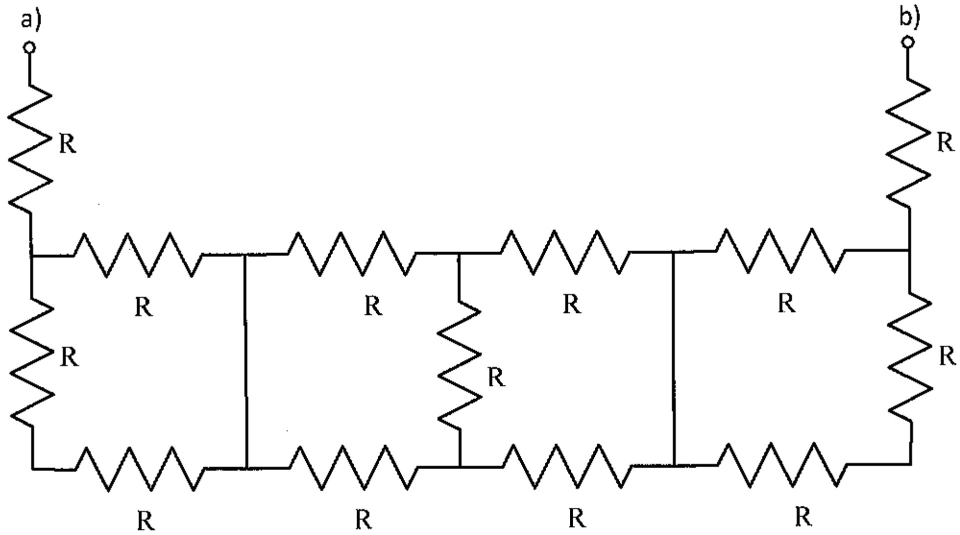
Room for extra work

1. (25 points) For each of the resistor networks shown on this and the following page, find the equivalent resistance at terminals a, b.

Network 1:

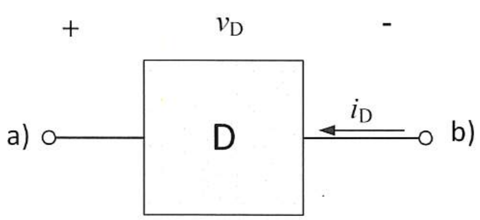


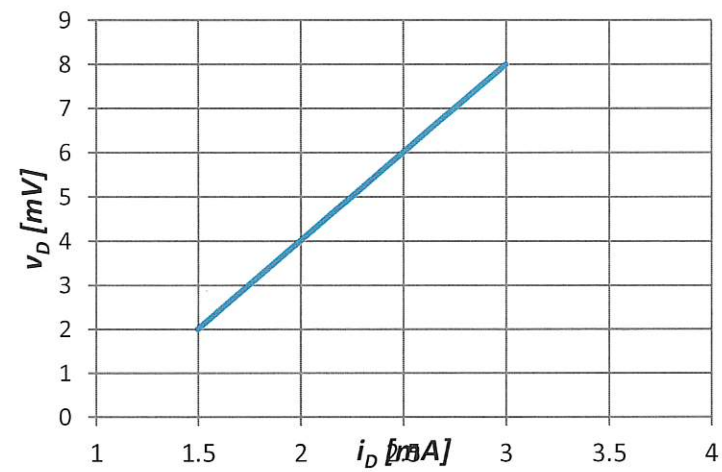
Network 2:

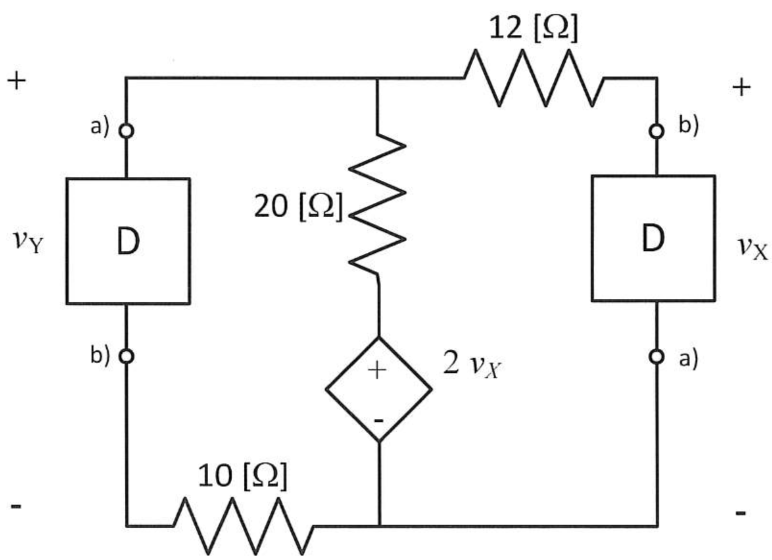


2. (25 points) The device D can be modeled as either a voltage source in series with a resistor or as a current source in parallel with a resistor – the choice is yours. The relationship between the device voltage v_D and current i_D is shown in the graph.

The device is inserted into the circuit shown, with terminals a, b connected as indicated on the circuit diagram. Find v_Y.

