Name: ______________________________ (please print)

Signature: ___________________________

ECE 2201 – Final Exam
May 3, 2017

Keep this exam closed 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 that is not given in a reasonable order will lose credit. Clearly indicate your answer (for example by enclosing it in a box).
3. It is assumed that your work will begin on the same page as the problem statement. If you choose to begin your work on another page, you must indicate this on the page with the problem statement, with a clear indication of where the work can be found. **If your work continues on to another page, indicate clearly where your work can be found. Failure to indicate this clearly will result in a loss of credit.**
4. Show all units in solutions, intermediate results, and figures. Units in the exam will be included between square brackets.
5. Do not use red ink. Do not use red pencil.
6. You will have 170 minutes to work on this exam.

1. ______________/30

2. ______________/30

3. ______________/35

4. ______________/35

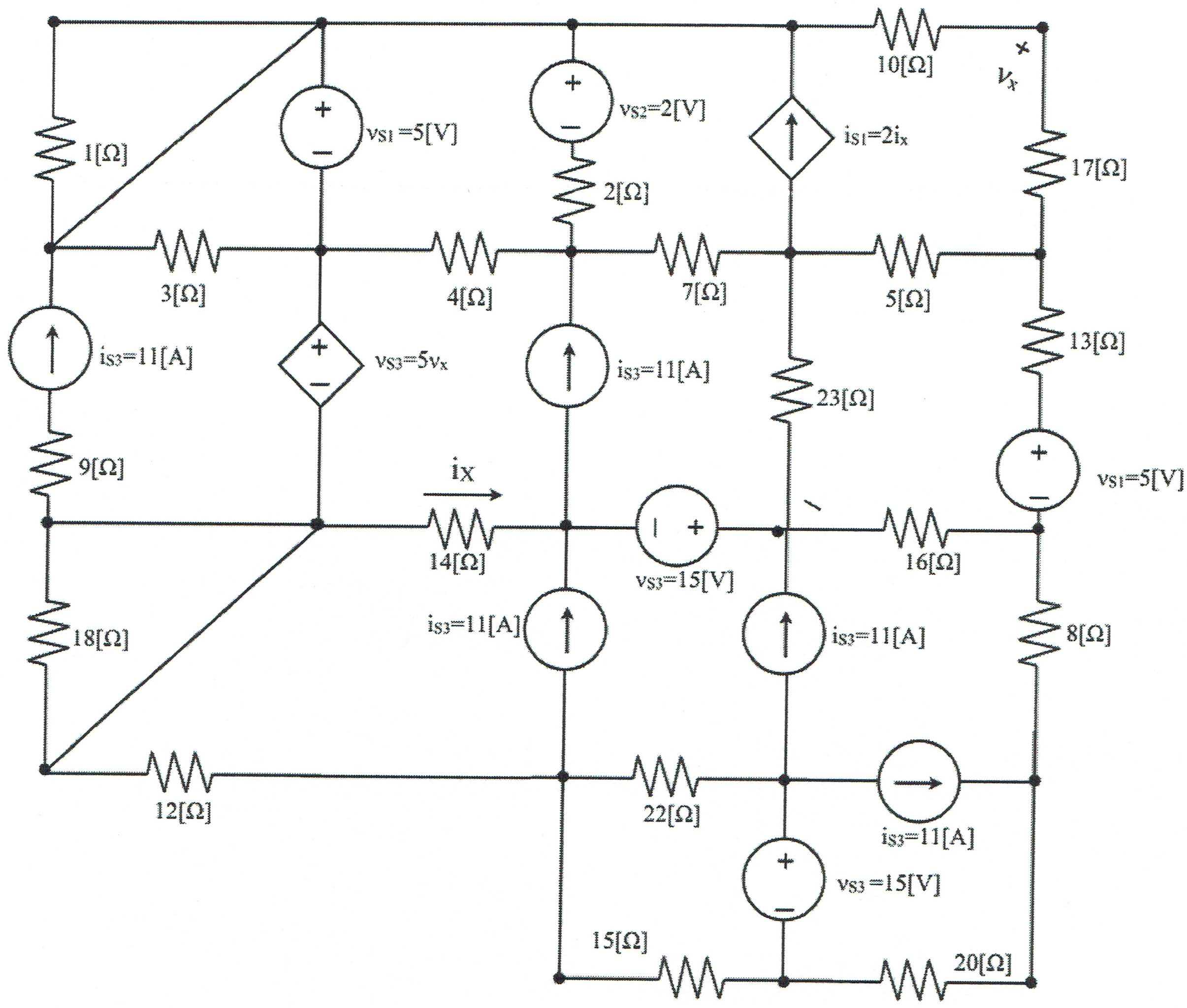
5. ______________/35

6. ______________/35

Total = 200

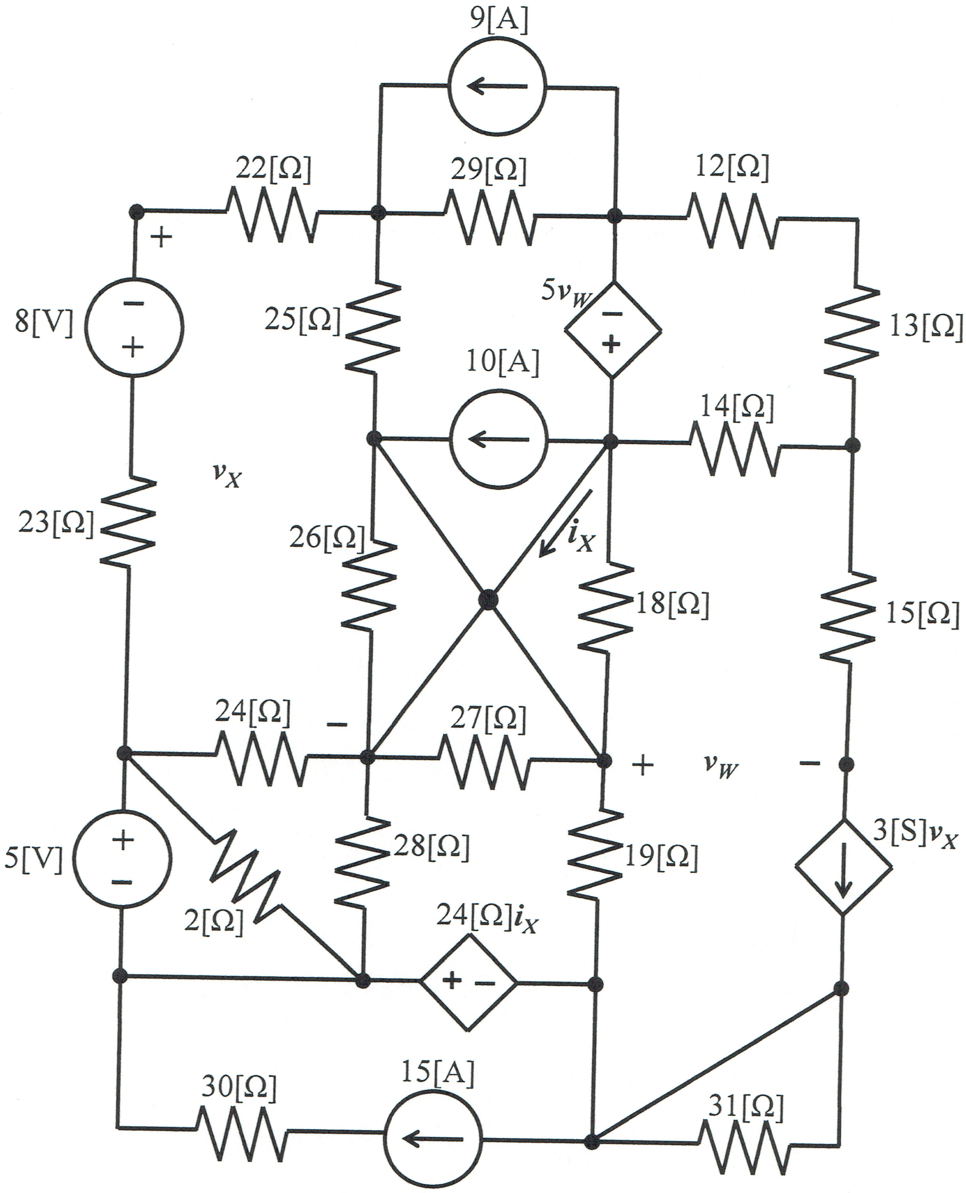
Room for extra work

1. {30 Points} Use the **mesh-current method** to write a complete set of equations that could be used to solve this circuit. Do not simplify the circuit. Do not attempt to simplify or solve your equations. Define all variables clearly.



Room for extra work

2. {30 Points} Use the **node-voltage method** to write a complete set of equations that could be used to solve this circuit. Do not simplify the circuit. Do not attempt to simplify or solve your equations. Define all variables clearly.



Room for extra work

3. {35 Points} A device can be modeled as a current source in parallel with a resistance. This device is shown in Figure 1. The relationship between the voltage across the device and the current through the device is shown in Figure 2. This device is connected to the circuit as shown in Figure 3.

a) Find the device model and draw it, showing terminals **a** and **b**.
b) Find the Thevenin equivalent circuit seen by the device.
c) Find the power absorbed by the device.

