Name: ____________SOLUTION_________ (please print)

Signature: _____________________________

ECE 2201 – Final Exam
May 2, 2019

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 160 minutes to work on this exam.

1. ________________/35

2. ________________/30

3. ________________/35

4. ________________/30

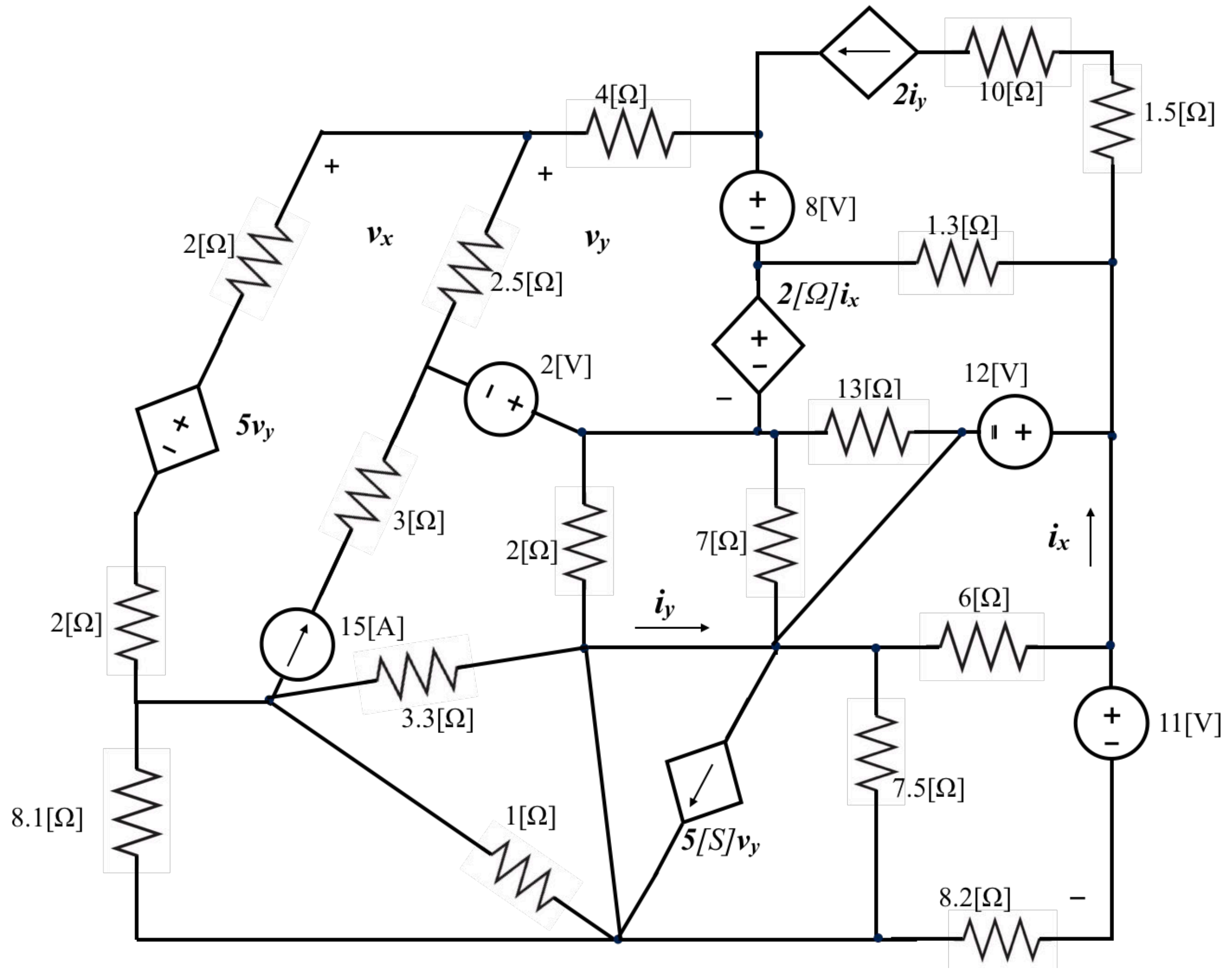
5. ________________/35

6. ________________/35

Total = 200

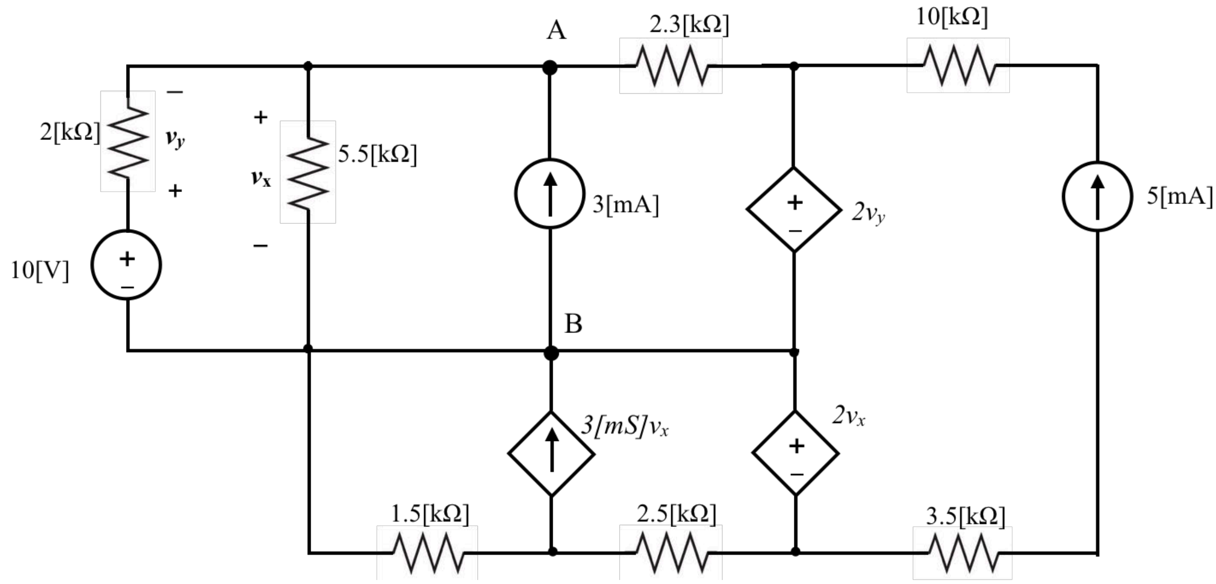
Room for extra work

1. {35 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

2. {30 Points} Use the circuit shown below to solve.
a) Find and draw the Norton equivalent seen by the independent current source 3[mA].
b) Find the power delivered by the independent current source 3[mA].
c) Which way (direction) electrons are moving when crossing the terminal A?



Room for extra work

3. {35 Points} A device shown in Figure 1 can be modeled as a voltage source in series with a resistance. The relationship between the voltage across the device and the current through the device is shown in Figure 1. This device is connected to the circuit as shown in Figure 2.
Power delivered by the independent current source 1[mA] is measured as 7.5 [mW].
a) Find the model of this device operating in the circuit below (Figure 2), and draw it, showing terminals **A** and **B**.
b) Find the coefficient **k** in the dependent voltage source $\boldsymbol{kv_x}$.
c) Are the electrons losing or gaining energy while moving through the dependent voltage source $\boldsymbol{kv_x}$? Briefly explain your answer.

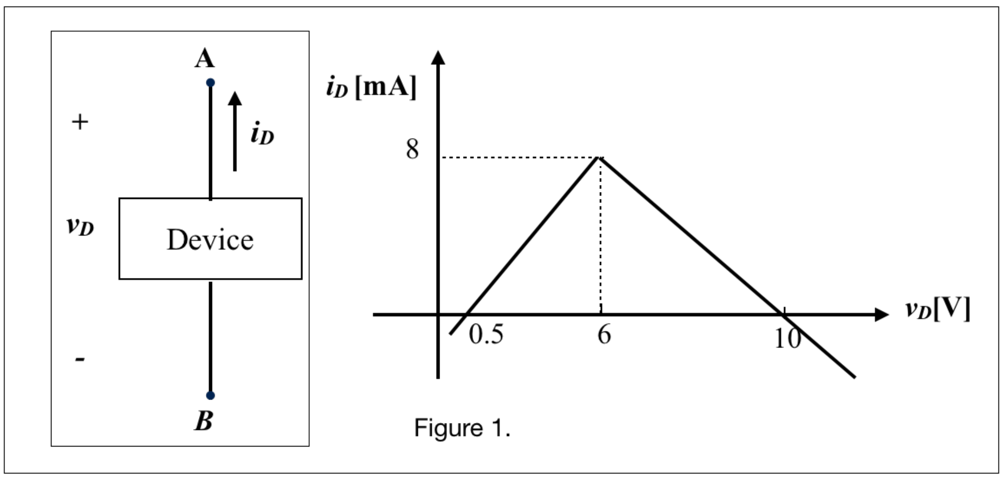


Figure 1.