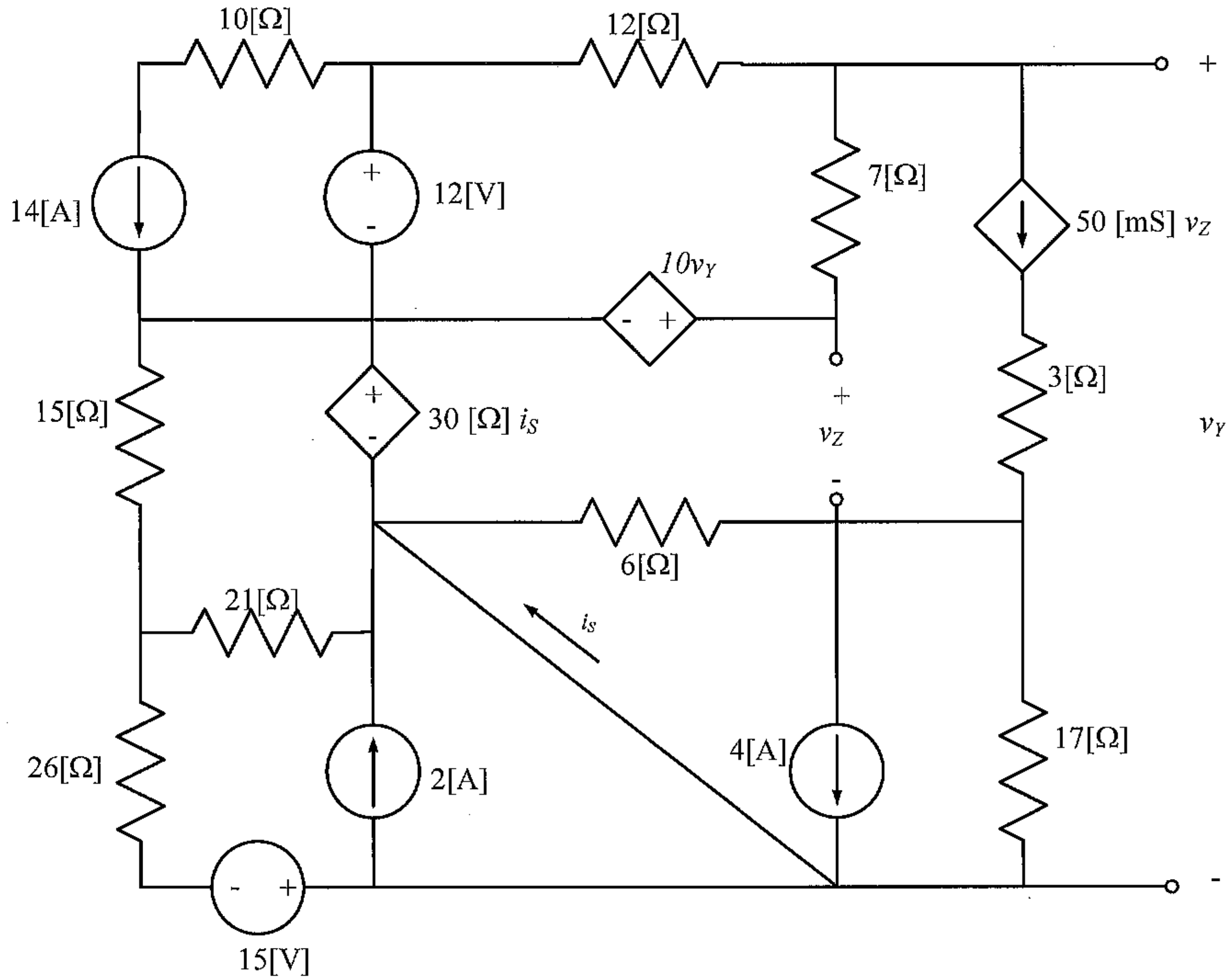






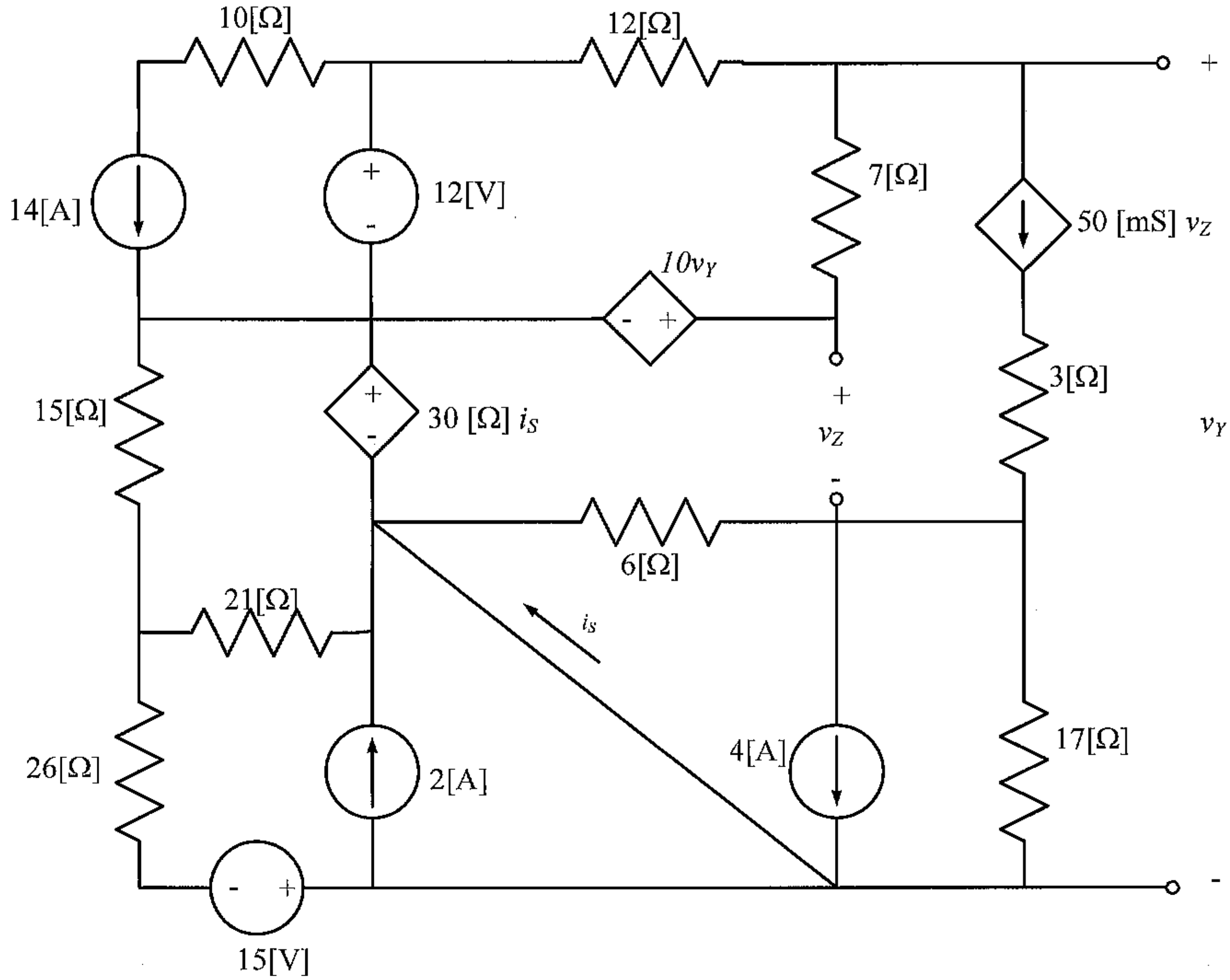
Room for extra work

3. (35 points) For the following circuit, write a complete set of node voltage equations that could be used to solve the circuit. Do not simply the circuit. Do not attempt to solve the equations.



Room for extra work

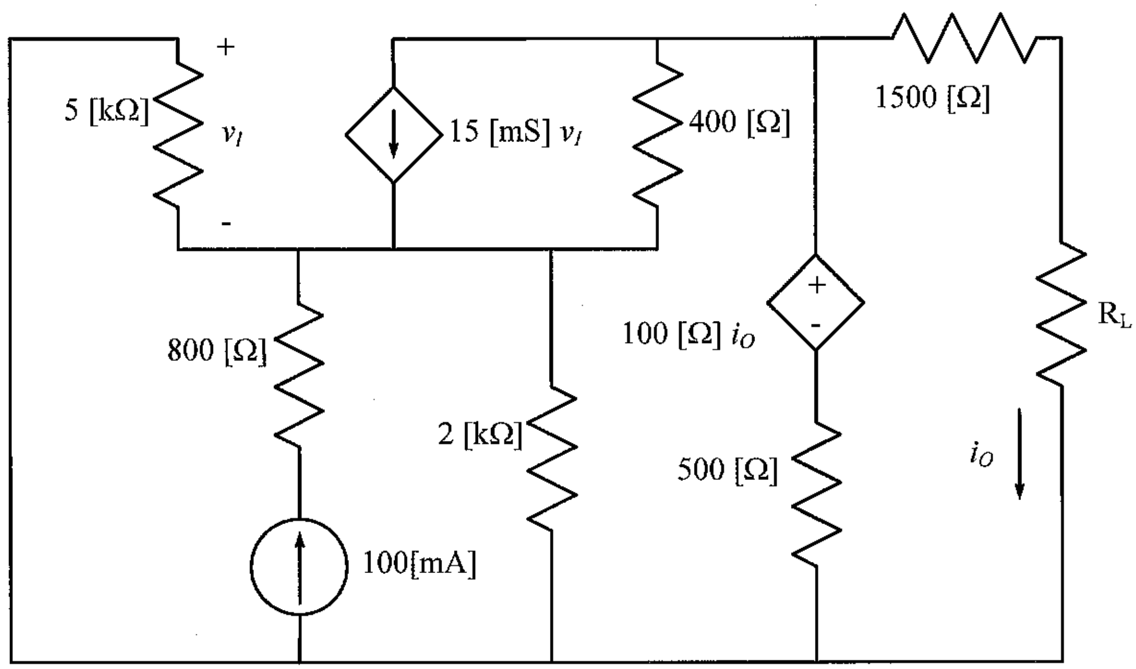
4. (35 points) For the following circuit, write a complete set of mesh current equations that could be used to solve the circuit. Do not simply the circuit. Do not attempt to solve the equations.