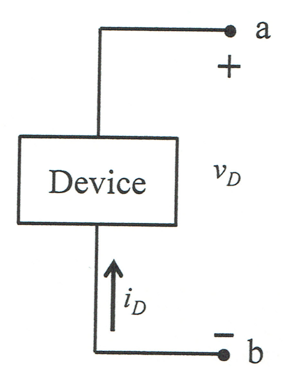


Figure 1

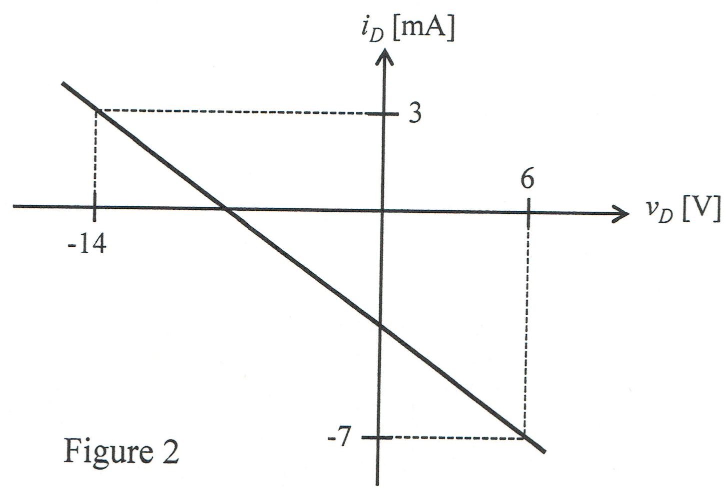


Figure 2

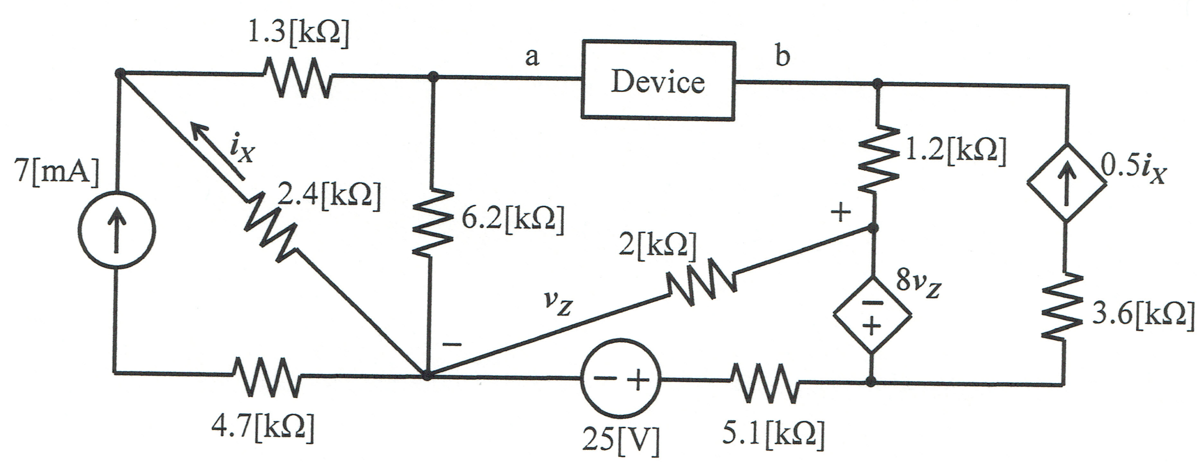
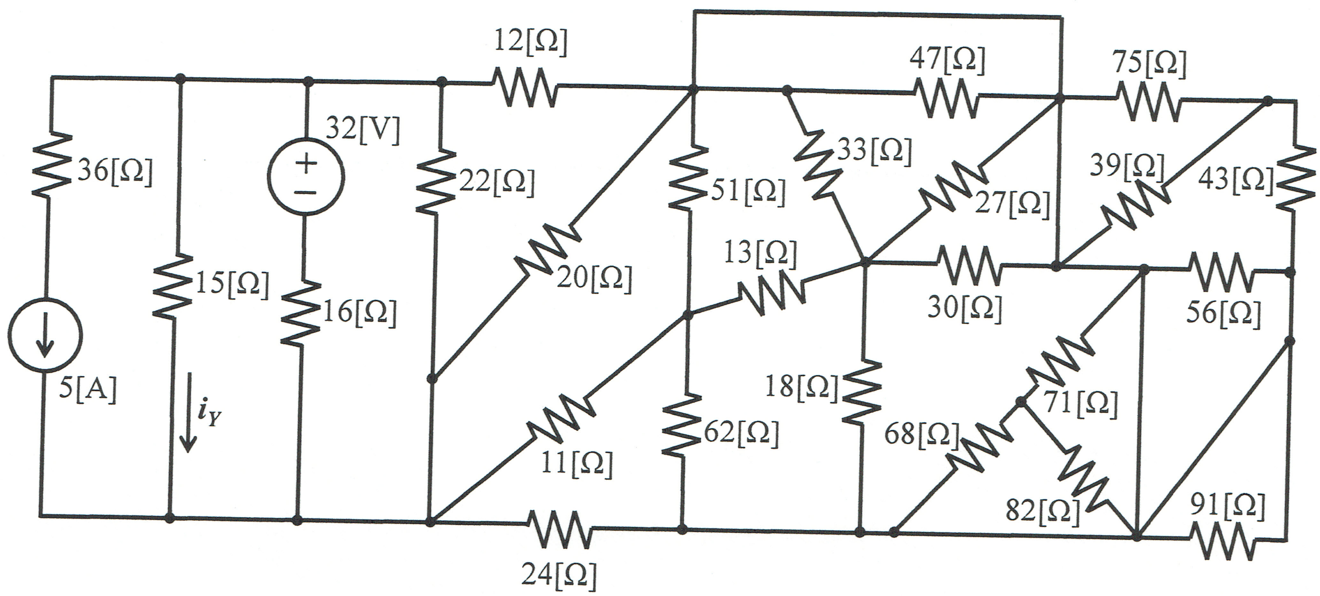


Figure 3

Room for extra work

4. {35 Points} Use the circuit below to solve this problem. **Do not use** the Node-Voltage Method or Mesh-Current Method.
a) Simplify the circuit and redraw.
b) Apply superposition theorem to find i_Y.



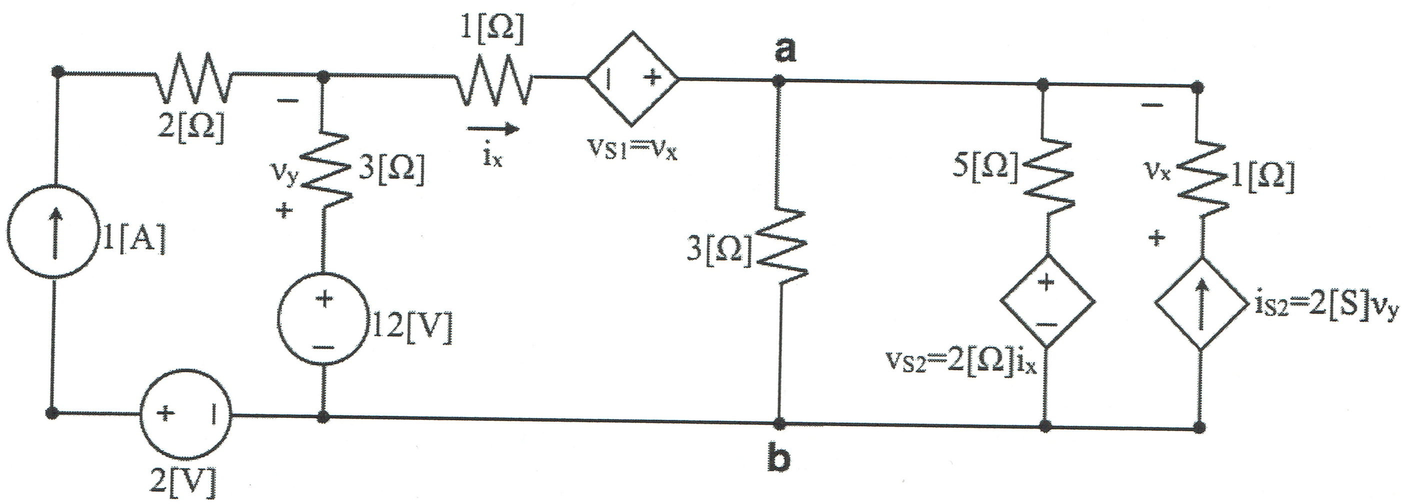
Room for extra work

5. {35 Points} Use the following circuit to solve this problem.

a) Find Thevenin equivalent seen at terminals **a** and **b**.

