Name: ______________________________ (please print)

Signature: ___________________________

ECE 2201 – Final Exam
December 4, 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).
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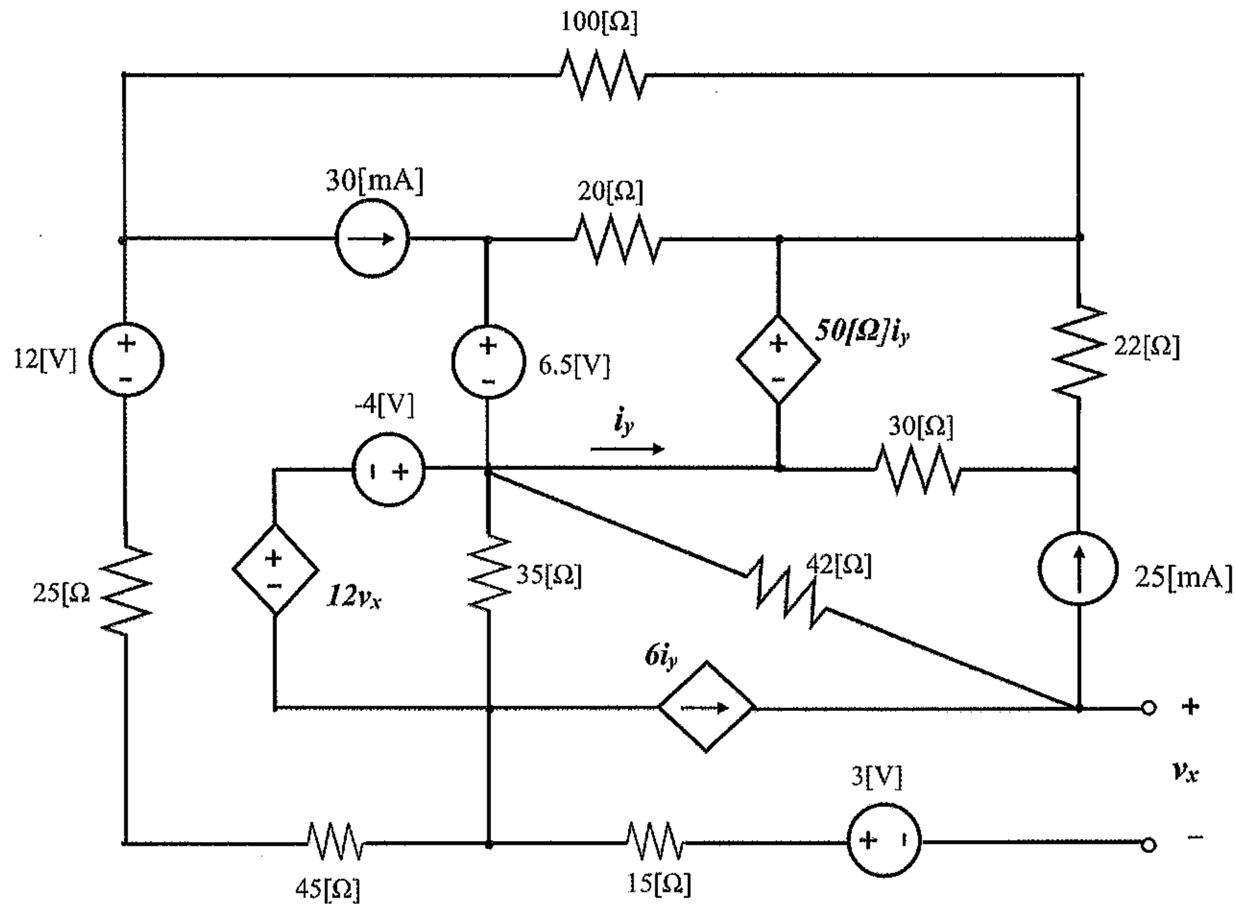
4. Show all units in solutions, intermediate results, and figures.
5. Do not use red ink. Do not use red pencil.
6. You will have 160 minutes to work on this exam.

1. ________________/35
2. ________________/25
3. ________________/40
4. ________________/33
5. ________________/35
6. ________________/32

Total = 200

Room for extra work

1. {35 Points} Use the **Node Voltage Method** to write a set of equations that could be used to solve the circuit below. Do not simplify the circuit, and do not attempt to solve the equations.