Room for extra work

5. (40 points) In the circuit below, the load resistor R_L has been adjusted for maximum power transfer to R_L.

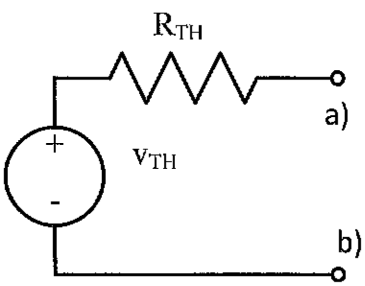
Find the value of R_L as well as the power delivered to R_L.

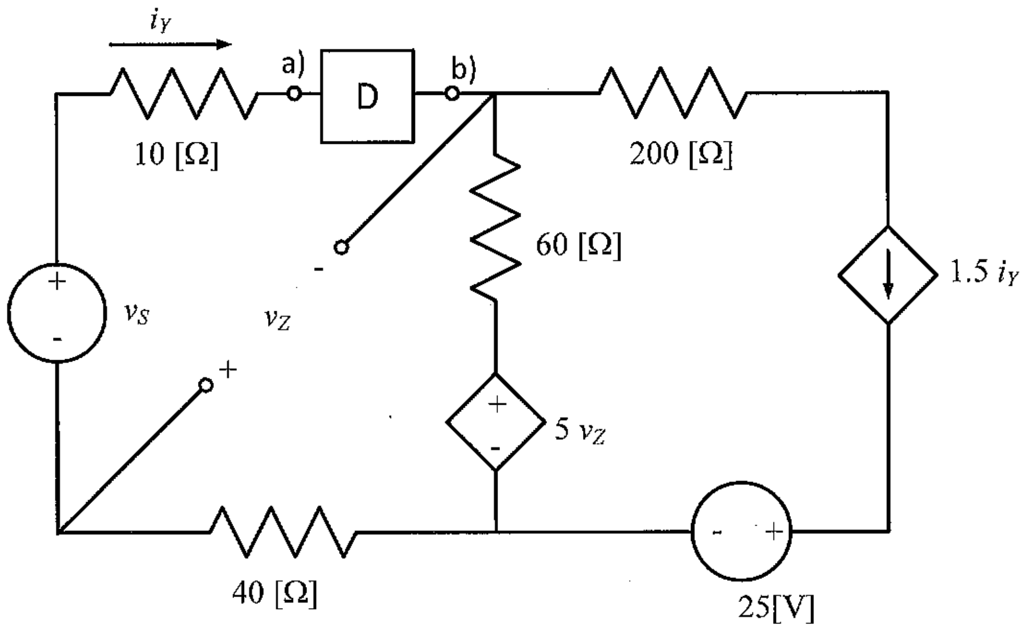


Room for extra work

6. (40 points) The Thevenin voltage of the circuit below at terminals a), b), as seen by device D, is known to be 15 [V]. The polarity of the Thevenin equivalent is indicated in the accompanying figure.

- Find the value of the voltage source v_S.
- Find the Norton equivalent of the circuit as seen by device D. Label your Norton equivalent, clearly showing terminals a), b).
- Find the power absorbed by device D if the current i_Y is 1 [A].





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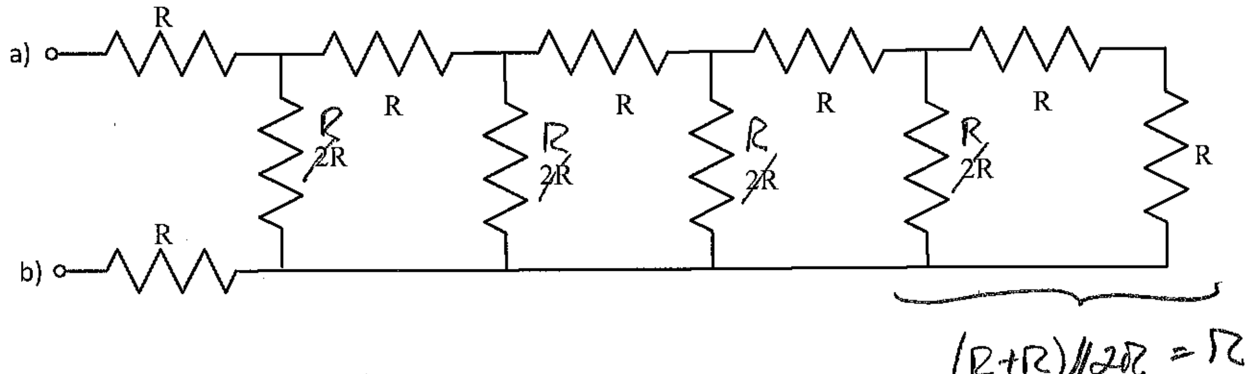
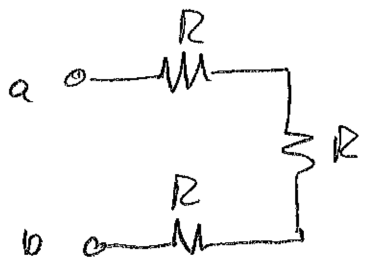
Total = 200

1. (25 points) For each of the resistor networks shown on this and the following page, find the equivalent resistance at terminals a, b.

Network 1:

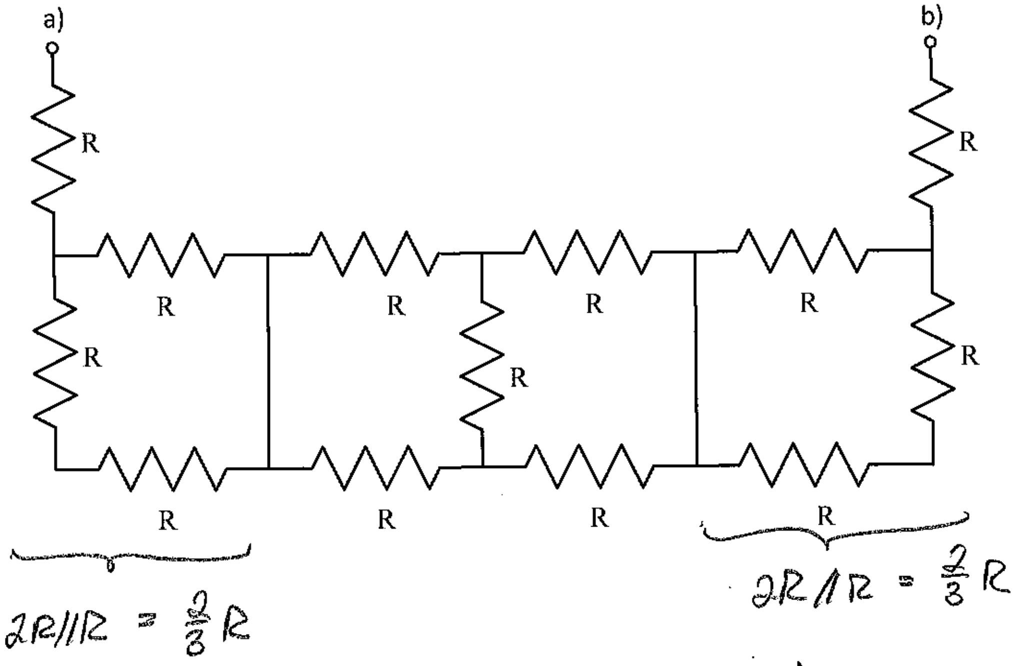


The combination of (R+R)//2R happens on each segment... so we end up with

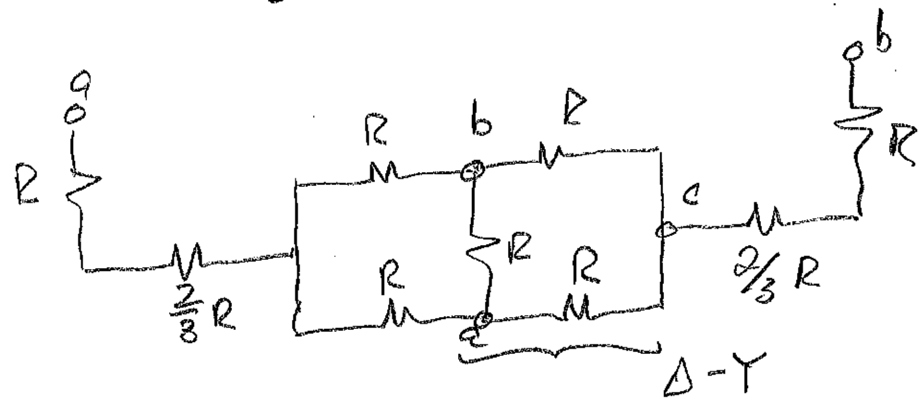


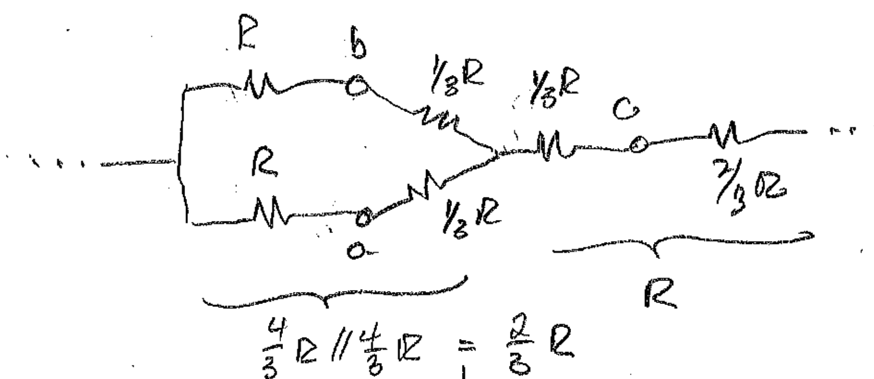
$\Rightarrow R_{ab} = 3R$

Network 2:

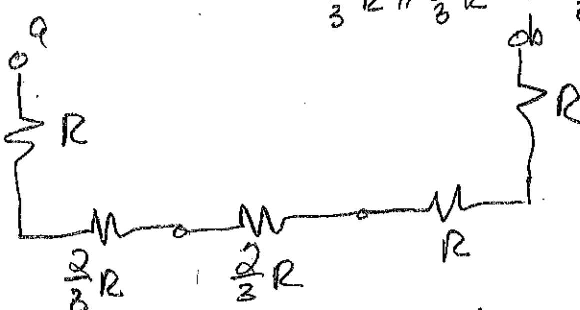


Re-draw





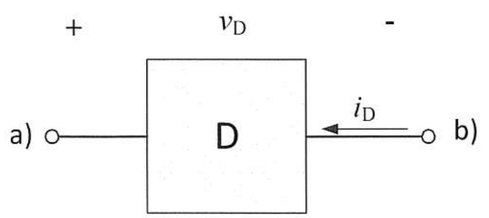
Re-draw

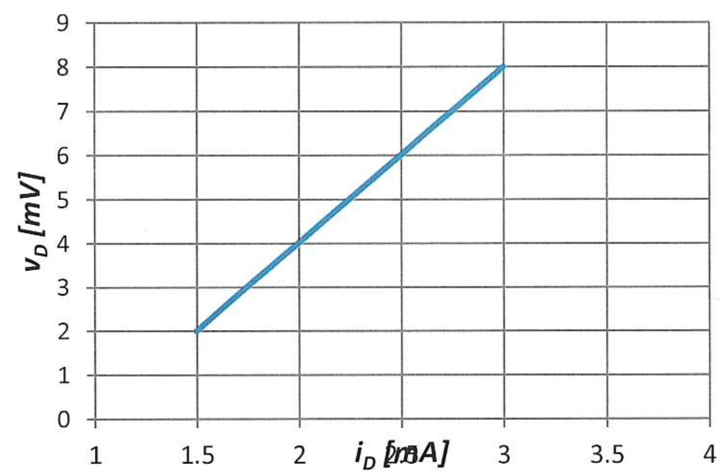


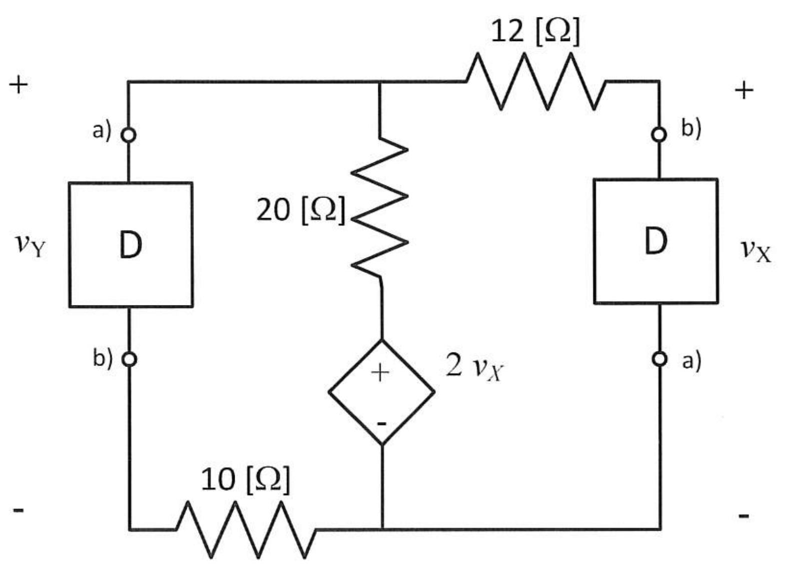
$$\Rightarrow R_{AB} = R + R + \frac{2}{3}R + \frac{2}{3}R + R = 4\frac{1}{3}R$$

2. (25 points) The device D can be modeled as either a voltage source in series with a resistor or as a current source in parallel with a resistor – the choice is yours. The relationship between the device voltage v_D and current i_D is shown in the graph.