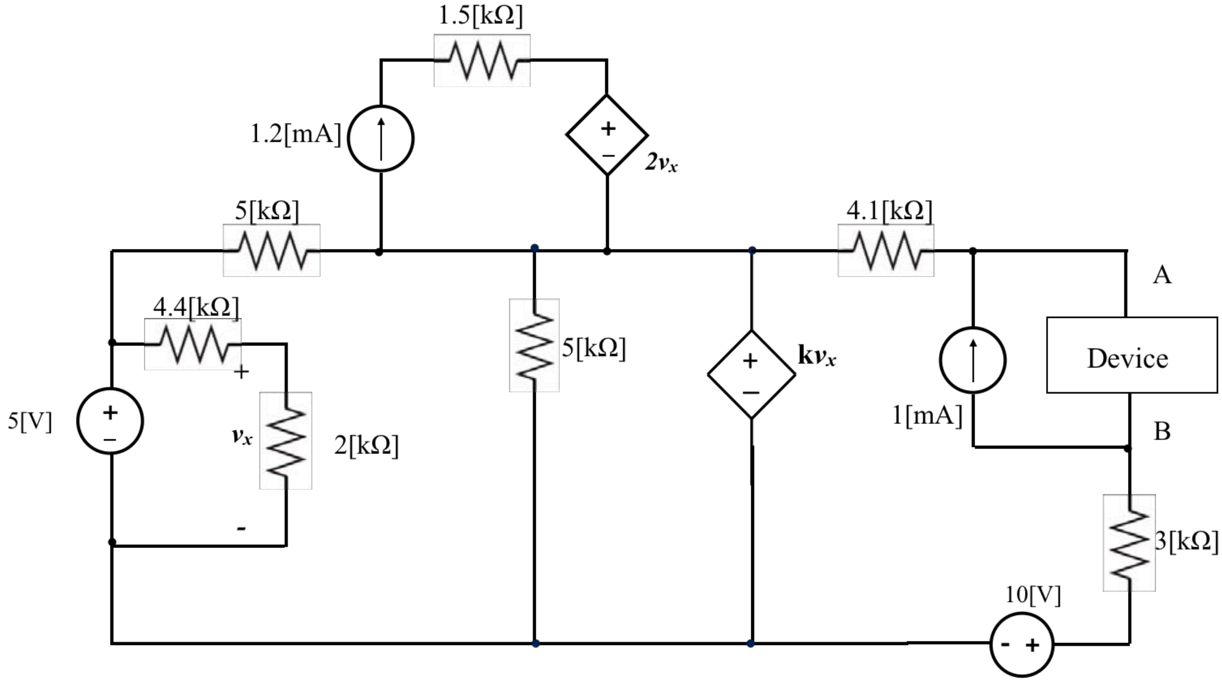
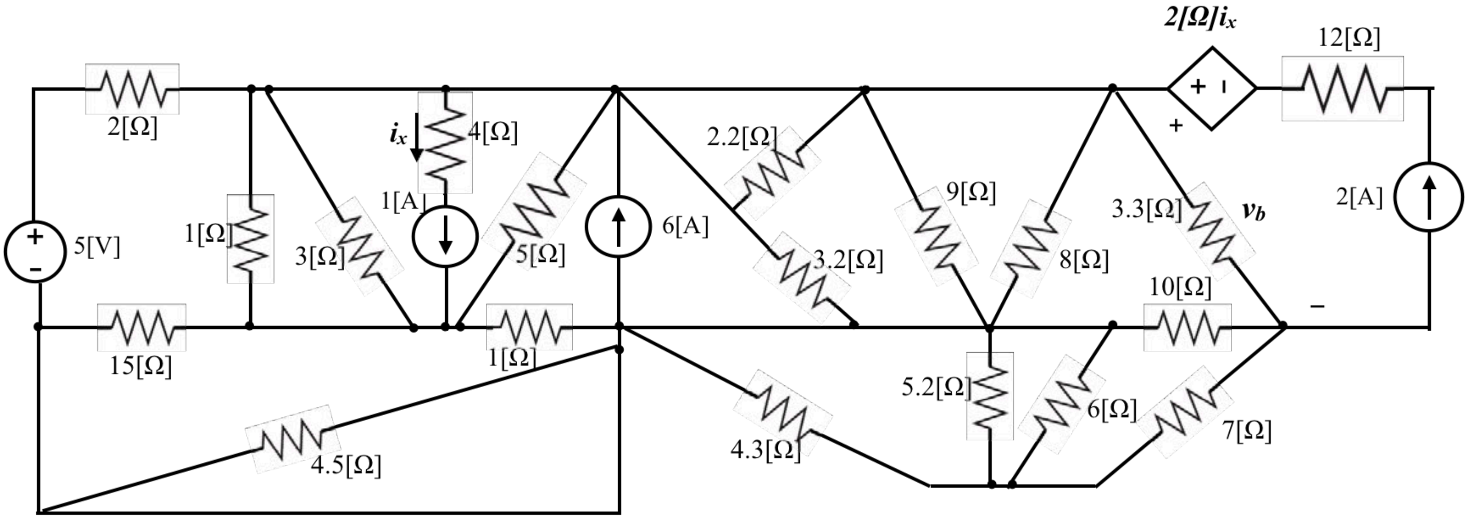


Figure 2.

Room for extra work

4. {30 Points} **Do not** use the Node-Voltage Method or Mesh-Current Method to solve this problem.

a) Simplify the following circuit and find v_b.

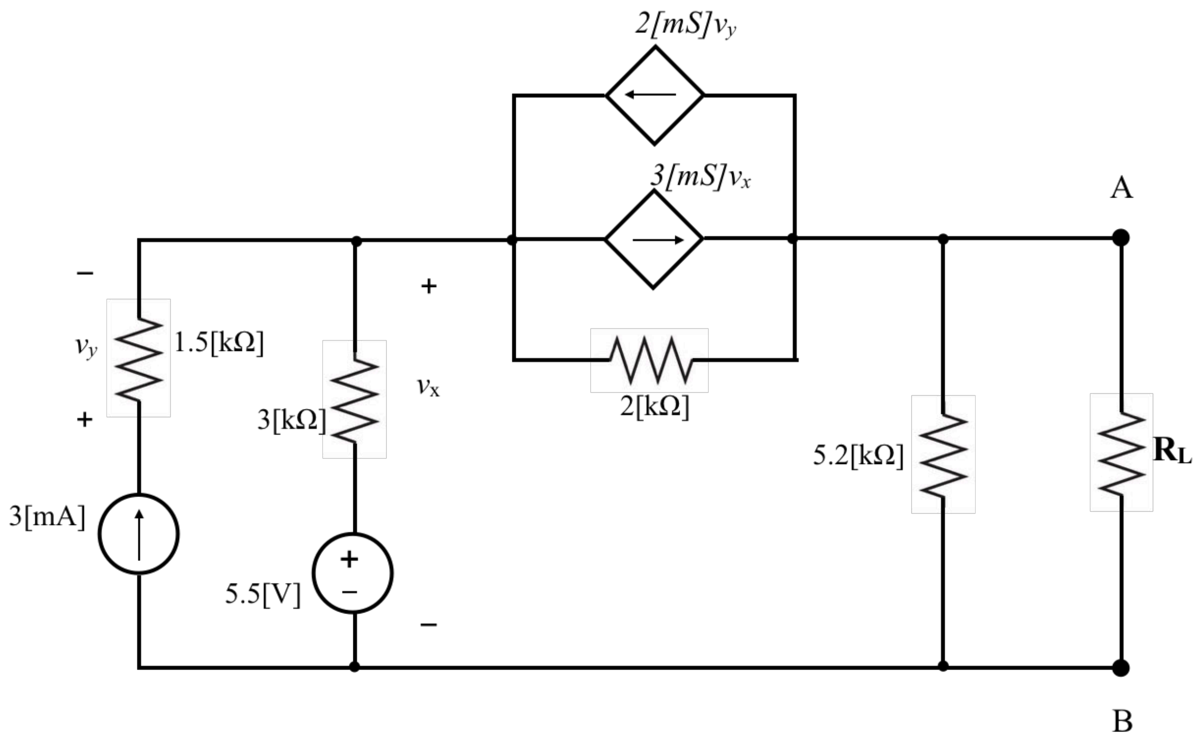


Room for extra work

5. {35 Points} In the following circuit, we will connect a load resistor R_L that will ensure maximum power delivered to this load R_L.