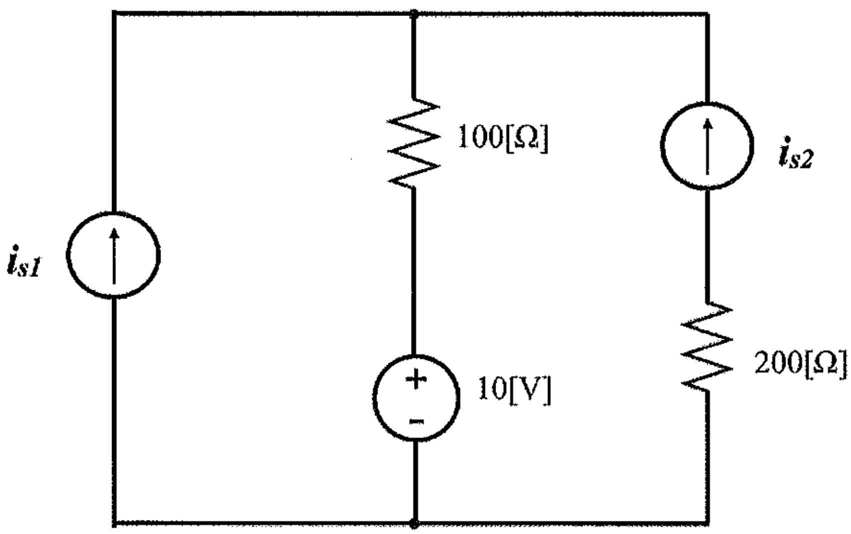


Room for extra work

2. {25 Points} In the circuit below, the current sources provide the following currents for t ≥ 0. For t < 0, $i_{S1} = i_{S2} = 0$.

$$i_{S1}(t) = 30[mA]e^{-2\left[\frac{1}{ks}\right]t} \qquad i_{S2}(t) = 50[mA]e^{-2\left[\frac{1}{ks}\right]t}$$

Find the energy delivered by the source i_{S1} in the time interval 0 to 0.1 [ks].

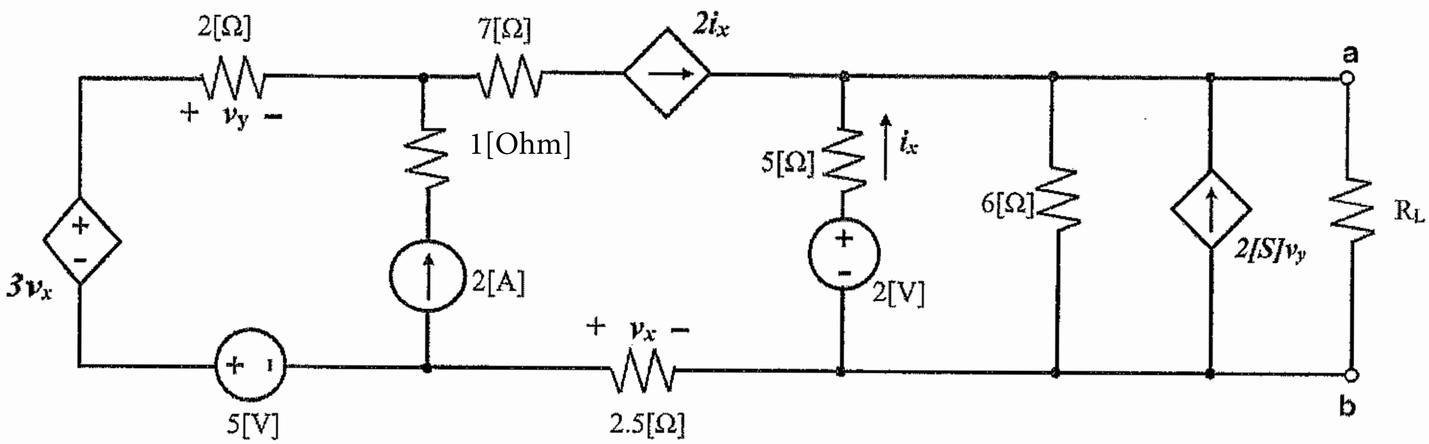


Room for extra work

Problem 3 is only shown in the solutions section, below.