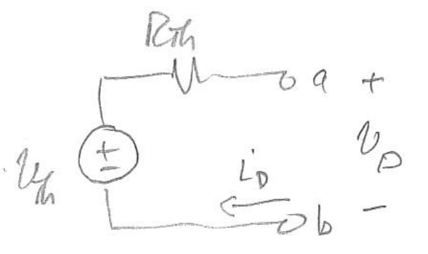
The device is inserted into the circuit shown, with terminals a, b connected as indicated on the circuit diagram. Find v_Y.







We will choose Thevenin because this will be easier to deal with when inserted into the circuit.



$-v_{Th} + i_D R_{Th} + v_D = 0$

$-v_{Th} + 0.0015\, R_{Th} + 0.002 = 0$

$-v_{Th} + 0.003\, R_{Th} + 0.008 = 0$

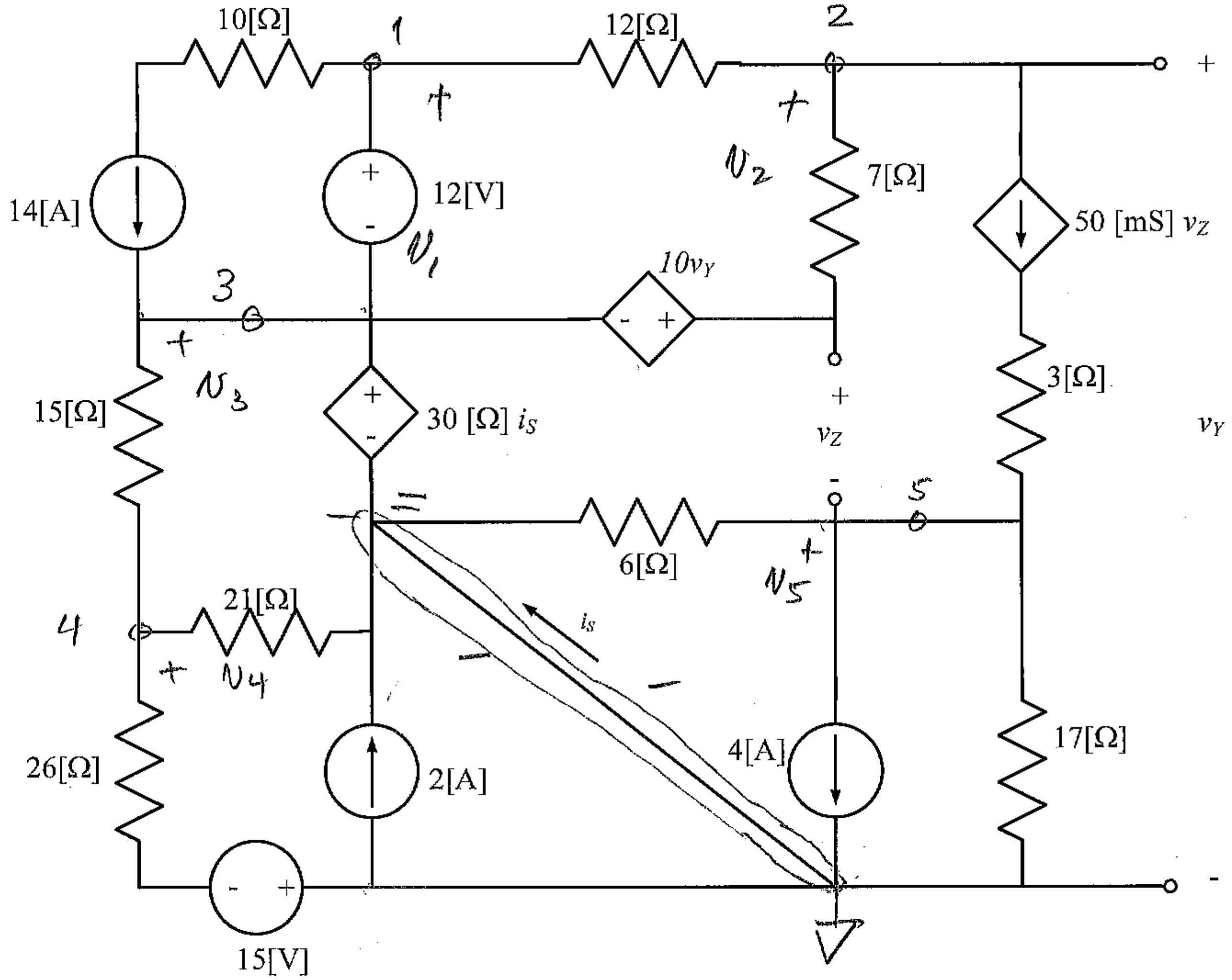
$-0.0015\, R_{Th} - 0.006 = 0$

$\Rightarrow \boxed{R_{Th} = -4\ [\Omega]}$

Problem is continued on the last page.

[redacted]

3. (35 points) For the following circuit, write a complete set of node voltage equations that could be used to solve the circuit. Do not simply the circuit. Do not attempt to solve the equations.



① $v_1 = 12\,[V] + 30 i_s$

② $\frac{v_2 - v_1}{12} + \frac{v_2 - v_3 - 10v_Y}{7} + 0.050\, v_Z = 0$

③ $v_3 = 30 i_s$

④ $\frac{v_4}{2} + \frac{v_4 - v_3}{15} + \frac{v_4 + 15}{26} = 0$

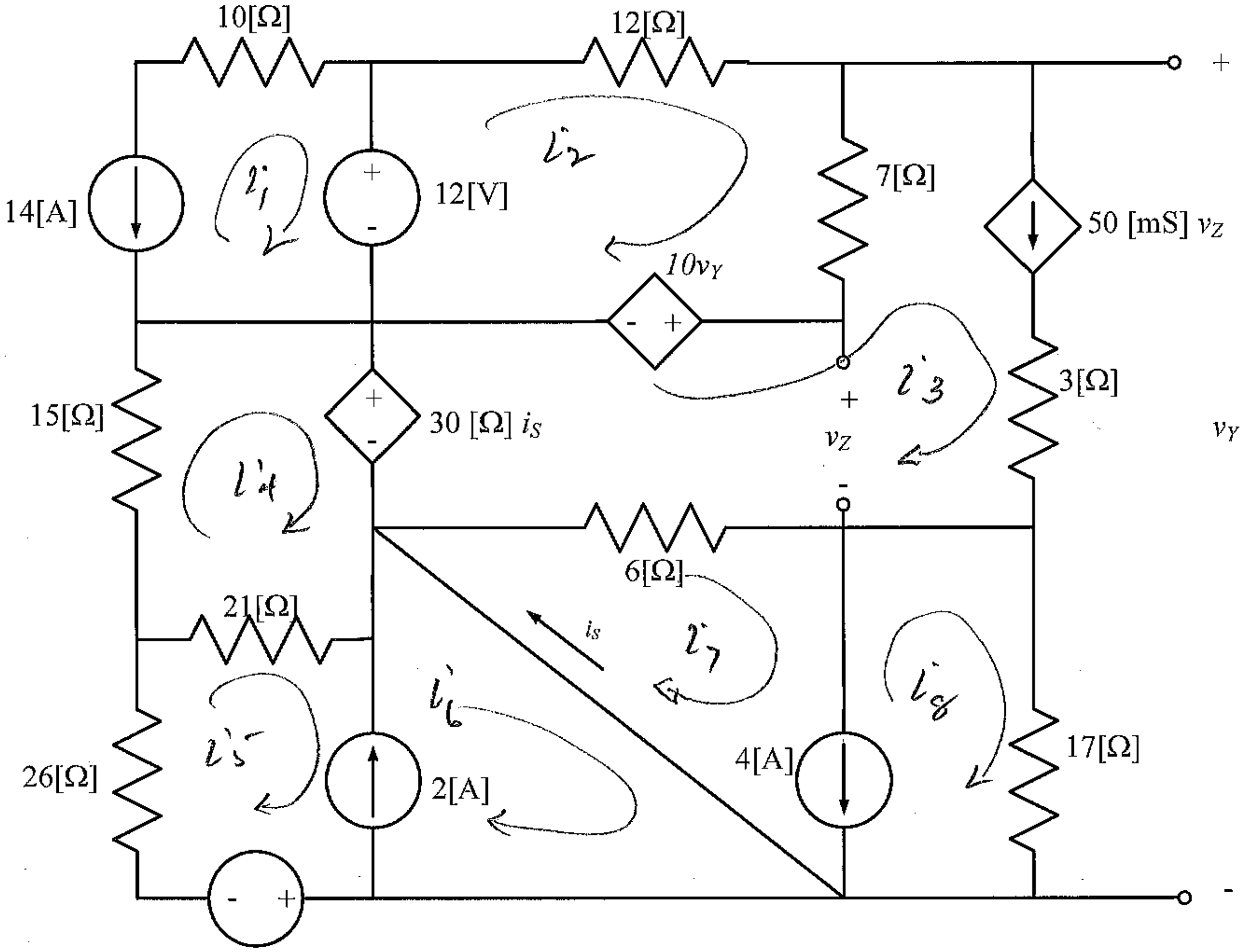
⑤ $-0.050\, v_Z + 4 + \frac{v_5}{6} + \frac{v_5}{17} = 0$