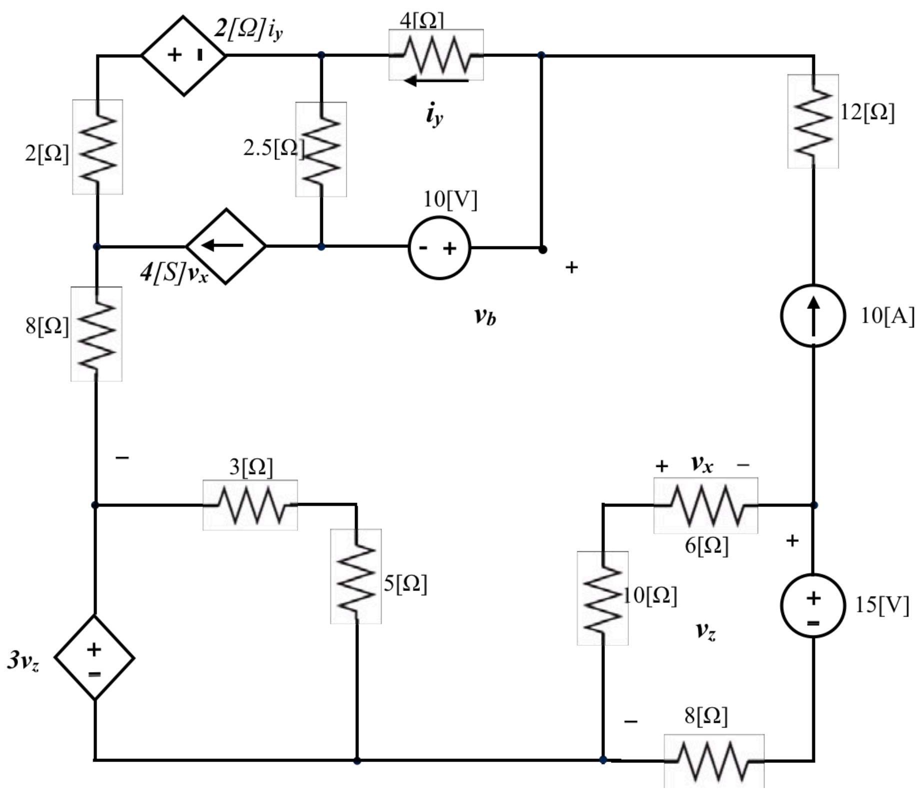
a) Find the value of R_L for this maximized power delivery.

b) Find the Thevenin equivalent seen by R_L and draw it showing terminals A and B.



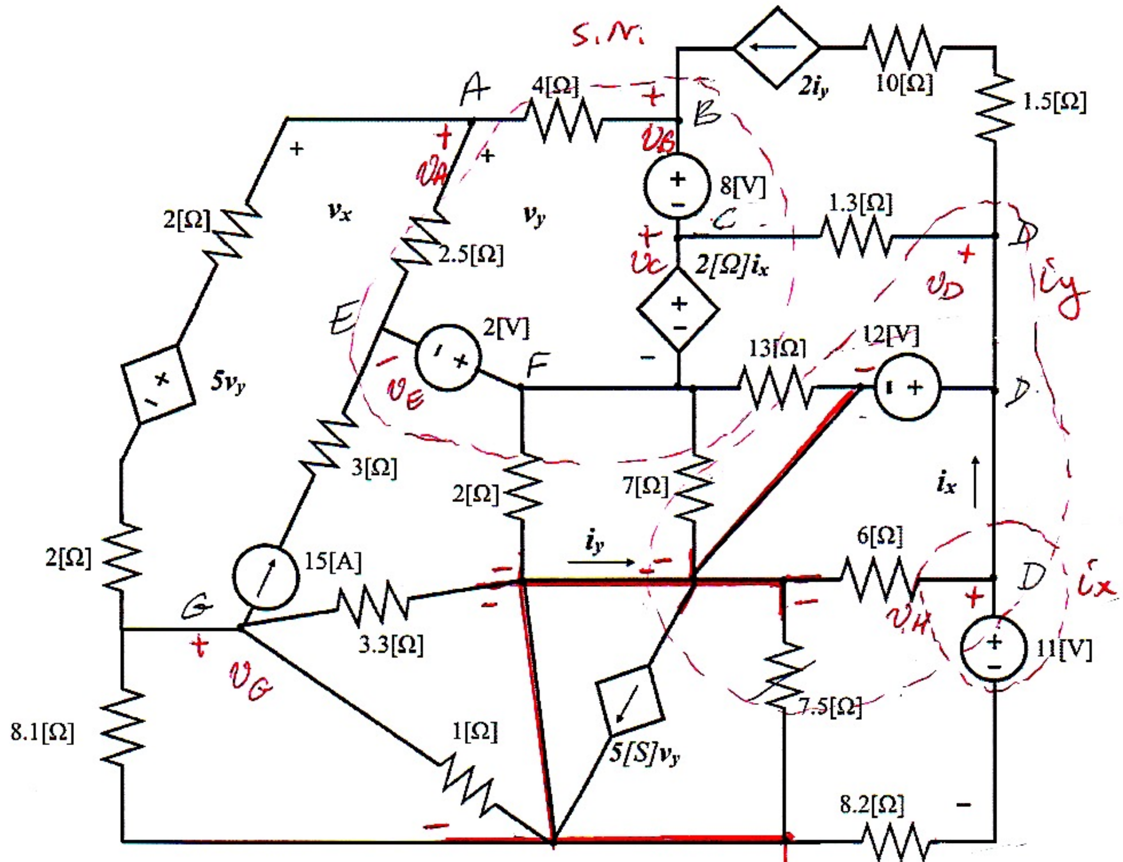
Room for extra work

6. {35 Points} Use the circuit shown below to solve this problem.
   a) Use the superposition principle to find the voltage v_b.



Room for extra work

1. {35 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.**



7 node voltage eqs. } 11 eqs.
4 auxiliary eqs.

(A) $$\frac{v_A - 5v_y - v_G}{4[\Omega]} + \frac{v_A - v_E}{2.5[\Omega]} + \frac{v_A - v_B}{4[\Omega]} = 0$$

(S.N. B+C+E) $$-2i_y + \frac{v_B - v_A}{4[\Omega]} + \frac{v_E - v_A}{2.5[\Omega]} - 15[A] + \frac{v_F}{2[\Omega]} + \frac{v_F}{7[\Omega]} + \frac{v_F}{13[\Omega]} + \frac{v_C - v_D}{1.3[\Omega]} = 0$$

(B+C) $$v_B - v_C = 8[V]$$

(C+F) $$v_C - v_F = 2i_x$$

(F+E) $$v_F - v_E = 2[V]$$

(D) $$v_D = 12[V]$$

Room for extra work

(G) $$\frac{v_G + 5v_y - v_A}{4[\Omega]} + 15[A] + \frac{v_G}{8.1[\Omega]} + \frac{v_G}{1[\Omega]} + \frac{v_G}{3.3[\Omega]} = 0$$