Room for extra work

4. {33 Points} Use the circuit shown below to:
   a. Find the Thevenin equivalent at terminals a, b. Draw your Thevenin equivalent, labeling terminals a, b.
   b. Find the Norton equivalent at terminals a, b. Draw your Norton equivalent, labeling terminals a, b.
   c. Find the load resistance R_L that absorbs maximum power from the circuit.



Room for extra work

5. {35 Points} In the circuit shown below (Figure 1) Device D is connected at terminals A and B. The Thevenin equivalent seen by this device is given in Figure 2. Information about the device include:

The device can be modeled as a voltage source connected in series with a resistor

It absorbs power of 28 [W] if connected to a current source of 2 [A] (Figure 3).

It delivers power of 27 [W] to 3 [Ω] resistor (Figure 4).

a. Find the device model and draw it, labeling terminals A, B.

b. Calculate the value of resistor R in the circuit.

c. Find the power delivered to this device by the circuit.

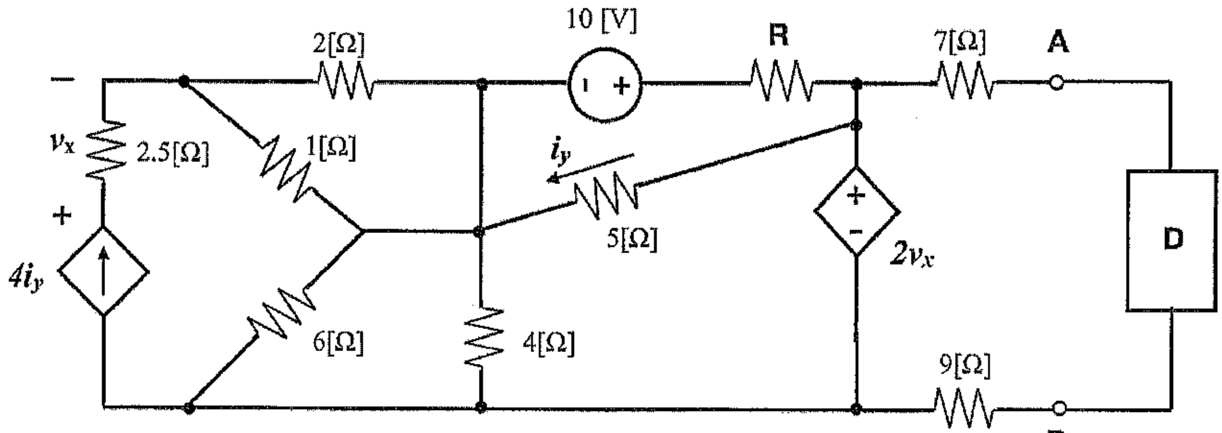


Figure 1.

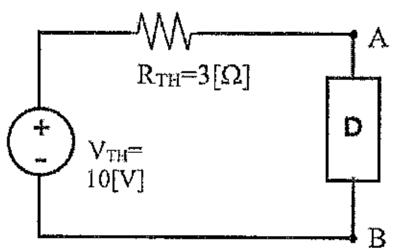


Figure 2.