v_Z: $v_Z + v_5 - 30 i_s - 10 v_Y = 0$

v_Y: $v_Y - v_2 = 0$

i_s: $i_s - 4 - \frac{v_5}{17} + 2 - \frac{v_4 + 15}{26} = 0$

4. (35 points) For the following circuit, write a complete set of mesh current equations that could be used to solve the circuit. Do not simply the circuit. Do not attempt to solve the equations.



i_1: $i_1 = -14$ [A]

i_2: $12(i_2) + 7(i_2 - i_3) + 10\,v_Y - 12 = 0$

i_3: $i_3 = 0.050\,v_Z$

i_4: $15 i_4 + 30 i_S + 21(i_4 - i_5) = 0$

i_5, i_6: $21(i_5 - i_4) + 15 + 26(i_5) = 0$

$i_6 - i_5 = 2$ [A]

i_7, i_8: $6(i_7 - i_3) + 17 i_8 = 0$

$i_7 - i_8 = 4$ [A]

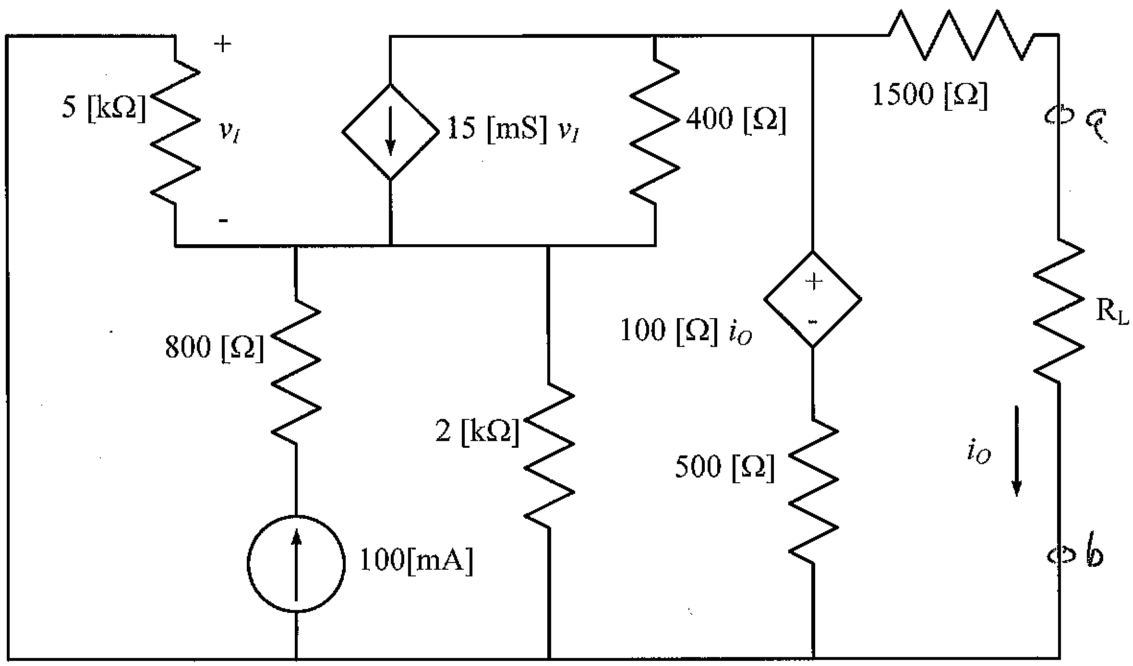
v_Y: $v_Y - 17 i_8 - v_Z + 7(i_3 - i_2) = 0$

v_Z: $v_Z + 6(i_3 - i_7) - 30 i_S - 10 v_Y = 0$

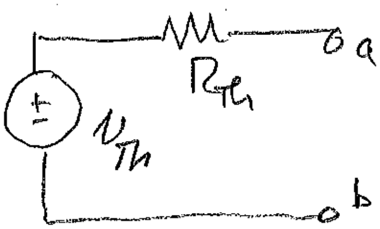
i_S: $i_S = i_7 - i_6$

5. (40 points) In the circuit below, the load resistor R_L has been adjusted for maximum power transfer to R_L.

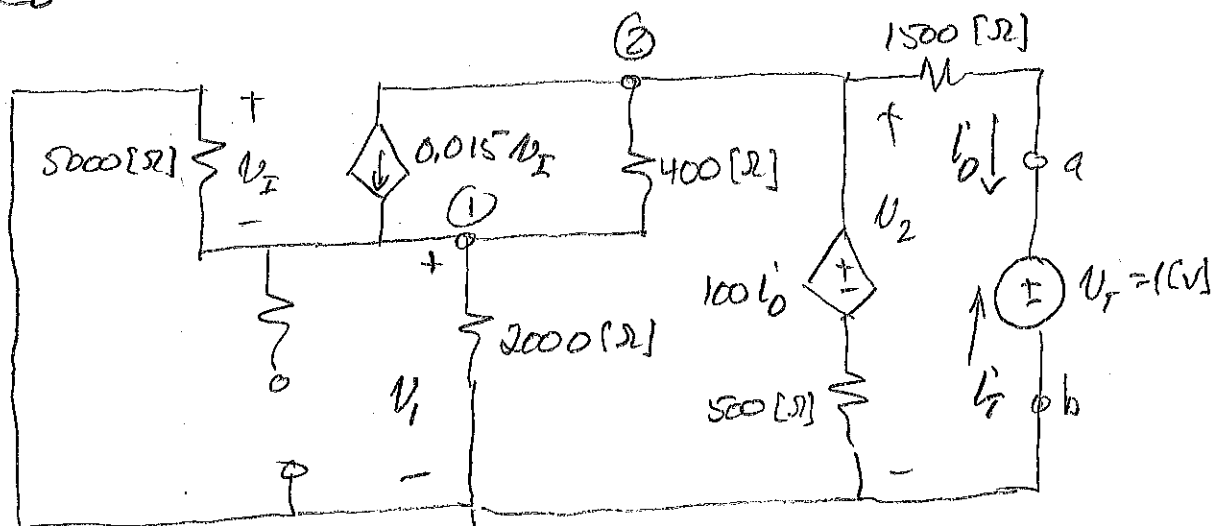
Find the value of R_L as well as the power delivered to R_L.