(i_x) $$i_x + \frac{v_D}{6[\Omega]} + \frac{v_D - 11[V]}{8.2[\Omega]} = 0$$

(i_y) $$-i_y + 5[S]v_y + \frac{v_D - 11[V]}{8.2[\Omega]} + 2i_y + \frac{v_D - v_C}{1.3[\Omega]} - \frac{v_F}{13[\Omega]} - \frac{v_F}{7[\Omega]} = 0$$

(v_y) $$v_y + 2[V] + v_E - v_A = 0$$

(v_x) $$v_x = v_A - v_D - 11[V]$$

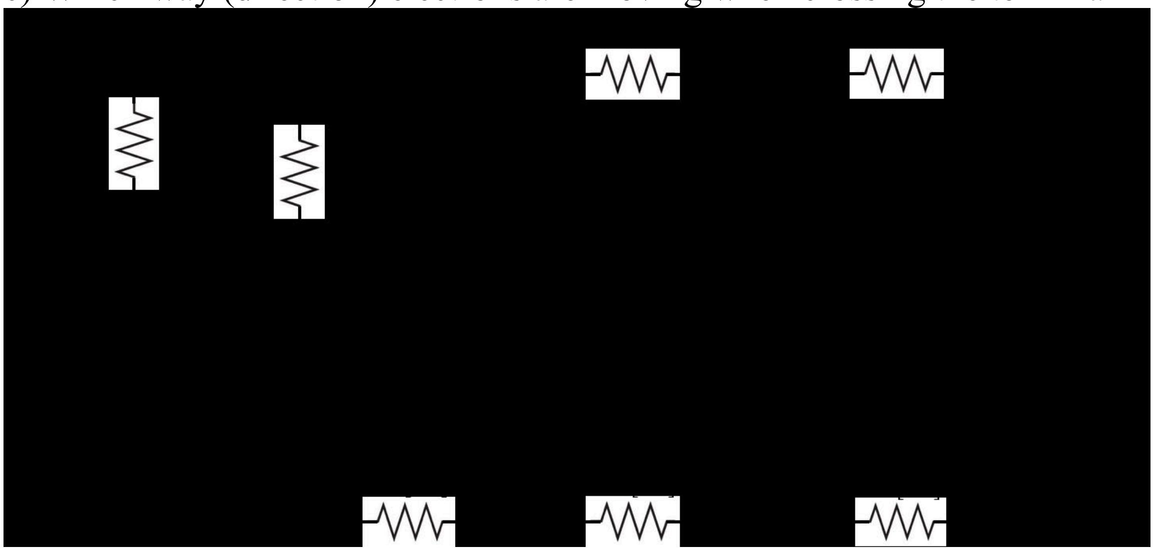
Not needed (no dependent source w/ v_x)

2. {30 Points} Use the circuit shown below to solve.

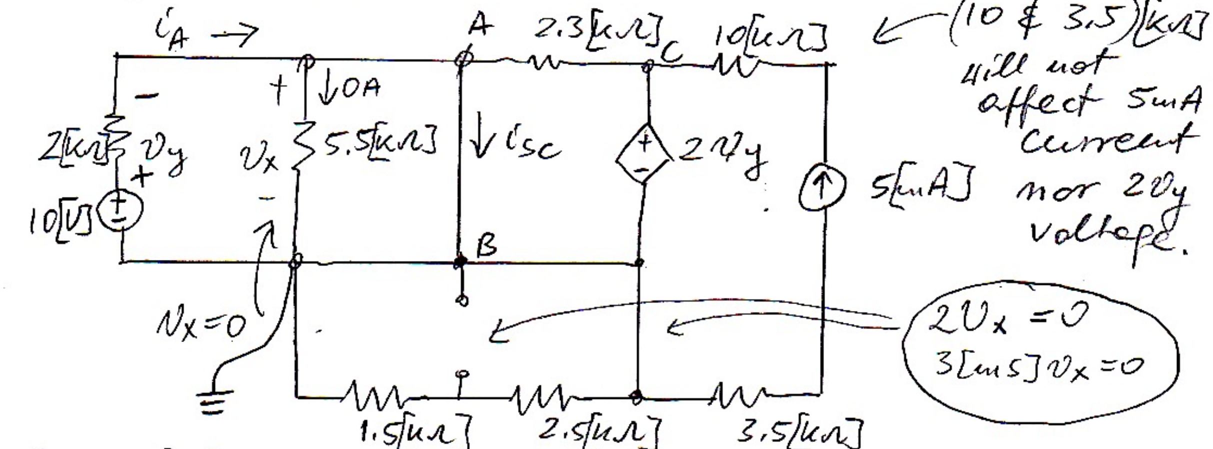
a) Find and draw the Norton equivalent seen by the independent current source 3[mA].

b) Find the power delivered by the independent current source 3[mA].

c) Which way (direction) electrons are moving when crossing the terminal A?



Disconnect 3[mA] source and short A & B. to find i_{sc}.



$v_y = 10[V]$

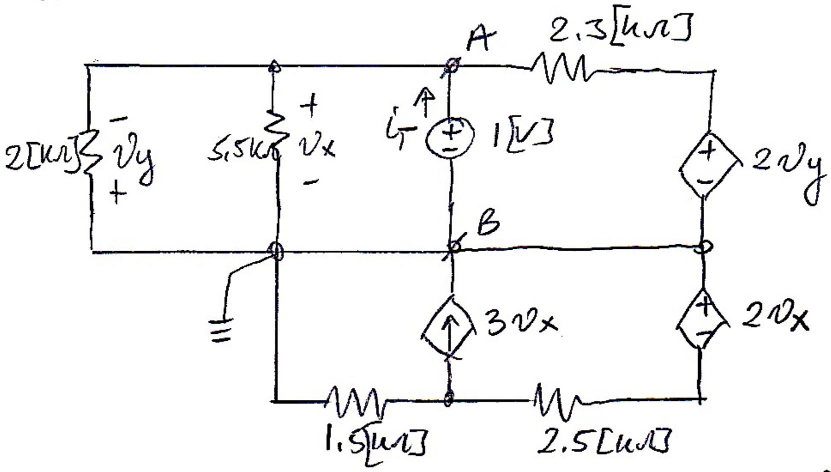
$v_C = 2v_y = 20[V]$; $i_A = \frac{10[V]}{2[k\Omega]} = 5[mA]$

(KCL) @ A $\quad -i_A + i_{sc} - \frac{20[V]}{2.3[k\Omega]} = 0 \rightarrow i_{sc} = 13.7[mA]$

Room for extra work

Find R_{TH}

Deactivate independent sources & connect a test source.



$v_x = 1[V]$

$v_y = -1[V]$

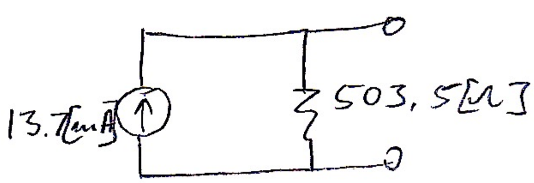
$v_A = 1[V]$

KCL @ A $\quad -i_T + \frac{v_A}{5.5[k\Omega]} + \frac{v_A}{2[k\Omega]} + \frac{v_A - 2v_y}{2.3[k\Omega]} = 0$

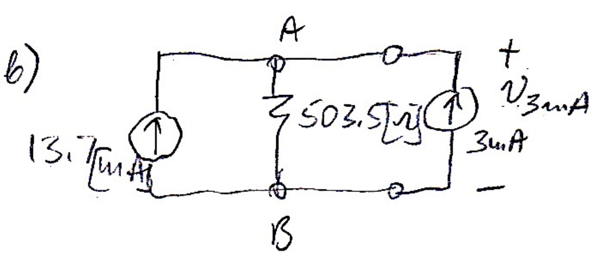
$i_T = 1.986[mA]$

$R_{TH} = 0.5035[k\Omega] = 503.5[\Omega]$

Norton equivalent



b)



$v_{3[mA]} = 503.5 \cdot (3 + 13.7) =$

$= -8\,408[V]$

$P_{del,3mA} = v_{3mA} \cdot 3[mA] =$

$= 25.23[mW]$

So power is delivered

c) Electrons move down when passing terminal (A)