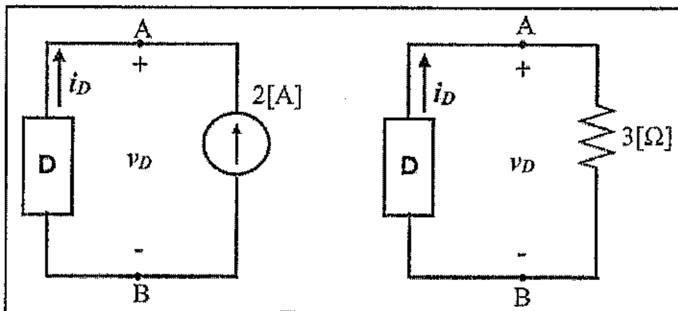
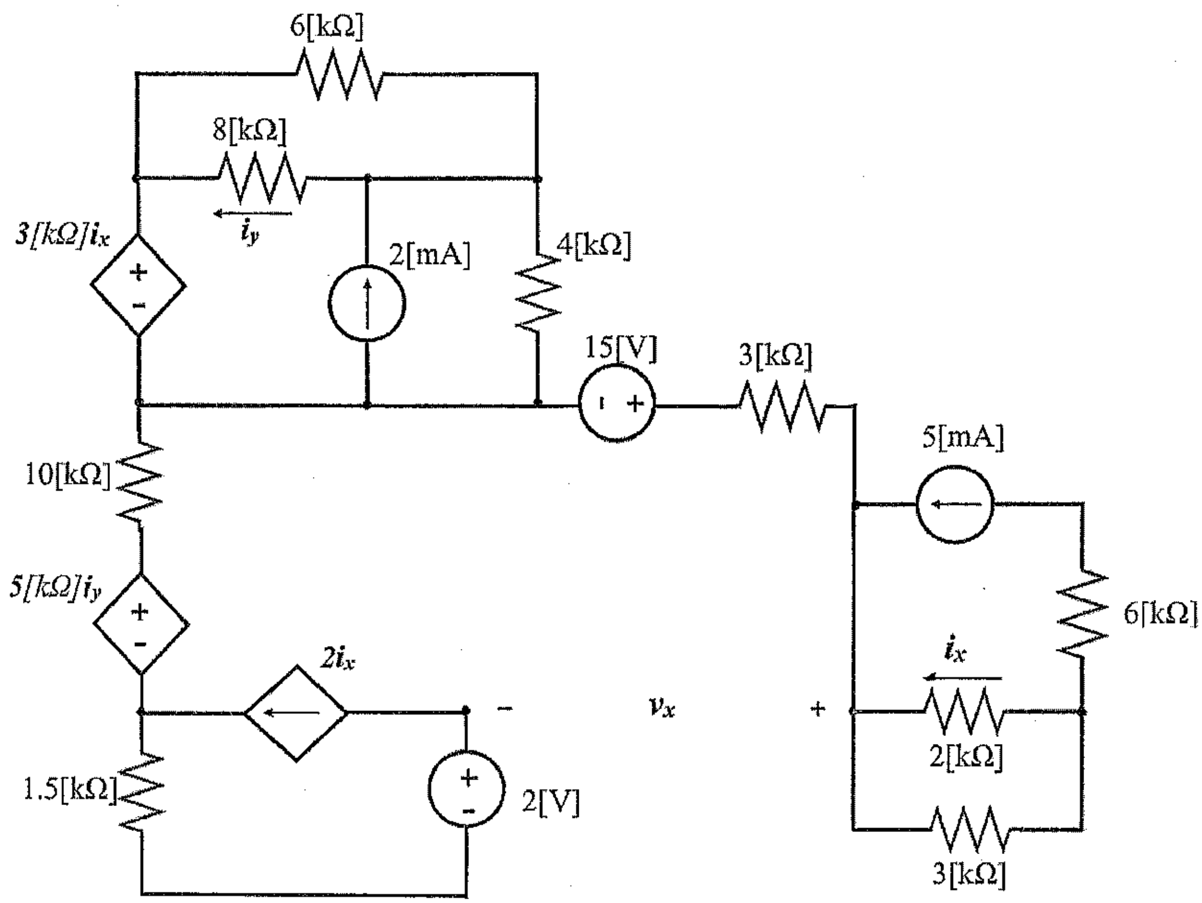


Figure 3.

Room for extra work

6. {32 Points} For the circuit shown below use superposition principle to find the voltage v_x.



Room for extra work

Name: ___SOLUTION____________________ (please print)

Signature: ____________________________

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1. ________________/35

2. ________________/25

3. ________________/40

4. ________________/

5. ________________/

6. ________________/

Total = 200

[redacted]

3. {40 Points} Device D can be modeled by a current source in parallel with a resistor. When the device is connected to a 10 [V] source, the current i_S is 36.11 [mA], as shown in Figure 1. When it is connected to a 25 [mA] current source, the voltage v_S is 12.00 [V], as shown in Figure 2.

Two identical copies of device D, called D1 and D2, are inserted into the circuit shown in Figure 3, with their terminals a, b connected as shown. Find the power delivered to the rest of the circuit by D1.

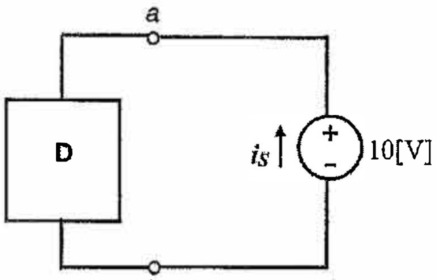


Figure 1.