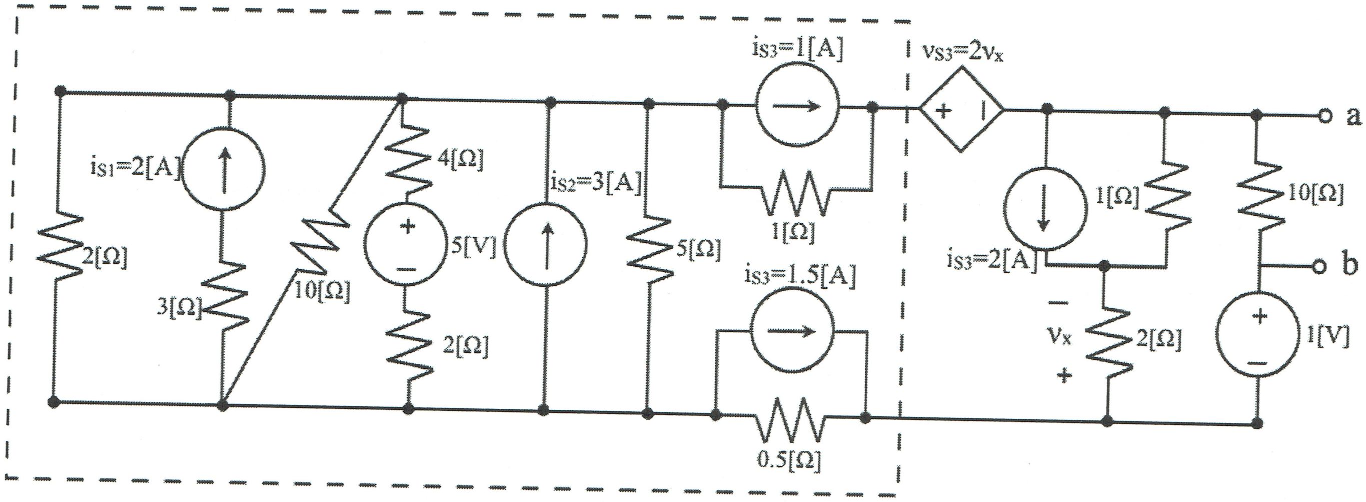
b) Find the value of R_L that will maximize the power delivered to it.

c) Calculate the maximum power delivered to R_L.



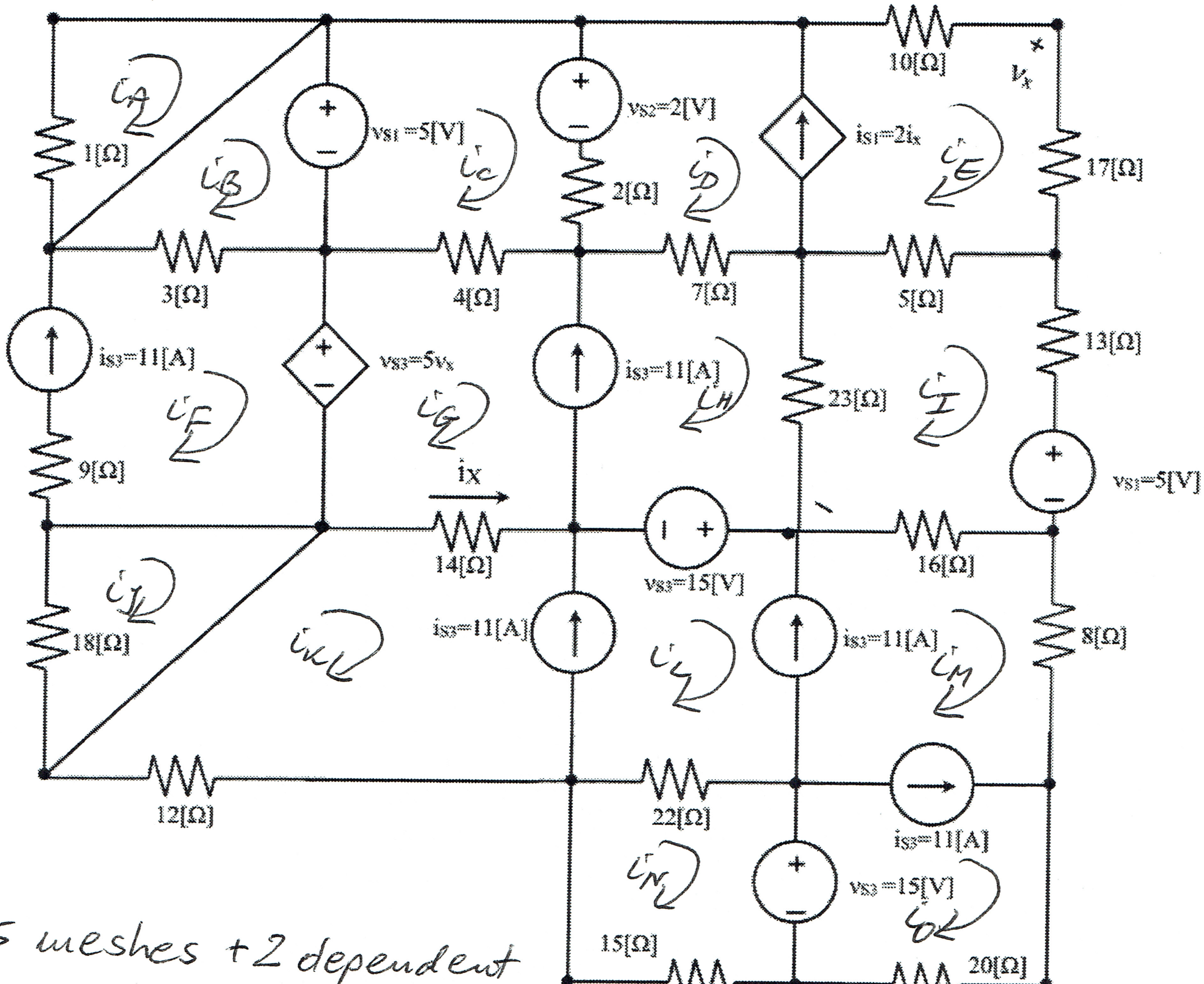
Room for extra work

6. {35 Points} Use the following circuit to solve this problem.
a) Simplify the circuit within the marked area, using source transformations only.
b) Find the Norton equivalent as seen from terminals **a** and **b**.



Room for extra work

1. {30 Points} Use the **mesh-current method** to write a complete set of equations that could be used to solve this circuit. Do not simplify the circuit. Do not attempt to simplify or solve your equations. Define all variables clearly.



15 meshes + 2 dependent sources

⇓

17 equations

(A) $i_A \cdot 1\Omega = 0$

(B) $5V + (i_B - i_F)3\Omega = 0$

(C) $2V + (i_C - i_D)2\Omega + (i_C - i_G)4\Omega - 5V = 0$

(D)+(E) $(i_D - i_H)7\Omega + (i_D - i_C)2\Omega - 2V + i_E \cdot 10\Omega + i_E \cdot 17\Omega + (i_E - i_I)5 = 0$

(D + E) $i_E - i_D = 2i_x$

(F) $i_F = 11A$

Room for extra work

(S.M.) (G+H) $(i_G - i_K)14\Omega - 5v_x + (i_G - i_C)4\Omega + (i_H - i_D)7\Omega + (i_H - i_I)23\Omega + 15V = 0$

(G+H) $i_H - i_G = 11A$

(I) $i_I \cdot 13\Omega + 5V + (i_I - i_M)16\Omega + (i_I - i_H)23\Omega + (i_H - i_E)5\Omega = 0$

(J) $i_J = 0$

(S.M.) (K+L+M+O) $i_K \cdot 12\Omega + (i_K - i_G)14\Omega - 15V + (i_M - i_I)16\Omega + i_M \cdot 8\Omega + i_O \cdot 20\Omega - 15V + (i_L - i_N)22\Omega = 0$