We will find the Thevenin equivalent, with polarity indicated:



Test source:



Room for extra work

$$\frac{v_1}{2000} + \frac{v_1}{5000} - 0.015(-v_1) + \frac{v_1 - v_2}{400} = 0 \qquad (v_I = -v_1)$$

$$\frac{v_2 - v_1}{400} + 0.015(-v_1) + \frac{v_2 - 100 i_0}{500} + \frac{v_2 - 1}{1500} = 0$$

$$i_0 = \frac{v_2 - 1}{1500} \Rightarrow \quad v_1 = 27.86\ [mV], \quad v_2 = 20.28\ [mV]$$

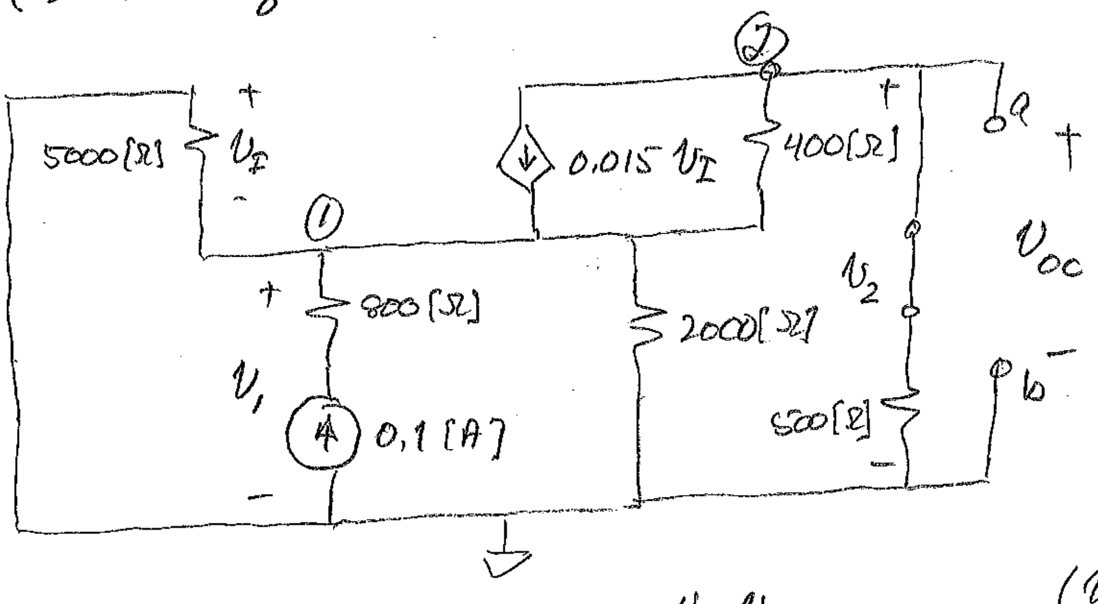
$$i_0 = -0.5314\ [mA] \qquad i_T = -i_0$$

$$R_{Th} = \frac{1}{i_T} = 1881.6\ [\Omega]$$

$$R_L = R_{Th} = 1881.6\ [\Omega]$$

$$P_{del\ to\ R_L} = \frac{v_{Th}^2}{4R_{Th}} = 279.6\ [mW]$$

v_{oc} (so that $i_0 \to 0$):



$$-0.1 + \frac{v_1}{5000} - 0.015(-v_1) + \frac{v_1}{2000} + \frac{v_1 - v_2}{400} = 0 \qquad (v_I = -v_1)$$