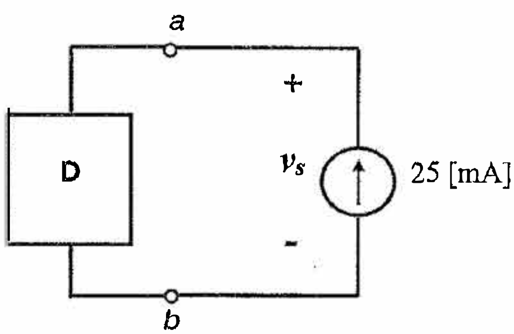


Figure 2.

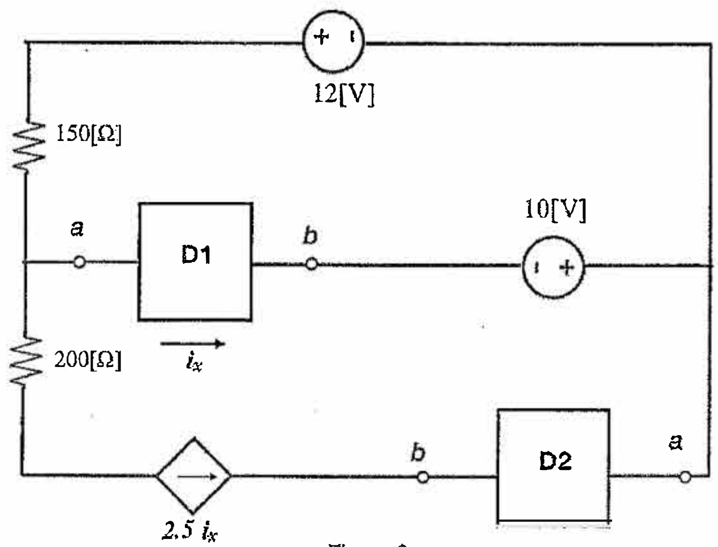
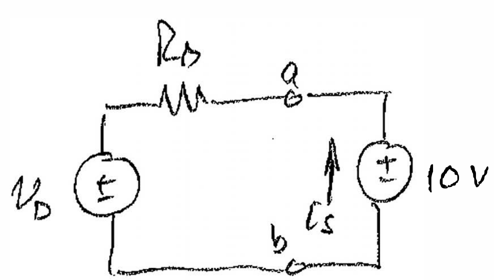
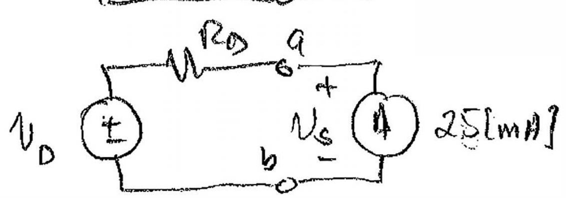


Figure 3.

Although D can be modeled by a current source in parallel with a resistor, we will use source transformation theorem to change it to a voltage source in series with a resistor, because this will be easier to substitute into our circuit.



$V_D + 0.03611 R_D = 10$



$V_D + 0.025 R_D = 12$

+15

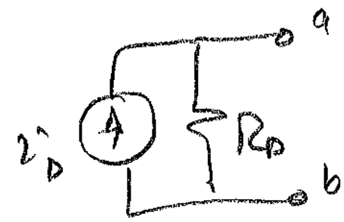
$\Rightarrow V_D = 16.5$ [V] $R_D = -180$ [Ω]