(K+L) $i_L - i_K = 11A$

(M+L) $i_M - i_L = 11A$

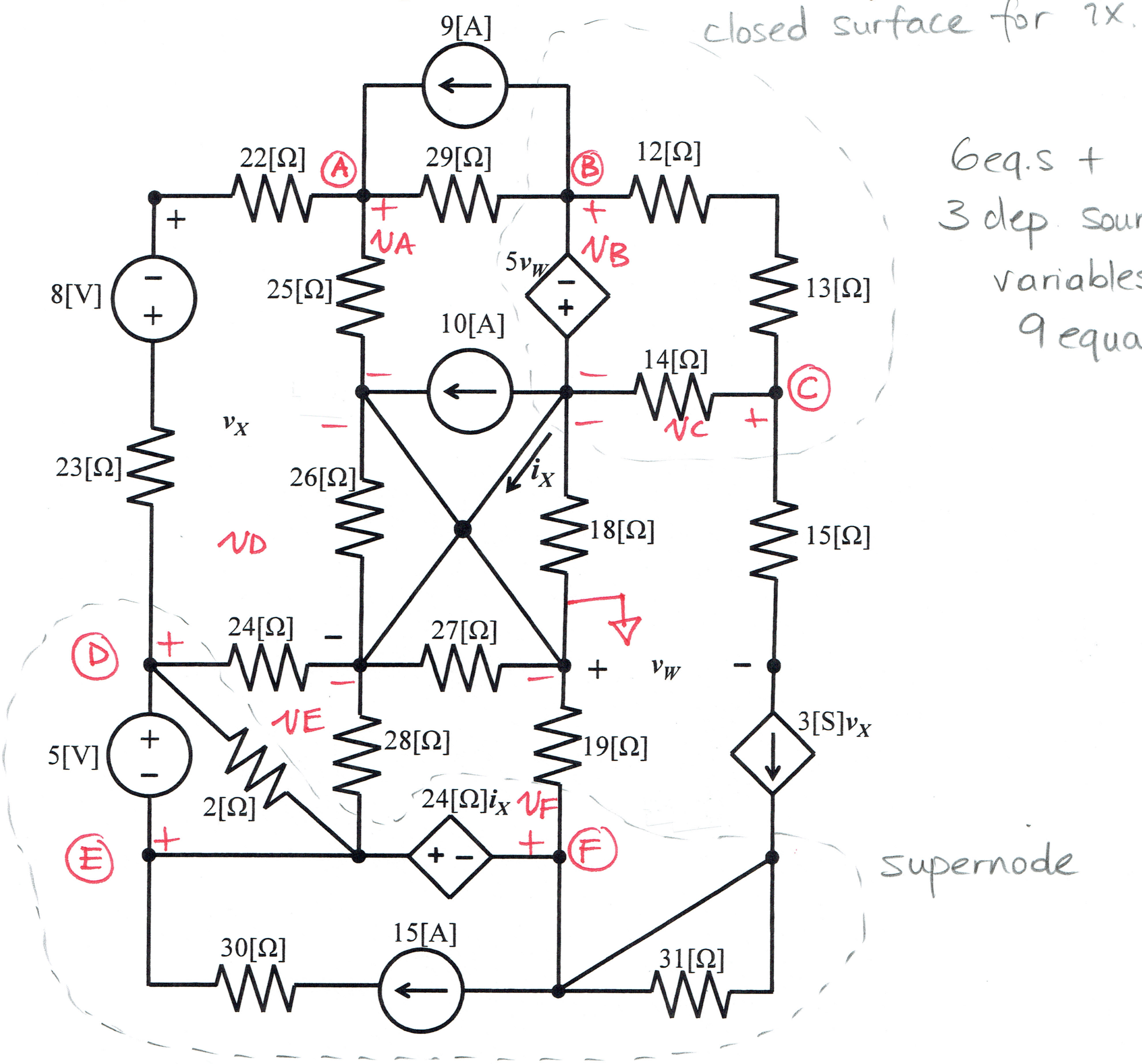
(O+M) $i_O - i_M = 11A$

(N) $15V + i_N \cdot 15\Omega + (i_N - i_L)22\Omega = 0$

(i_x) $i_x = i_K - i_G$

(v_x) $v_x = i_E \cdot 17\Omega + i_I \cdot 13\Omega + 5V + (i_I - i_M) \cdot 16\Omega$

2. {30 Points} Use the **node-voltage method** to write a complete set of equations that could be used to solve this circuit. Do not simplify the circuit. Do not attempt to simplify or solve your equations. Define all variables clearly.



6eq.s + 3 dep. source variables = 9 equations

(A): $\dfrac{v_A - v_D + 8[V]}{(23+22)[\Omega]} - 9[A] + \dfrac{v_A - v_B}{29[\Omega]} + \dfrac{v_A}{25[\Omega]} = 0$

(B) $v_B = -5 v_W$

(C) $\dfrac{v_C - v_B}{(12+13)[\Omega]} + \dfrac{v_C}{14[\Omega]} + 3[S] v_X = 0$

Room for extra work

(D+E+F): $$\frac{v_D - v_A - 8[V]}{(23+22)[\Omega]} + \frac{v_D}{24[\Omega]} + \frac{v_E}{28[\Omega]} + \frac{v_F}{19[\Omega]} \ldots$$

$$\ldots -3[S]\,v_X = 0$$

(D+E) $$v_D - v_E = 5[V]$$

(E+F) $$v_E - v_F = 24[\Omega]\,i_X$$

(i_X) $$9[A] + \frac{v_B - v_A}{29[\Omega]} + 10[A] + i_X + \frac{0}{18[\Omega]} + 3[S]\,v_X = 0$$

(v_W) $$-v_W - v_C + 15[\Omega]\,3[S]\,v_X = 0$$

(v_X) $$-v_X + \left(\frac{v_D - v_A - 8[V]}{(23+22)[\Omega]}\right) \cdot 22[\Omega] + v_A = 0$$

3. {35 Points} A device can be modeled as a current source in parallel with a resistance. This device is shown in Figure 1. The relationship between the voltage across the device and the current through the device is shown in Figure 2. This device is connected to the circuit as shown in Figure 3.

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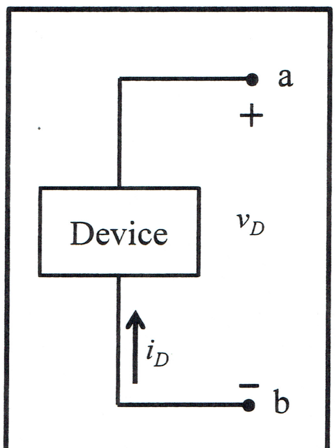


Figure 1

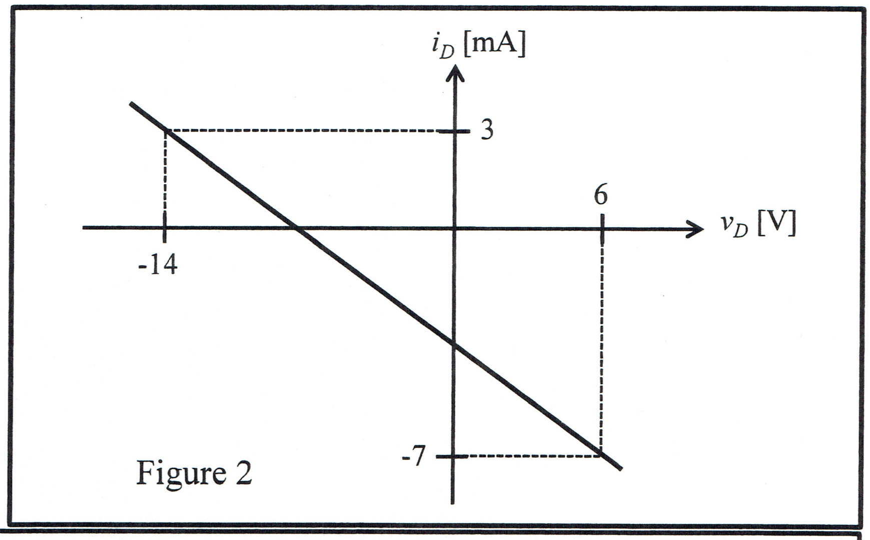


Figure 2

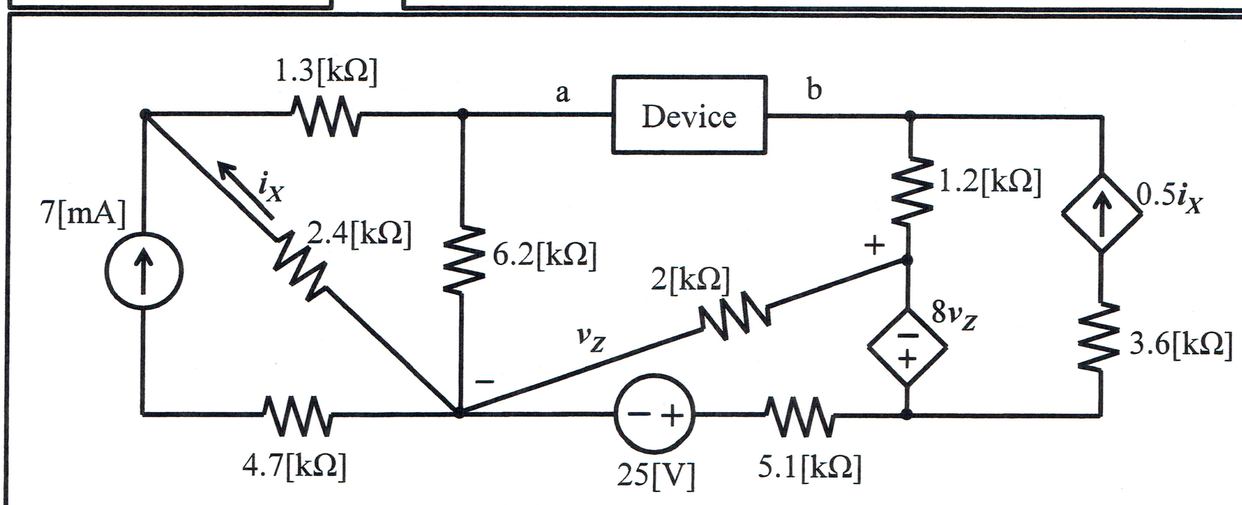
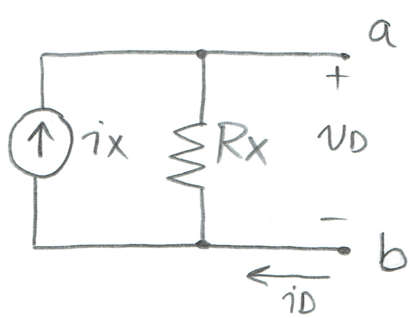


Figure 3

a)