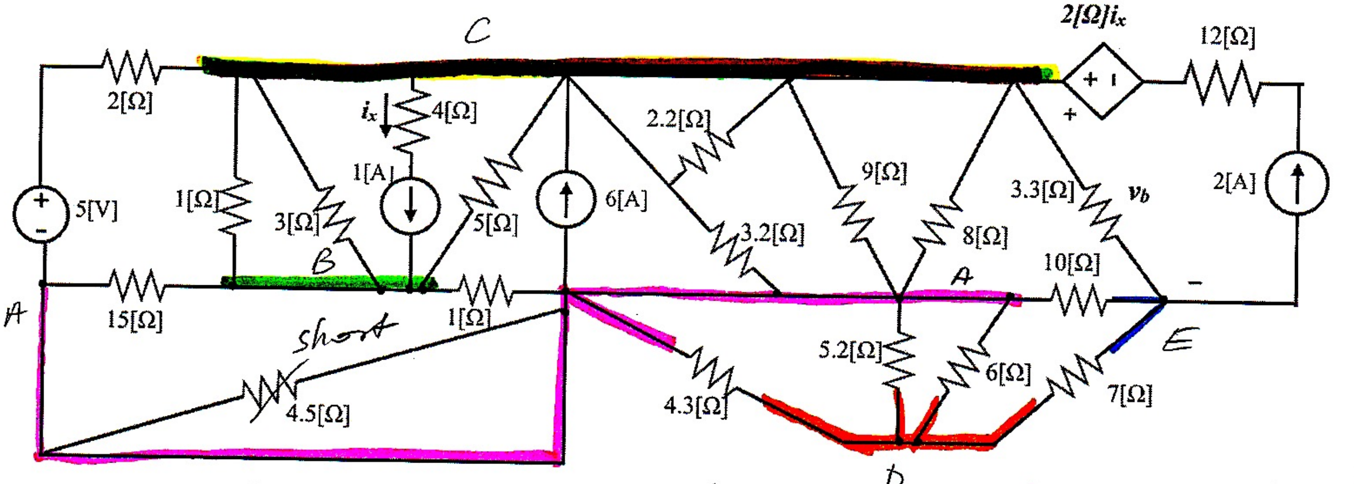
Problem 3 solved at end of document.

[redacted]

[redacted]

4. {30 Points} **Do not** use the Node-Voltage Method or Mesh-Current Method to solve this problem.

a) Simplify the following circuit and find v_b.



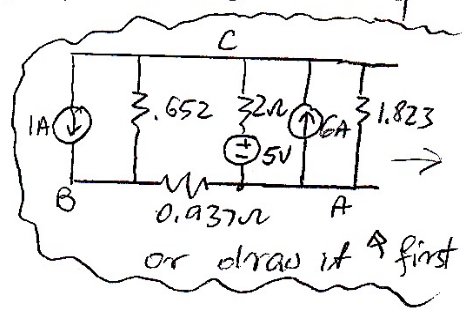
$i_x = 1$ A   4[Ω] removed since it is in series with ⊕ source transformation

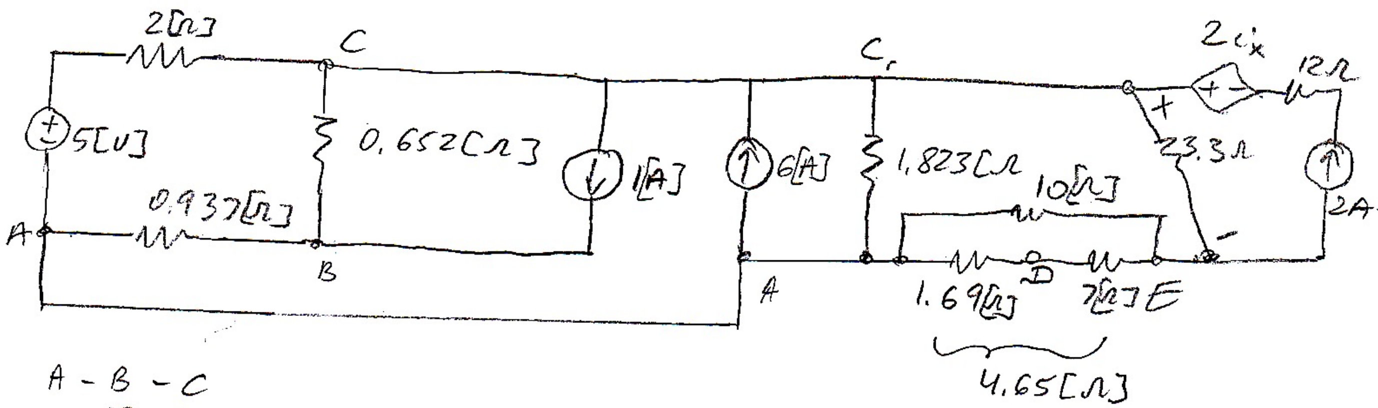
AB   15[Ω] || 1[Ω] = 0.937[Ω]

CB   1[Ω] || 3[Ω] || 5[Ω] = 0.652 [Ω]

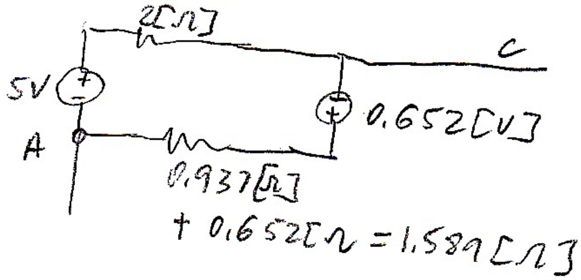
AC   3.2[Ω] || 9[Ω] || 8[Ω] = 1.823 [Ω]

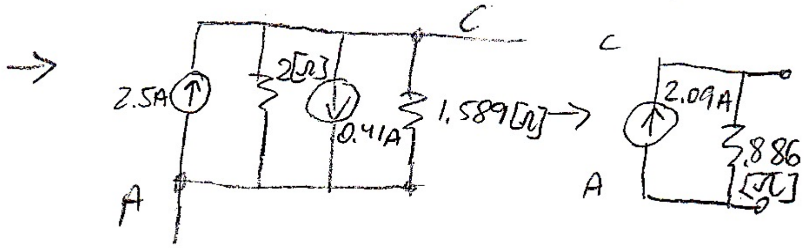
AD   4.3[Ω] || 5.2[Ω] || 6[Ω] = 1.69 [Ω]