Room for extra work

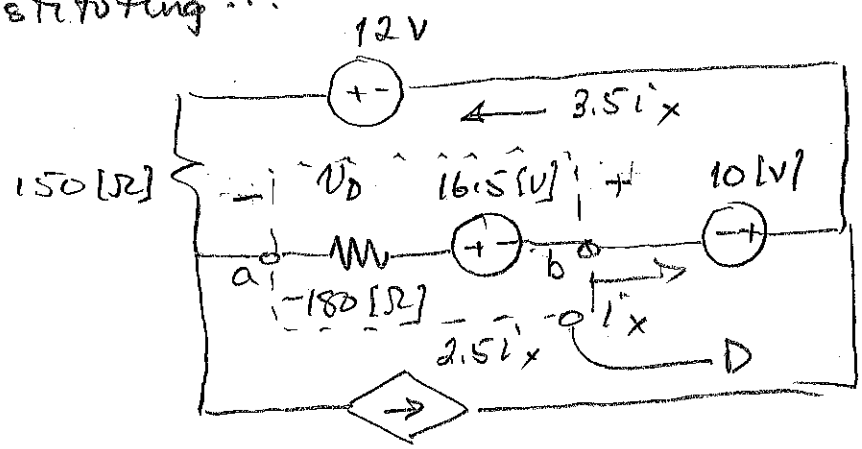
Note that the current source equivalent is

$i_D = -91.667$ [mA]

$R_D = -180$ [Ω]



Substituting ...



we have ignored D_2 and 200 [Ω] because they are in series with a current source!

ckt +8

analysis +10

Pdel by D1 +5

calc. +2

(sign −3)

$$-12 + 3.5 i_x (150) - 180 i_x + 16.5 - 10 = 0$$

$$345 i_x = 5.5 \Rightarrow i_x = 15.942 \text{ [mA]}$$

$$v_D = -16.5 - (-180) i_x = 0 \Rightarrow v_D = -13.63 \text{ [V]}$$

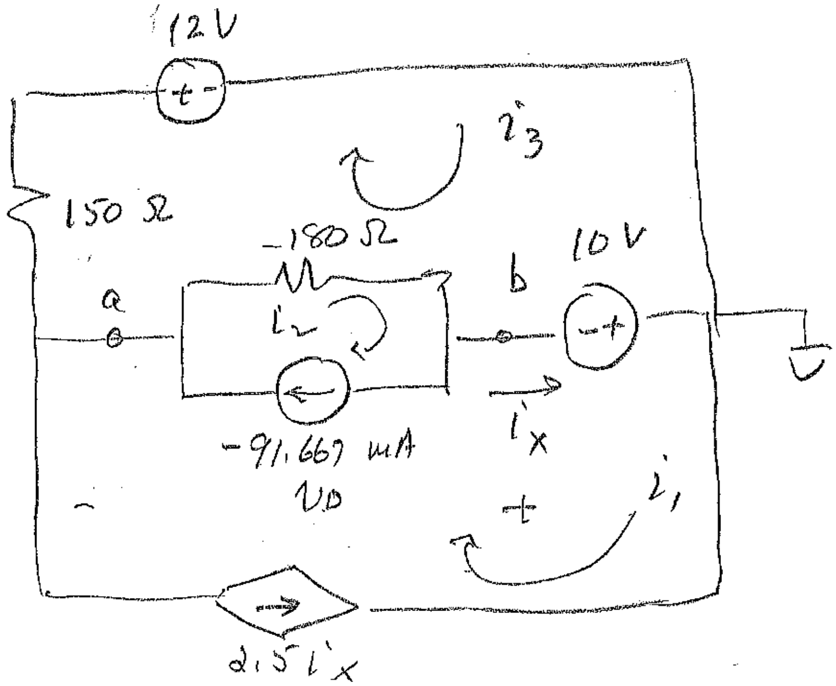
$$P_{\text{del by D}} = v_D \cdot i_x = -217.3 \text{ [mW]}$$

$$P_{\text{del by } -180} = +180 \cdot i_x^2$$

$$+ \quad P_{\text{del by } 16.5} = -16.5 \cdot i_x$$

$$P_{\text{del by D}} = -217.3 \text{ [mW]}$$

Using current source ...



ckt diagram +8

analysis +10

$P_{del\ by\ D1}$ +7

└ calc (+2)

sign -3

c b a

$i_1 = -2.5\, i_x$ $\quad i_2 - i_1 = -0.091667$

$12 + 10 - 180\,(i_3 - i_2) + 150\, i_3 = 0$ $\quad i_x = i_1 - i_3$

$i_1 = -39.855$ mA

$i_2 = -131.52$ mA

$i_3 = -55.796$ mA

$i_x = 15.942$ mA

$V_D = +180\,(i_2 - i_3)$

$= -13.63$ V

$P_{del\ by\ D1} = V_D \cdot i_x = -217.3$ [mW]