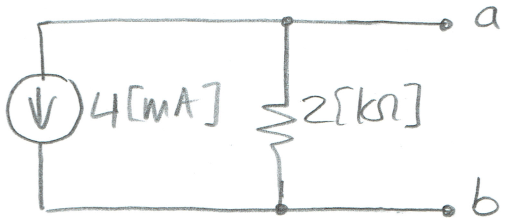
$$-i_X + \frac{v_D}{R_X} + i_D = 0$$

$$-i_X - \frac{14V}{R_X} + 3mA = 0 \quad (1)$$

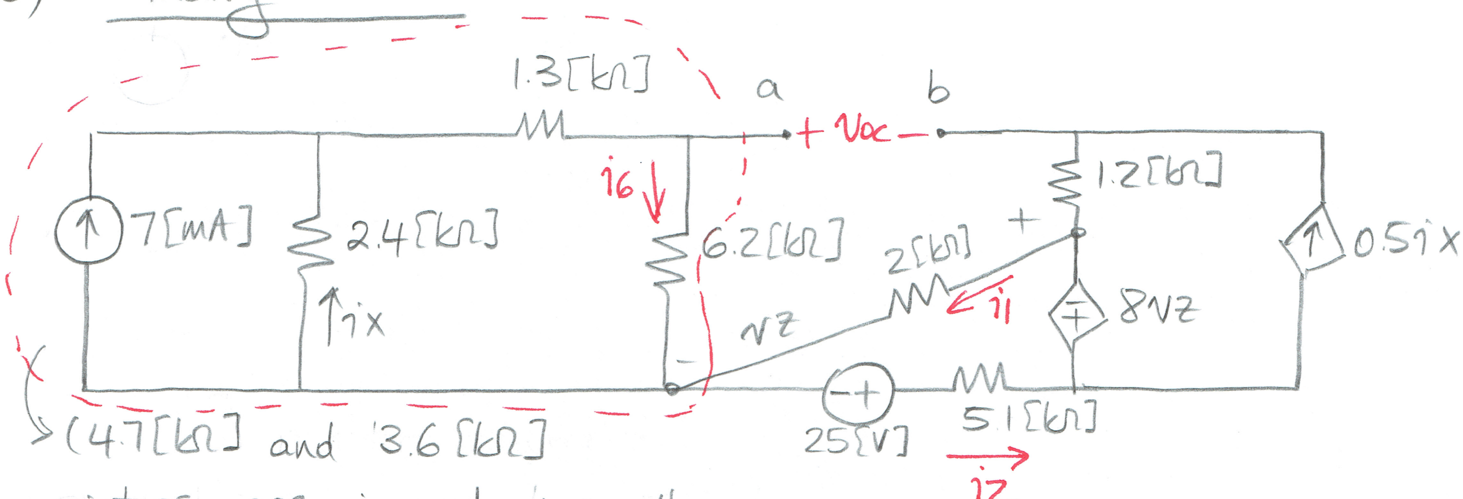
$$-i_X + \frac{6V}{R_X} - 7mA = 0 \quad (2)$$

Room for extra work

Solving (1) and (2), we get $i_x = -4[mA]$, $R_x = 2[k\Omega]$



b) <u>Finding Voc</u>:



(4.7[kΩ] and 3.6[kΩ] resistors are ignored, since they are in series w/ a current source)

KCL @ closed surface : $i_1 = i_z$ $\quad i_1 = v_z / 2[k\Omega]$

KVL : $v_z - 25[V] + 5.1[k\Omega] \cdot \dfrac{v_z}{2[k\Omega]} + 8v_z = 0$

$\Rightarrow v_z = 2.164[V]$

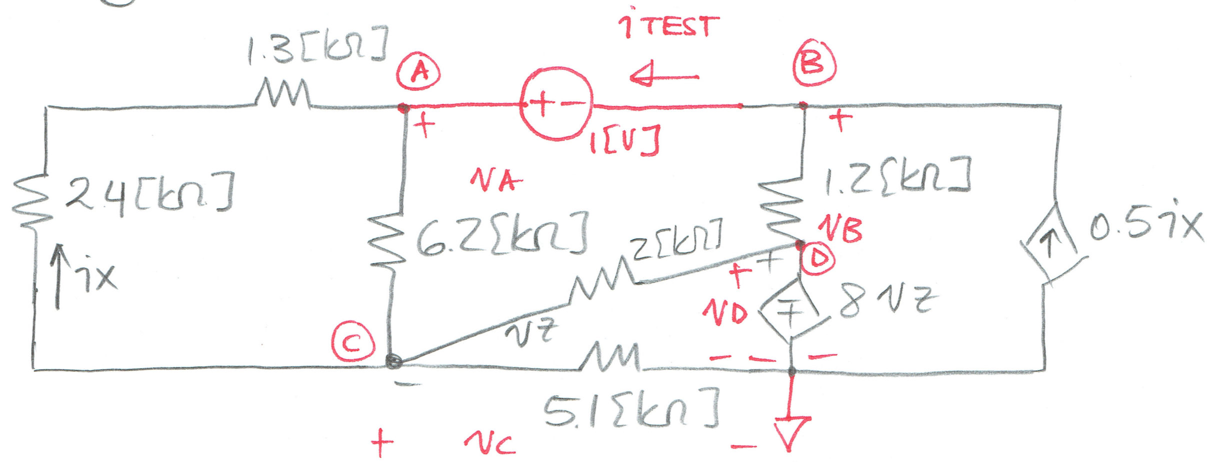
CDR : $i_6 = \dfrac{2.4}{2.4+1.3+6.2} \cdot 7[mA] = 1.69[mA]$

$i_x = i_6 - 7[mA] = -5.31[mA]$

KVL : $V_{oc} + 0.5 i_x \cdot 1.2[k\Omega] + v_z - i_6 \cdot 6.2[k\Omega] = 0$ $\quad \boxed{V_{oc} = 11.5[V]}$

Room for extra work

Finding R_{TH} : First we need to kill the independent sources.



(A+B) $\frac{v_A - v_C}{3.7[k\Omega]} + \frac{v_A - v_C}{6.2[k\Omega]} + \frac{v_B - v_D}{1.2[k\Omega]} - 0.5 i_x = 0$

(A+B) $v_A - v_B = 1[V]$

(C) $\frac{v_C - v_A}{3.7[k\Omega]} + \frac{v_C - v_A}{6.2[k\Omega]} + \frac{v_C - v_D}{2[k\Omega]} + \frac{v_C}{5.1[k\Omega]} = 0$

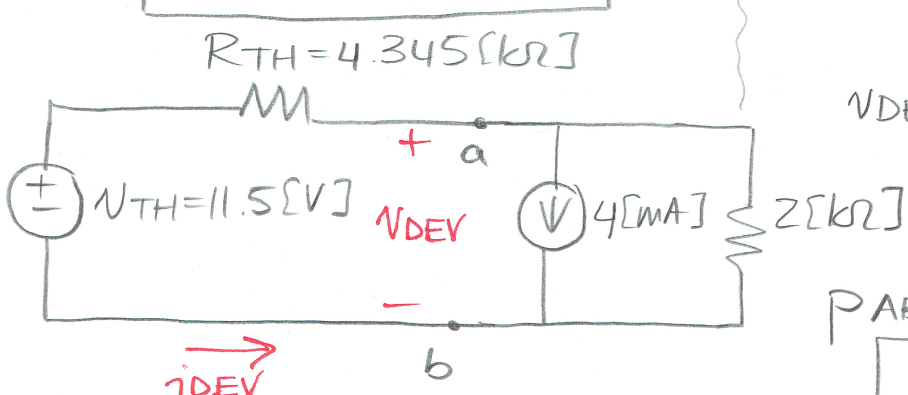
(D) $v_D = -8 v_z$ (ix) $\frac{v_C - v_A}{3.7[k\Omega]} = i_x$ (vz) $v_D - v_C = v_z$

KCL : $i_{TEST} - 0.5 i_x + \frac{v_B - v_D}{1.2[k\Omega]} = 0$

Solving, we get $i_{TEST} = 0.23[mA]$ $R_{TH} = \frac{1[V]}{0.23[mA]}$

$\boxed{R_{TH} = 4.345[k\Omega]}$

c)