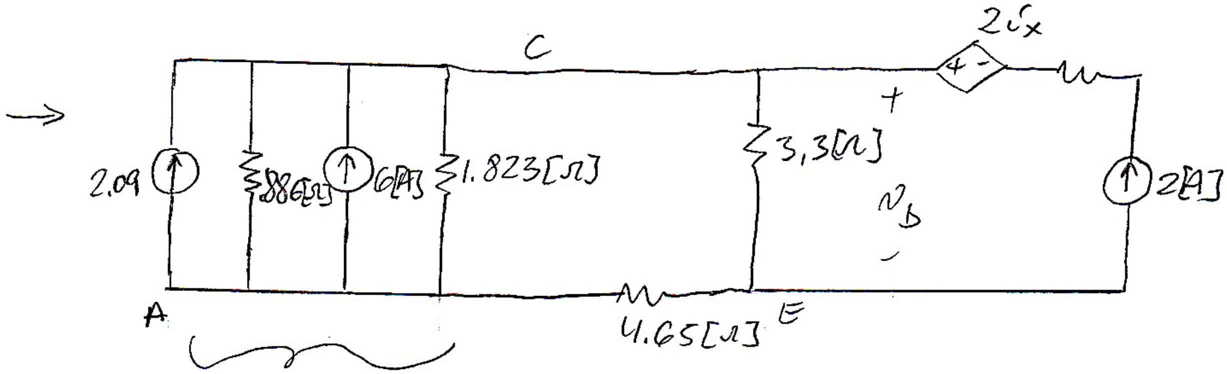


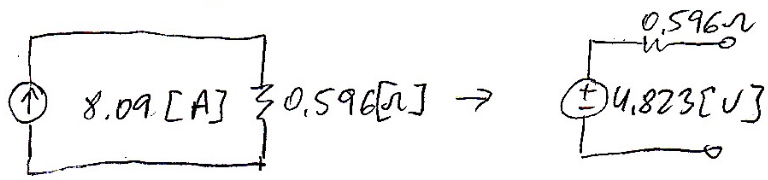
A - B - C

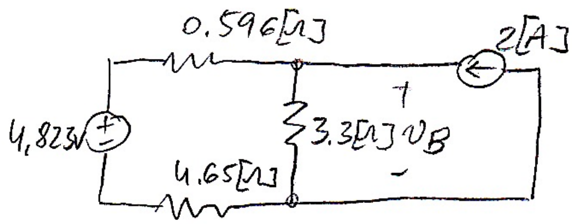




Room for extra work







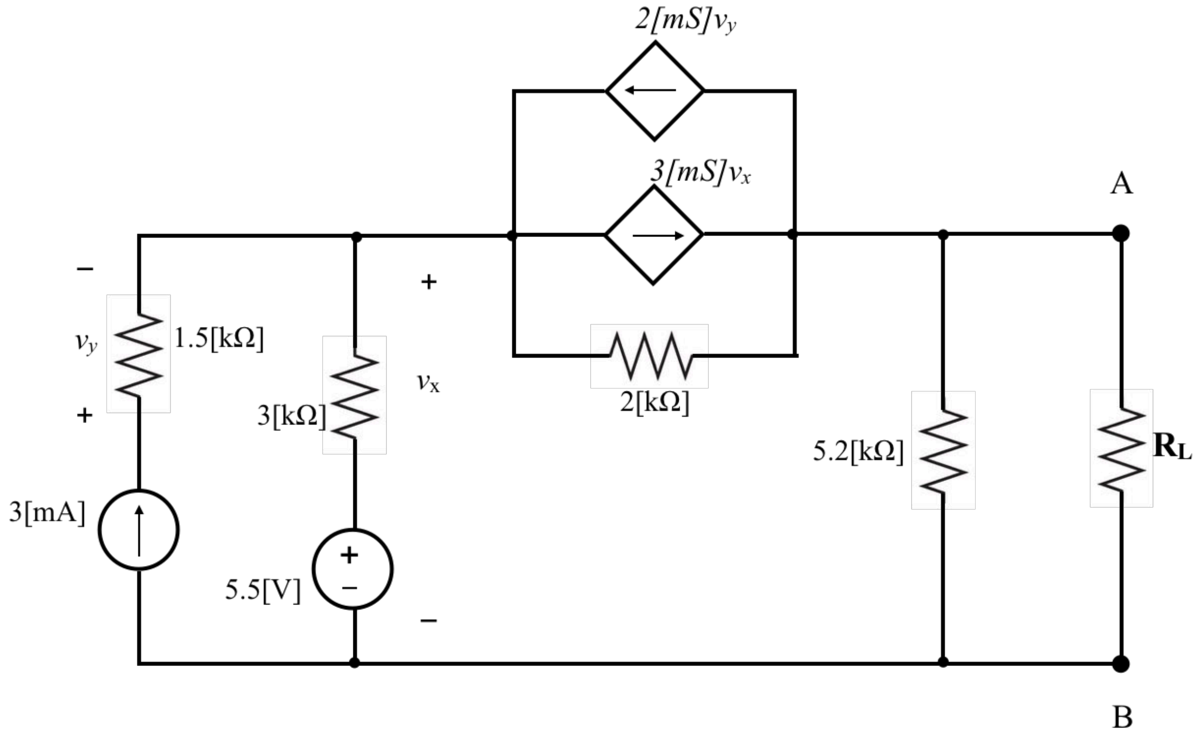
$$\frac{v_B}{3.3[\Omega]} + \frac{v_B - 4.823\ [V]}{(0.596 + 4.65)[\Omega]} - 2\ [A] = 0$$

$$v_B = 5.914[V]$$

5. {35 Points} In the following circuit, we will connect a load resistor R_L that will ensure maximum power delivered to this load R_L.

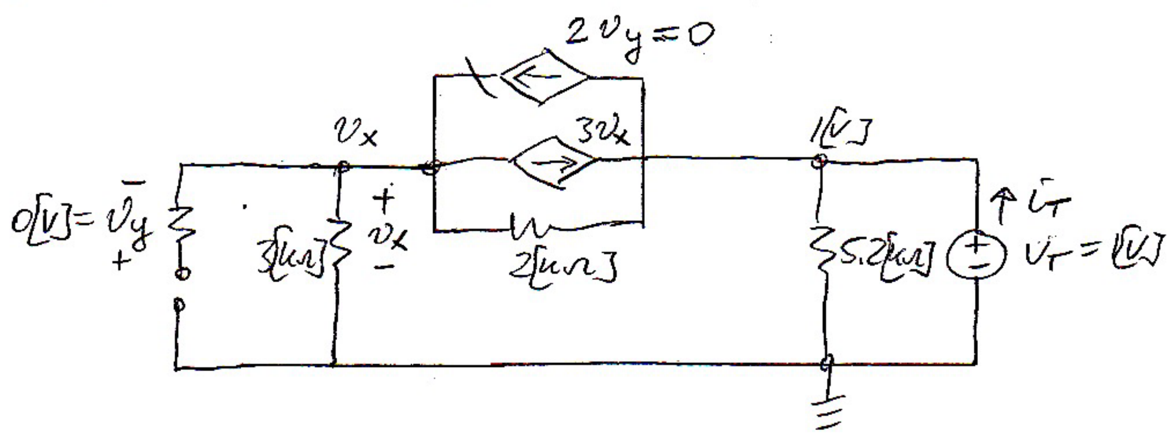
a) Find the value of R_L for this maximized power delivery.

b) Find the Thevenin equivalent seen by R_L and draw it showing terminals A and B.



a) - Disconnect R_L and find R_{TH} seen @ A & B terminals.

- Deactivate independent sources & connect a test source @ A & B.



Room for extra work

KCL @ v_x $\quad \dfrac{v_x}{3[k\Omega]} + 3[mS]\,v_x + \dfrac{v_x - 1[V]}{2[k\Omega]} = 0$

$\downarrow$

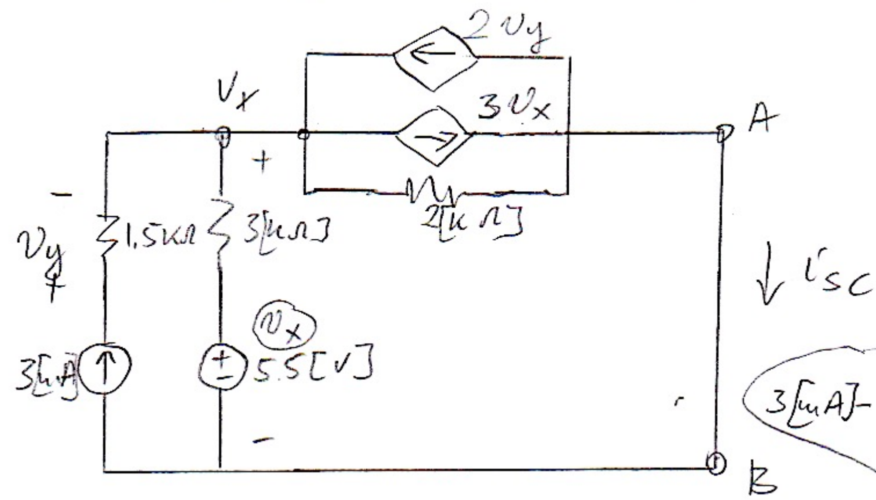
$v_x = 0.13\,[V]$

KCL @ v_T $\quad i_T - \dfrac{1[V]}{5.2[k\Omega]} - \dfrac{v_x}{3[k\Omega]} = 0$

$i_T = 0.236\,[mA]$

$R_{TH} = \dfrac{1[V]}{0.236[mA]} = 4.241\,[k\Omega]$

b) Remove R_L and short A & B to find i_{SC}.