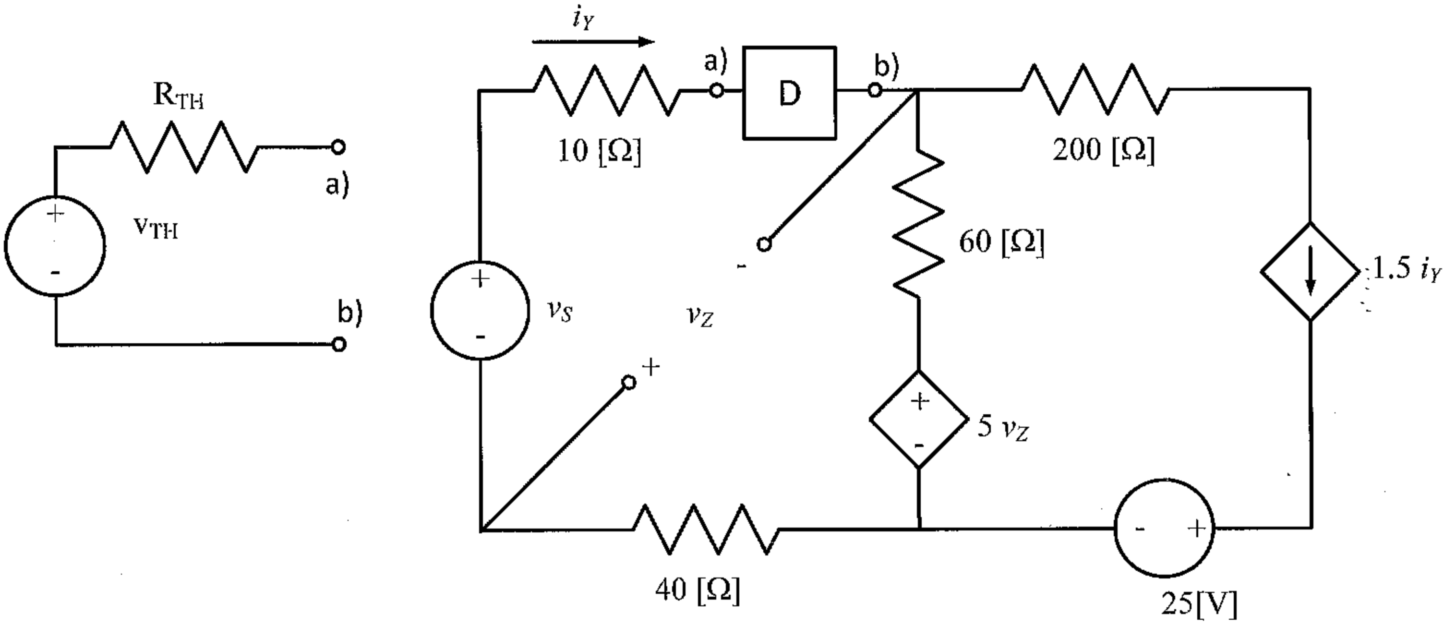
$$v_1 = 11.80\ [V]$$

$$\frac{v_2}{500} + \frac{v_2 - v_1}{400} + 0.015(-v_1) = 0$$

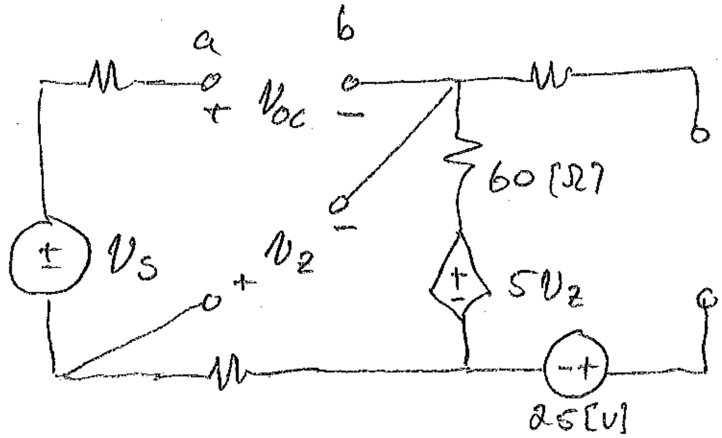
$$v_2 = v_{oc} = 45.87\ [V]$$

6. (40 points) The Thevenin voltage of the circuit below at terminals a), b), as seen by device D, is known to be 15 [V]. The polarity of the Thevenin equivalent is indicated in the accompanying figure.

- Find the value of the voltage source v_S.
- Find the Norton equivalent of the circuit as seen by device D. Label your Norton equivalent, clearly showing terminals a), b).
- Find the power absorbed by device D if the current i_Y is 1 [A].



We can find V_{Th} by replacing D with V_{oc}. Then $i_y \to 0$.



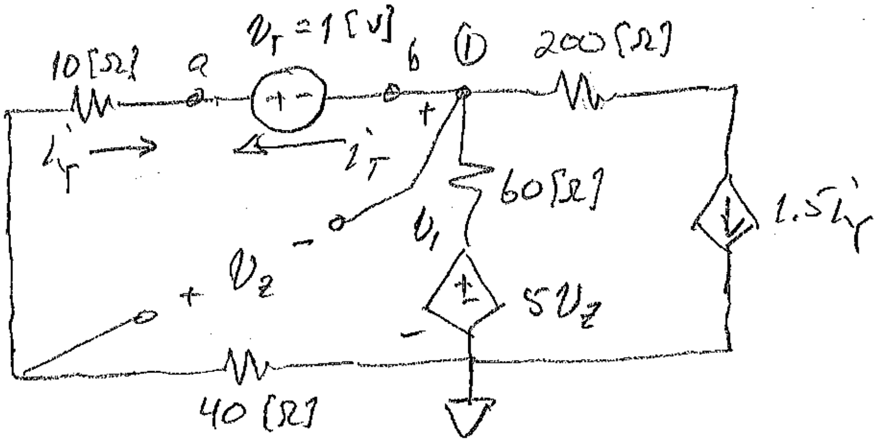
Since no current flows in any branch,

$V_{Th} = V_{oc} = V_S = 15$ [V]

17

Room for extra work

Let's go with a test source to find R_{Th}:



$$\frac{v_1 + 1}{50} + \frac{v_1 - 5v_2}{60} + 1.5 i_Y' = 0$$

$$v_2 - 1 - 10 i_Y' = 0 \qquad i_Y' = -\frac{v_1 + 1}{50}$$

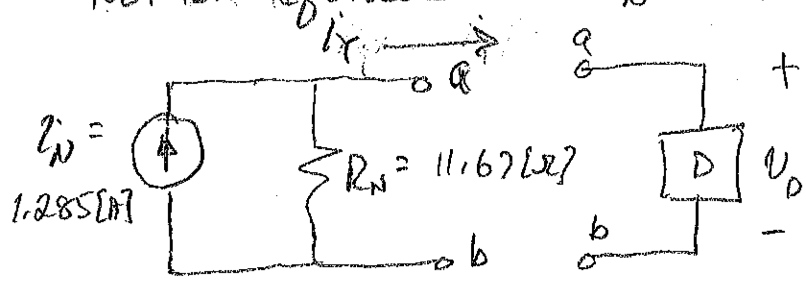
$$i_T = -i_Y' \Rightarrow \boxed{R_{Th} = 11.67 \, [\Omega]}$$

$v_1 = 3.2857$ [V]

$v_2 = 0.1429$ [V]

$i_Y' = -85.714$ [mA]

Norton equivalent: $R_N = R_{Th}$, $i_N = \dfrac{v_{Th}}{R_{Th}} = \underline{1.285}$ [A]



If $i_Y = 1$ [A], then

$$v_D = (i_N - i_Y) R_N = 3.326 \text{ [V]}$$

Note that i_Y is entering D at terminal a of D.

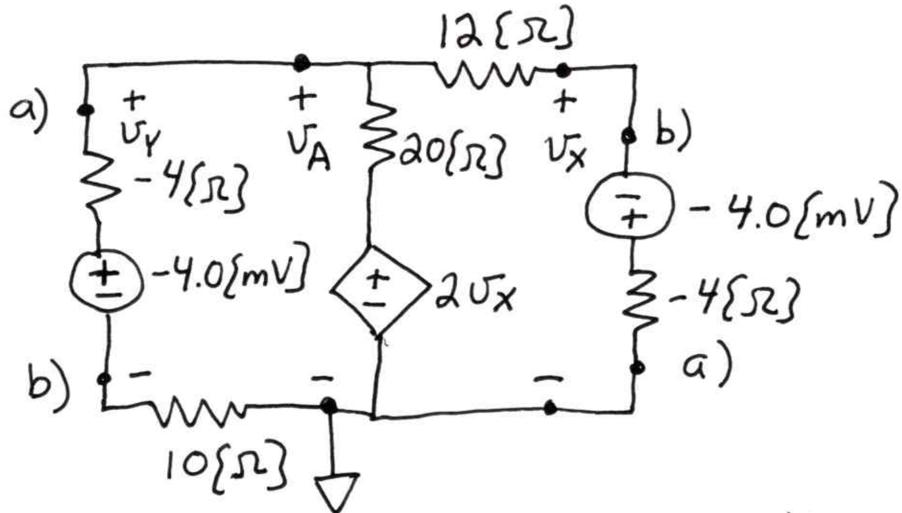
∴ $P_{abs \text{ by } D} = i_Y \cdot v_D$

$= 3.326$ [W]

Problem 2 continued

$$v_{TH} = 0.003(-4) + 0.008 = -4.0\{mV\}$$

Now, we redraw the circuit, with the Thevenin equivalent in place of D in both locations.



We have the following equations:

$$\frac{v_A - 2v_X}{20\{\Omega\}} + \frac{v_A - 4.0\{mV\}}{8\{\Omega\}} + \frac{v_A + 4.0\{mV\}}{6\{\Omega\}} = 0$$

$$v_X = \left(\frac{v_A - 4.0\{mV\}}{8\{\Omega\}}\right)(-4\{\Omega\}) + 4.0\{mV\}$$

$$v_Y = \left(\frac{v_A + 4.0\{mV\}}{6\{\Omega\}}\right)(-4\{\Omega\}) - 4.0\{mV\}$$

Solving, we get

$v_A = 1.106\{mV\}$ $\quad$ $v_X = 5.447\{mV\}$

$$\boxed{v_Y = -7.404\{mV\}}$$