$i_{DEV} + 4[mA] + \frac{v_{DEV}}{2[k\Omega]} = 0$

$v_{DEV} = i_{DEV} R_{TH} + v_{TH}$

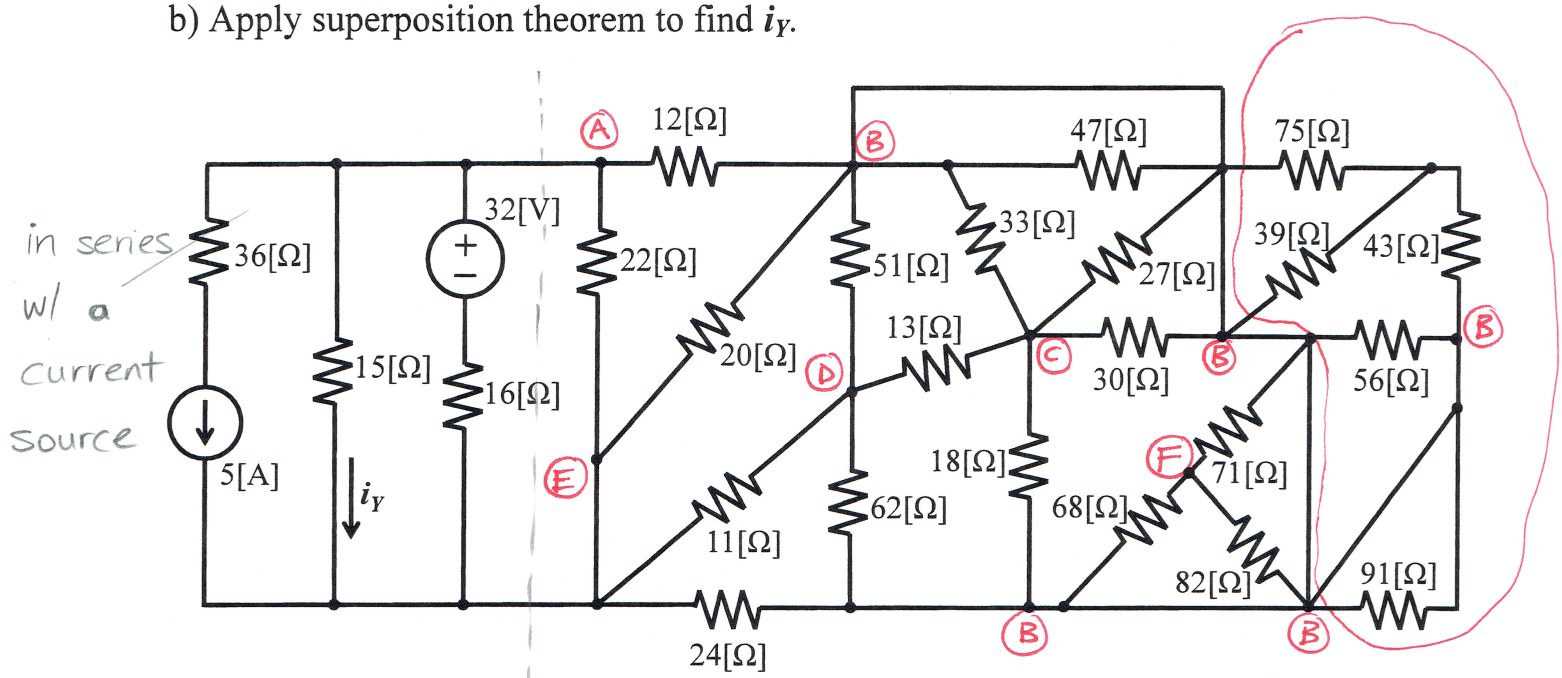
$i_{DEV} = -3.07[mA]$

$v_{DEV} = -1.85[V]$

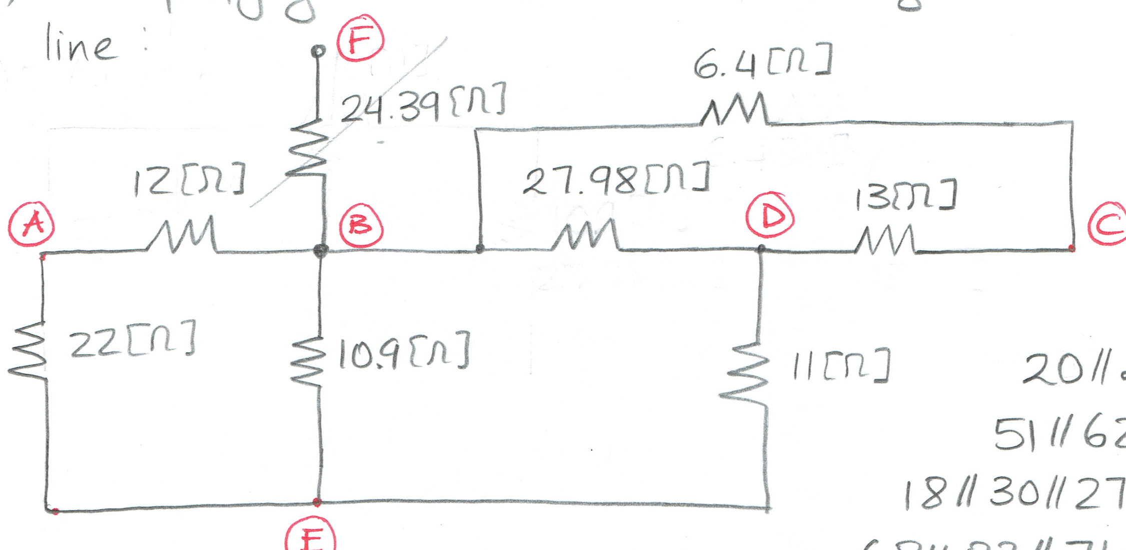
$p_{ABS,DEV} = -v_{DEV} \cdot i_{DEV}$

$\boxed{= -5.7[mW]}$

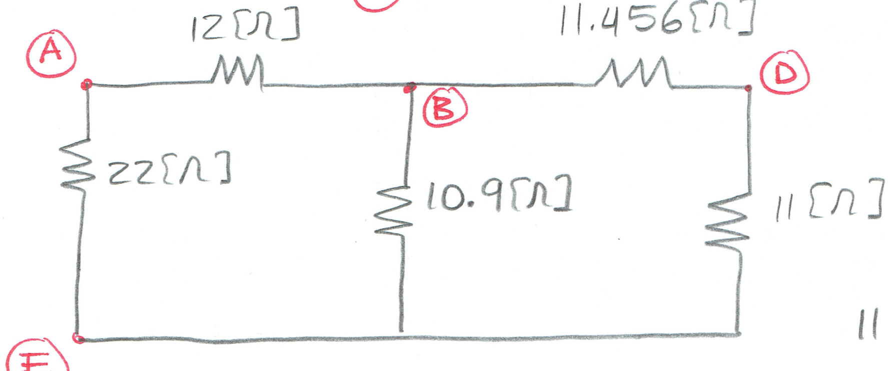
4. {35 Points} Use the circuit below to solve this problem. **Do not use** the Node-Voltage Method or Mesh-Current Method.
a) Simplify the circuit and redraw.
b) Apply superposition theorem to find i_Y.



a) Simplifying the circuit to the right of the dashed line:



20 // 24 = 10.9 [Ω]
51 // 62 = 27.98 [Ω]
18 // 30 // 27 // 33 = 6.4 [Ω]
68 // 82 // 71 = 24.39 [Ω]



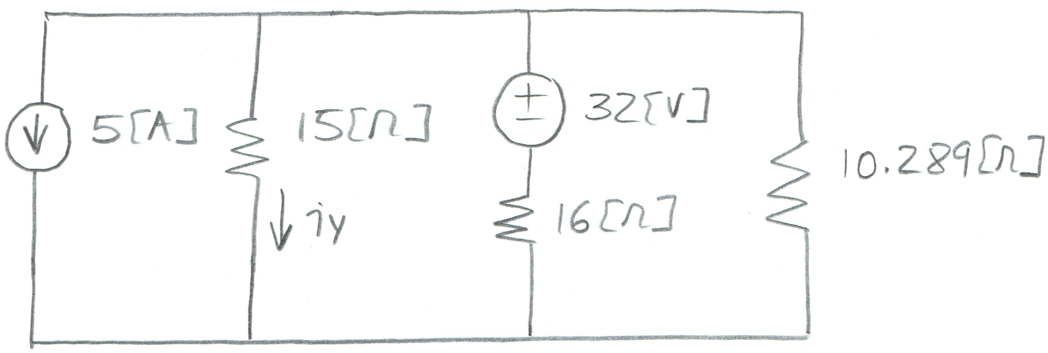
(13+6.4) // 27.98 = 11.456 [Ω]

11 + 11.456 = 22.456 [Ω]

Room for extra work

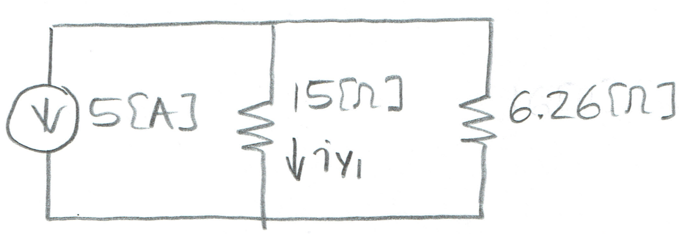
$$R_{AE} = 22 \,//\, [12 + (10.9 \,//\, 22.456)] = 10.289\ [\Omega]$$

Simplified circuit:



b) Superposition: Take 1 independent source into account at a time.