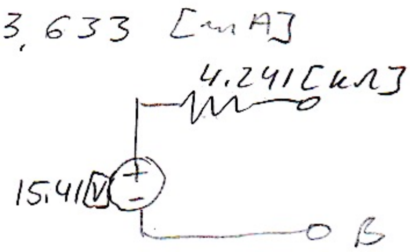
$3[mA] - i_{SC} - \dfrac{(v_1 - 5.5[V])}{3[k\Omega]} = 0$

$3[mA] \rightarrow \quad v_y = 3 \cdot 1.5 = 4.5\,[V]$

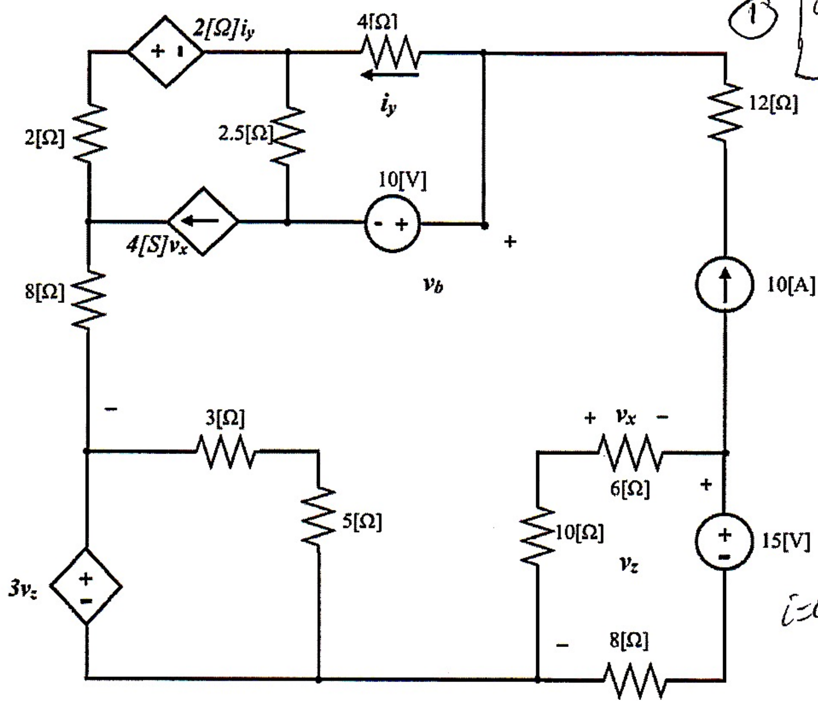
$-3[A] + \dfrac{v_x - 5.5[V]}{3[k\Omega]} - 2[mS]\cdot 4.5[V] + 3\,v_x + \dfrac{v_x}{2[k\Omega]} = 0$

$v_x = 3.6\,[V] \rightarrow i_{SC} = 3.633\,[mA]$

$v_{TH} = i_{SC} \cdot R_{TH} = 15.41\,[V]$



6. {35 Points} Use the circuit shown below to solve this problem.
   b) Use the superposition principle to find the voltage v_b.



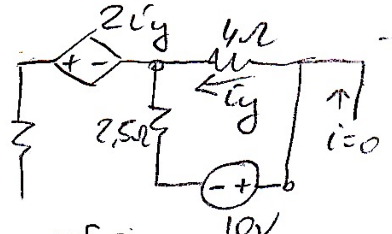
① v_b when 10[V] is active

10[A] → 0[A] open circuit

15[V] → 0[V] short circuit

$v_x = 0[V]$

$4[S]v_x$ → open circuit



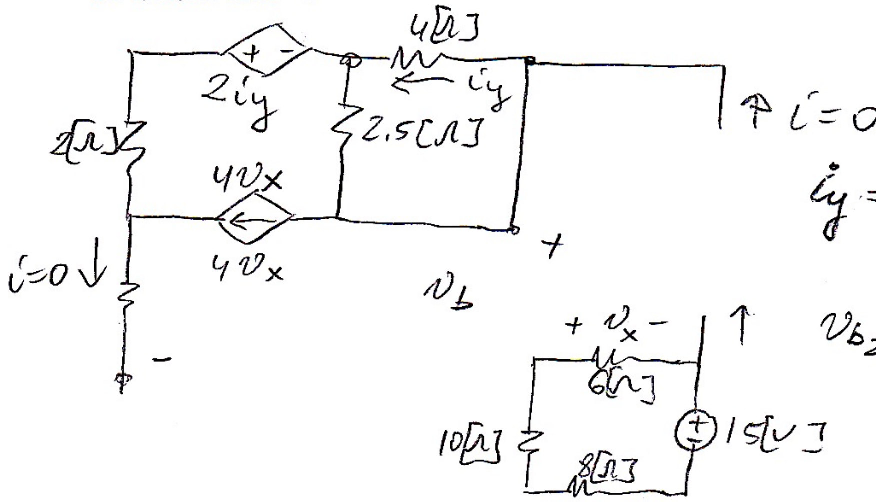
$$i_y = \frac{10[V]}{(2.5+4)[\Omega]} = 1.538[A]$$

$$v_{b_1} = 10[V] - 2.5[\Omega]\cdot 1.538[A] - 2\cdot 1.538 = 3.079[V]$$

10[V] OFF → shorted

10[A] OFF → open circuit

② 15[V] ON



$$v_x = -\frac{15[V]\cdot 6[\Omega]}{(6+10+8)[\Omega]} = -3.75[V]$$

$4v_x = -15[A]$

$$i_y = -4v_x \cdot \frac{2.5\,||\,4}{6.5}\cdot\frac{1}{4} = +5.769[A]$$

$$v_{b_2} = 4[\Omega]\cdot(+5.769[A]) - 2(+5.769) + 2[\Omega]4v_x = 41.54[V]$$

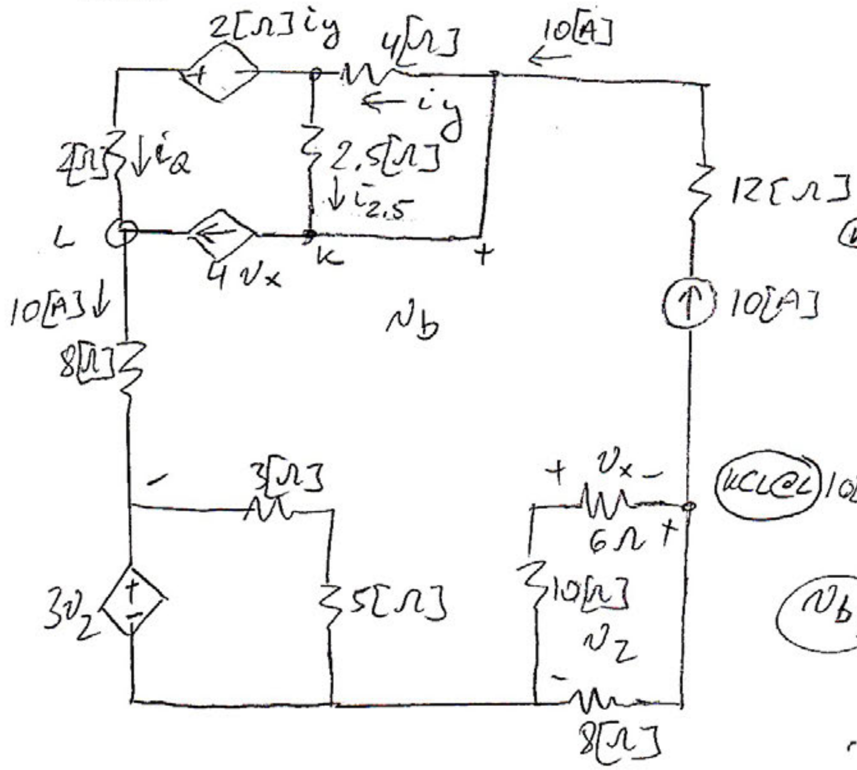
Room for extra work

(3) 10[A] ON

10[V] OFF (shorted)

15[V] OFF (shorted)

Redraw



$v_x = 10[A] \cdot \frac{(10+6)\cdot 8}{10+6+8} \cdot \frac{1}{10+6} \times 6[\Omega] = 20[V]$

KCL @ k

$-10[A] + i_y - i_{2.5} + 4v_x = 0$

$i_{2.5} \cdot 2.5[\Omega] = -i_y \, 4[\Omega]$

$i_y = -26.92[A]$

$i_{2.5\Omega} = -43.08[A]$

KCL@L $10[A] - 4v_x - i_Q = 0$

$i_Q = 10 - 80 = -70[A]$

$v_{b_3} = 43.08 \cdot 2.5 + 2 \cdot 26.92 + -2 \cdot 70 + 10[A] \cdot 8[\Omega] = -193.8\ [V]$

$v_b = v_{b_1} + v_{b_2} + v_{b_3} = -149.2\ [V]$

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

Power delivered by the independent current source 1[mA] is measured as 7.5 [mW].

a) Find the model of this device operating in the circuit below (Figure 2), and draw it, showing terminals **A** and **B**.

b) Find the coefficient **k** in the dependent voltage source kv_x.

c) Are the electrons losing or gaining energy while moving through the dependent voltage source kv_x? Briefly explain your answer.

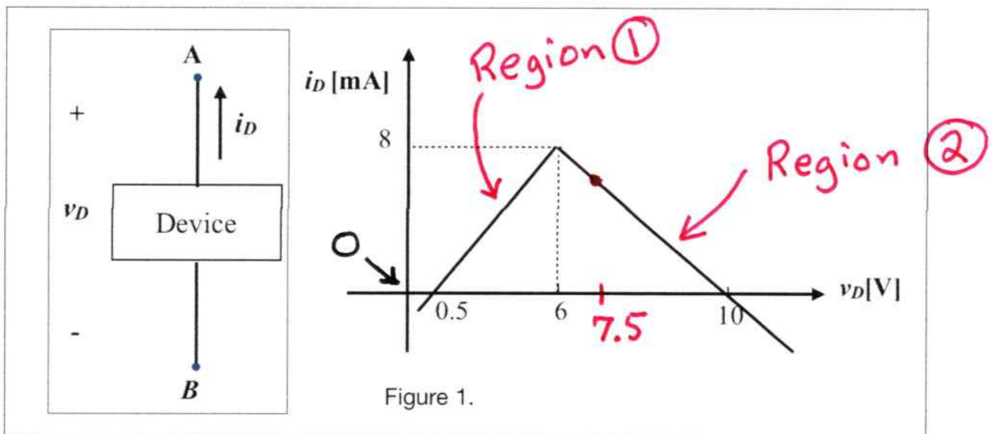


Figure 1.

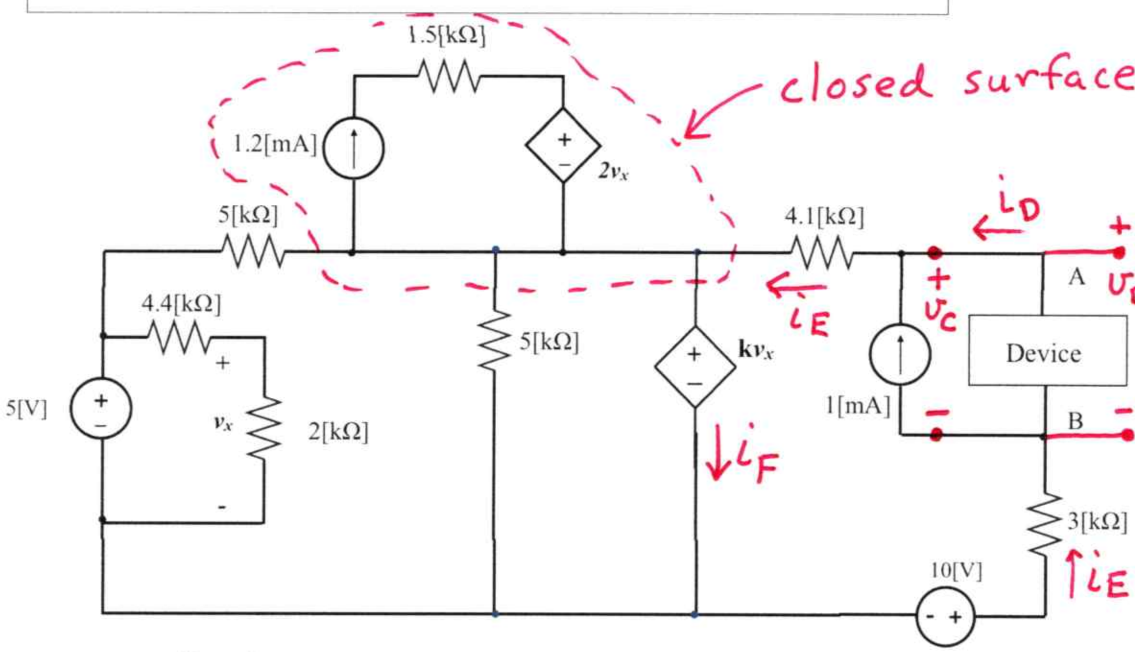


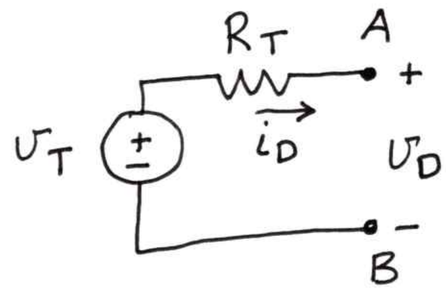
Figure 2.

We are given that $p_{DEL.BY.1[mA]} = 7.5[mW] = v_C \, 1[mA]$,

so, $v_C = 7.5[V] = v_D$ in Figure 2. See next page

Problem 3. continued | part a)

The device has two regions with different behaviors. We have labeled these as Region ① and Region ② in Figure 1. When the device is in Figure 2, it must be in Region ② since $v_D = 7.5\{V\}$. We know that the device can be modeled with a voltage source in series with a resistance, so we can draw it as



We can write KVL as

$$v_D - v_T + i_D R_T = 0$$

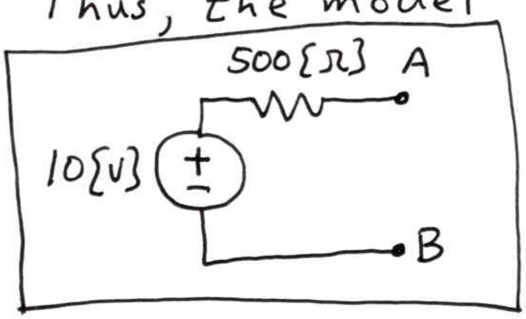
Plugging into 2 sets of values, we get 2 equations.

$$10\{V\} - v_T + 0\,R_T = 0 \quad (1)$$

$$6\{V\} - v_T + 8[mA]\,R_T = 0 \quad (2)$$

solving, we get $v_T = 10\{V\}$ and $R_T = 500\{\Omega\}$

Thus, the model for the device is



See next page

Problem 3. continued | Part b)

We can use VDR to write

$$v_X = 5\{V\}\left(\frac{2\{k\Omega\}}{2\{k\Omega\}+4.4\{k\Omega\}}\right)$$ [redacted]

$$v_X = 1.5625\{V\}$$

Next, we recall an equation for the device from part a),

$$v_D - v_T + i_D R_T = 0 \quad \text{or}$$

$$v_D - 10\{V\} + i_D(500\{\Omega\}) = 0.$$

Since for this problem, we know $v_D = 7.5\{V\}$,

$$7.5\{V\} - 10\{V\} + i_D(500\{\Omega\}) = 0 \quad \text{or}$$

$$i_D = 5.0\{mA\}$$

KCL in Figure 2 gives

$$i_E = (1.0 + 5.0)\{mA\} = 6.0\{mA\}.$$

Then, KVL in Figure 2 yields

$$-k(1.5625\{V\}) - 6.0\{mA\}(7.1\{k\Omega\}) + 7.5\{V\} + 10\{V\} = 0$$

Solving, we get

$$\boxed{k = -16.06}$$

See next page

Problem 3. continued | part c)

$$k v_X = -25.1\{V\}$$

Then, writing KCL for the closed surface in Figure 2, we have

$$-6.0\{mA\} + i_F + \frac{(-25.1\{V\})}{5\{k\Omega\}} + \frac{(-25.1\{V\} - 5\{V\})}{5\{k\Omega\}} = 0$$

which gives

$$i_F = 17.04\{mA\}$$

$$p_{ABS.BY.kv_X} = (k v_X) i_F = -427.7\{mW\}$$

which means the $k v_X$ voltage source is delivering positive power. Therefore, the charge carriers, in this case electrons, must be **gaining energy** while moving through the dependent voltage source.