5[A]:

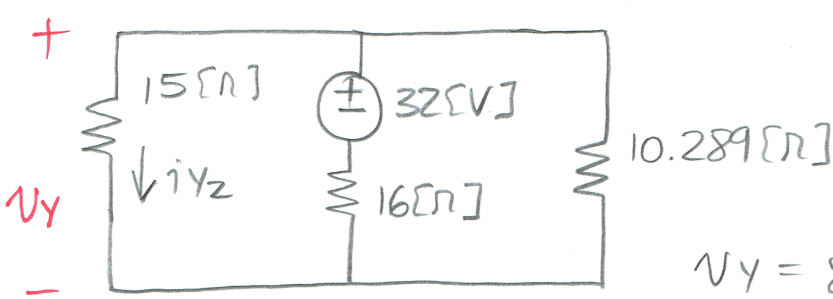


$$16 \,//\, 10.289 = 6.26\ [\Omega]$$

$$\text{CDR}: i_{y1} = -\frac{6.26}{15+6.26} \cdot 5\ [A]$$

$$i_{y1} = -1.472\ [A]$$

32[V]:



$$15 \,//\, 10.289 = 6.1\ [\Omega]$$

$$\text{VDR}: v_y = \frac{6.1}{6.1+16} \cdot 32\ [V]$$

$$v_y = 8.83\ [V] \qquad i_{y2} = v_y / 15[\Omega]$$

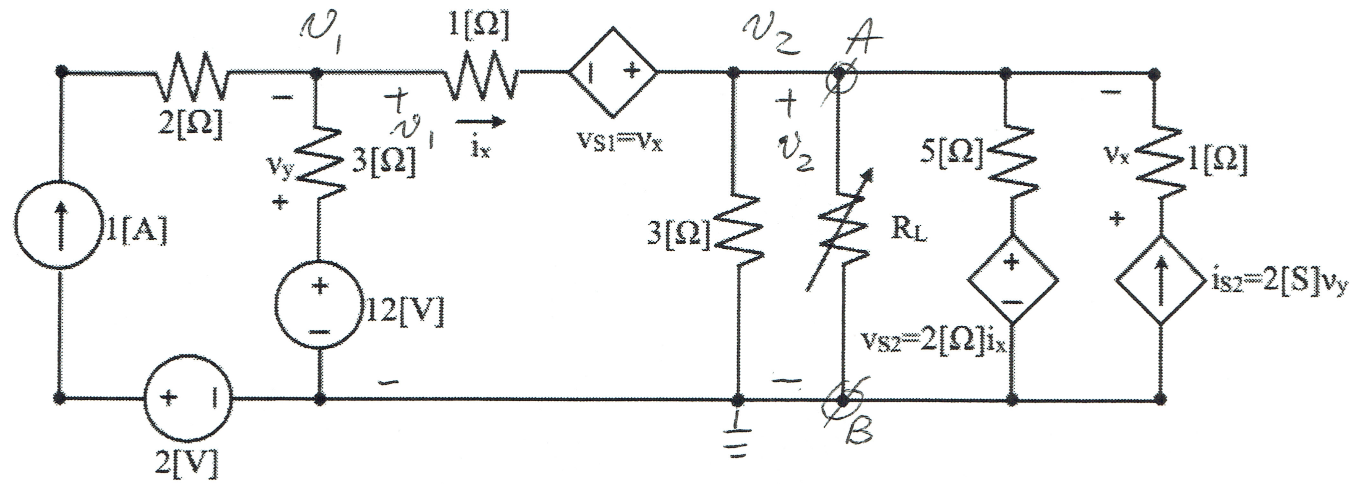
$$i_{y2} = 0.588\ [A]$$

$$i_y = i_{y1} + i_{y2} = \boxed{-0.884\ [A]}$$

5. {35 Points} Use the following circuit to solve this problem.

a) Find the value of R_L that will maximize the power delivered to it.

b) Calculate the maximum power delivered to R_L.



We start with removing R_L and we will obtain Thevenin equivalent seen from the terminals A & B.

$v_2 = v_{OC}$

@ v_1: $\dfrac{v_1 - 12V}{3\Omega} - 1A + \dfrac{v_1 - (v_2 - v_x)}{1\Omega} = 0$

$\downarrow$ $4v_1 - 3v_2 + 3v_x = 15$

@ v_2: $\dfrac{v_2 - v_x - v_1}{1\Omega} + \dfrac{v_2}{3\Omega} + \dfrac{v_2 - 2i_x}{5\Omega} - 2v_y = 0$

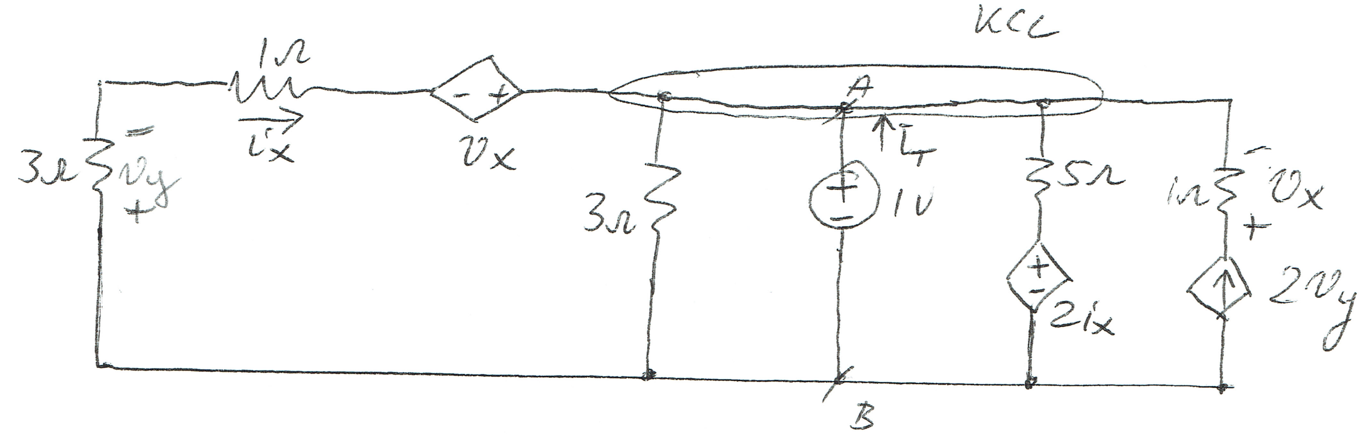
dependent Sources:
$$\begin{cases} v_y = 12V - v_1 \\ i_x = \dfrac{v_1 - v_2 + v_x}{1\Omega} \\ v_x = 2v_y \cdot 1\Omega \end{cases}$$

$v_1 = 9.88\,V$

$v_2 = 12.4V \Rightarrow v_{TH} = 12.4V$

Room for extra work

Deactivate independent sources & connect a test source 1V.



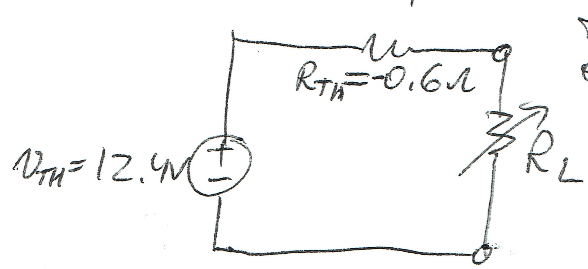
KCL @ A

$$-i_T + \frac{1-v_x}{3+1} + \frac{1V}{3\Omega} + \frac{1V - 2i_x}{5\Omega} - 2v_y = 0$$

$$\left.\begin{aligned} v_x &= 2v_y \\ v_y &= 3i_x \\ i_x &= -\frac{1-v_x}{4} \end{aligned}\right\} \quad \begin{aligned} i_x &= 0.5A \\ v_x &= 3V \\ v_y &= 1.5A \end{aligned}$$

$$i_T = -3.17\,A$$

$$R_{eq} = \frac{1V}{i_T} = -0.315\Omega \qquad R_{eq} = R_{TH}$$



thevenin equivalent

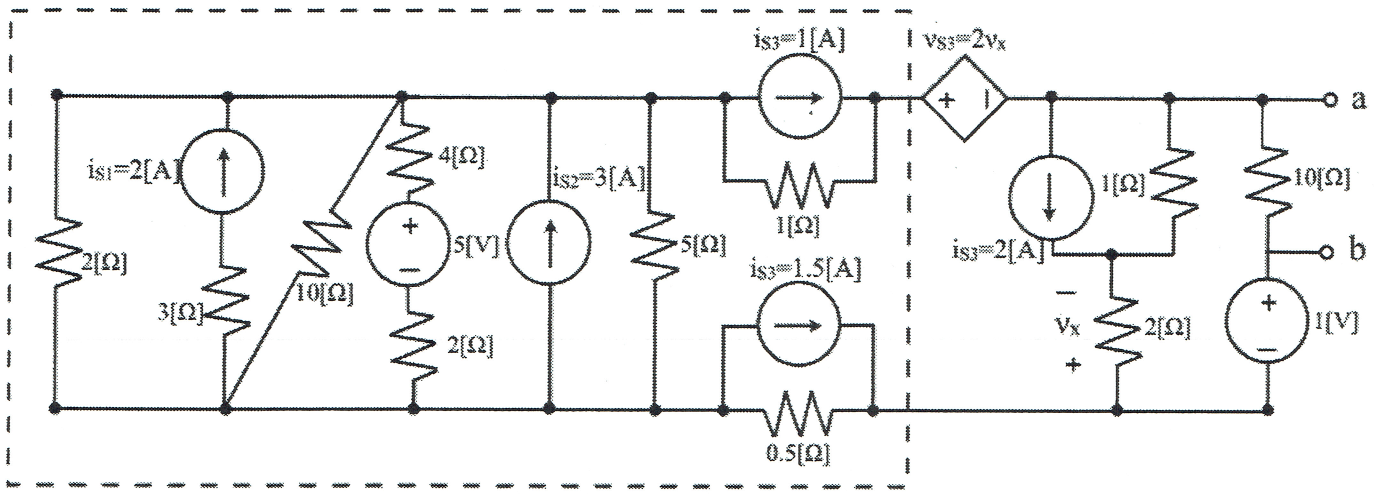
$$R_L = R_{TH} = -0.315\Omega$$

$$P_{abs,R_L} = \frac{v_{th}^2}{4R_{TH}} = -122\,[W]$$

6. {35 Points} Use the following circuit to solve this problem.

a) Simplify the circuit within the marked area, using source transformations only.

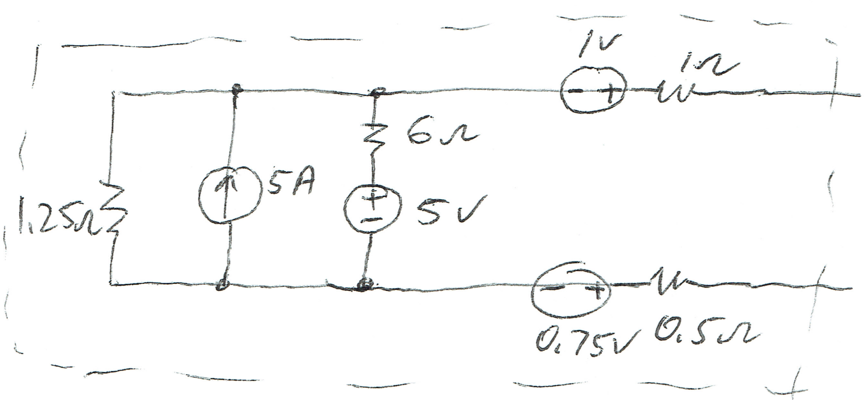
b) Find the Norton equivalent as seen from terminals **a** and **b**.

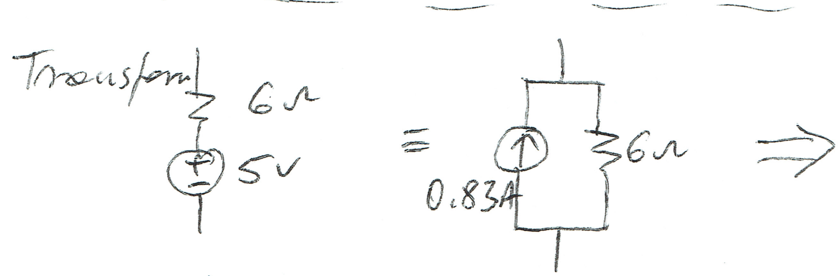


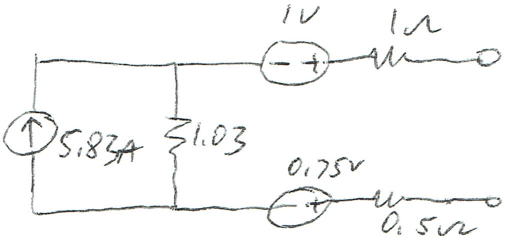
We can simplify 2A branch by removing 3Ω resistor.

Resistors 2Ω || 10Ω || 5Ω = 1.25Ω

Current sources 2A & 3A give 5A source

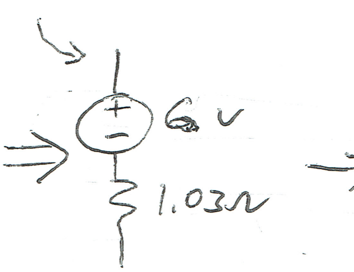




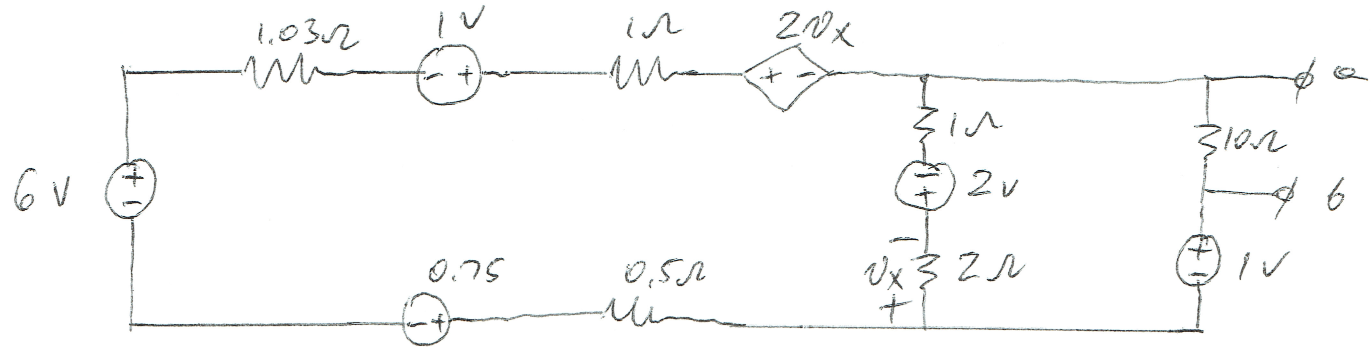


Add: 5A + 0.83A = 5.83A

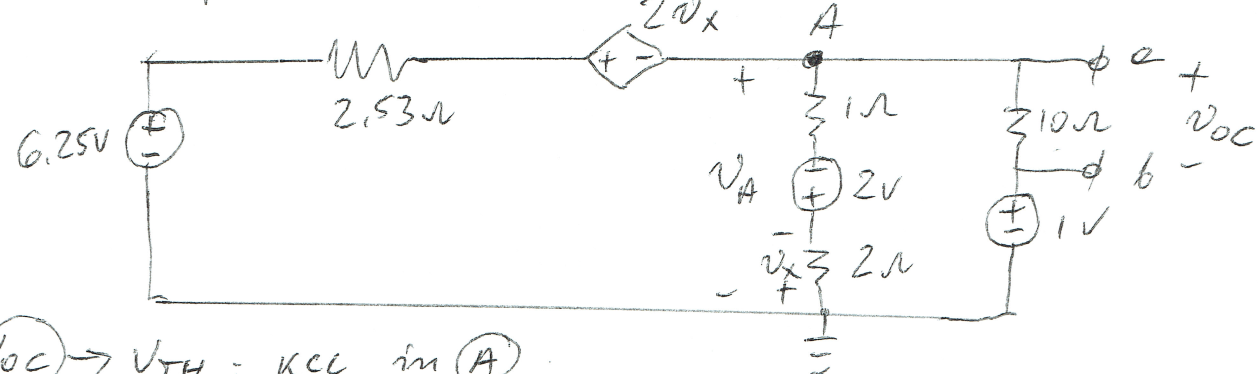
Req: 1.25Ω || 6Ω = 1.03Ω } transform again to Voltage + R



Room for extra work



add voltages + resistors



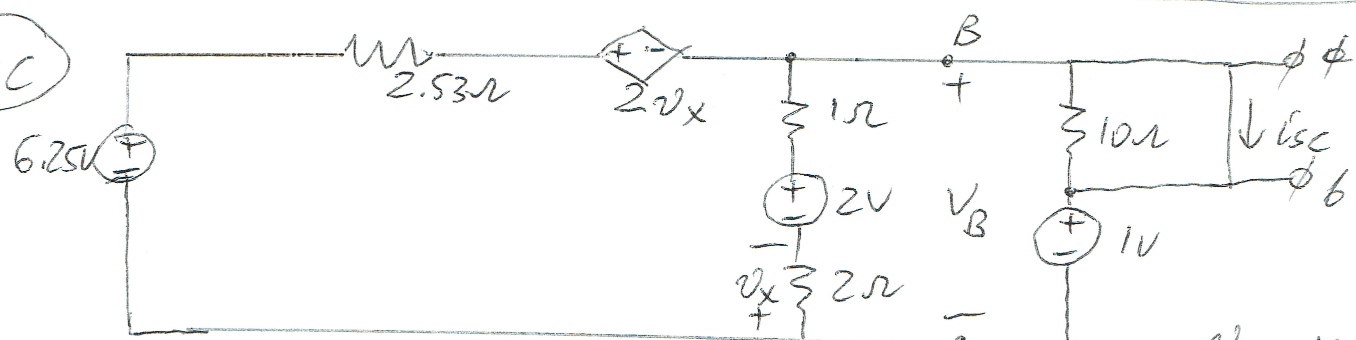
$v_{oc} \rightarrow V_{TH}$; KCL in (A)

$$\begin{cases} \dfrac{v_A + 2v_x - 6.25}{2.53\Omega} + \dfrac{v_A + 2V}{3\Omega} + \dfrac{v_A - 1V}{10\Omega} = 0 \\ -v_x = \dfrac{v_A + 2V}{3\Omega} \cdot 2\Omega \end{cases}$$

$v_A = 9.8\ V \quad v_x = -7.88$

$v_{oc} = v_A - 1V = 8.8V$

i_{SC}



$v_B = 1V$

KCL in B

$$\begin{cases} \dfrac{v_B + 2v_x - 6.25V}{2.53\Omega} + \dfrac{v_B + 2V}{3} + i_{SC} = 0 \\ -v_x = \dfrac{v_B + 2\Omega}{3\Omega} \cdot 2 = 2V \end{cases}$$

$i_{SC} = 2.66A$

$R_{TH} = \dfrac{V_{OC}}{i_{SC}} = \dfrac{8.8}{2.66} = 3.3$