Correct set-up, wrong $i_3\,R_a$ -4

wrong direction -5

$i_x = i_D$ -5

lots of work, wrong Norton -5

assume same V_D -4

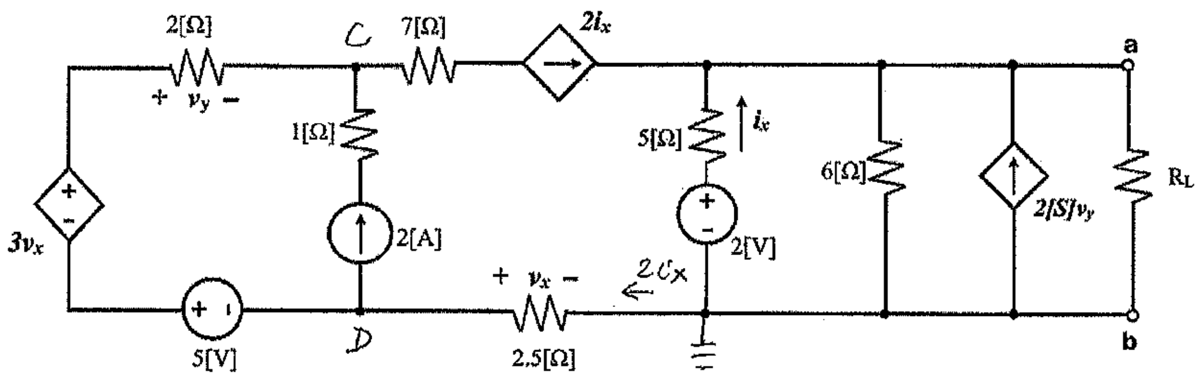
Ignore v across current source -4

missing mesh current -5

Use eqn w/ missing V_{cs} w/ no add'l eqn -4

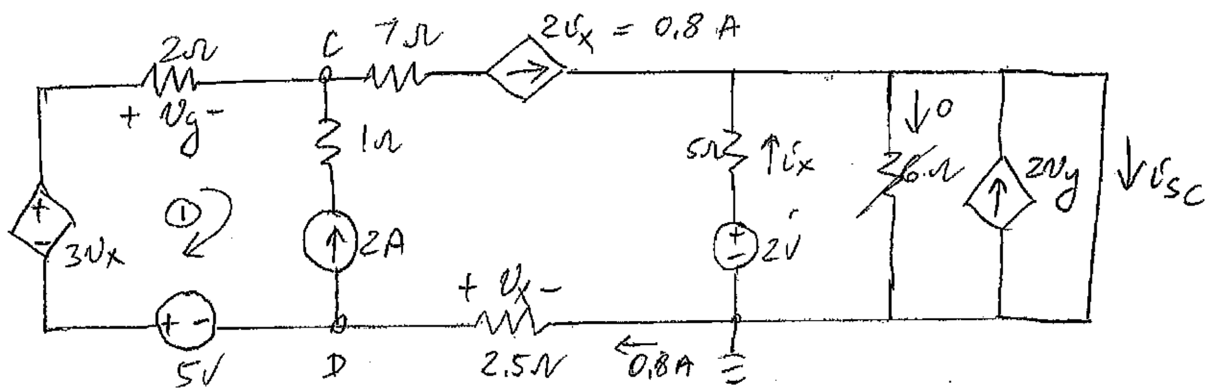
Unclear diagram -3

4. {35 Points} Use the circuit shown below to:
   a. Find the Thevenin equivalent seen by R_L. Draw your Thevenin equivalent, labeling terminals a, b.
   b. Find the Norton equivalent seen by R_L. Draw your Norton equivalent, labeling terminals a, b.
   c. Find the load resistance R_L that absorbs maximum power from the circuit.



Disconnect R_L & short a & b → (i_{sc})

$i_{6\Omega} = 0$, $i_x = \frac{2}{5} = 0.4[A]$



$v_x = -0.8 \cdot 2.5 = -2[V]$

$3v_x = -6[V]$

NVM @ C

$$\begin{cases} \frac{v_C - 3v_x - 5 - v_D}{2} + 2i_x - 2 = 0 \\ v_D = +v_x = -2[V] \end{cases}$$

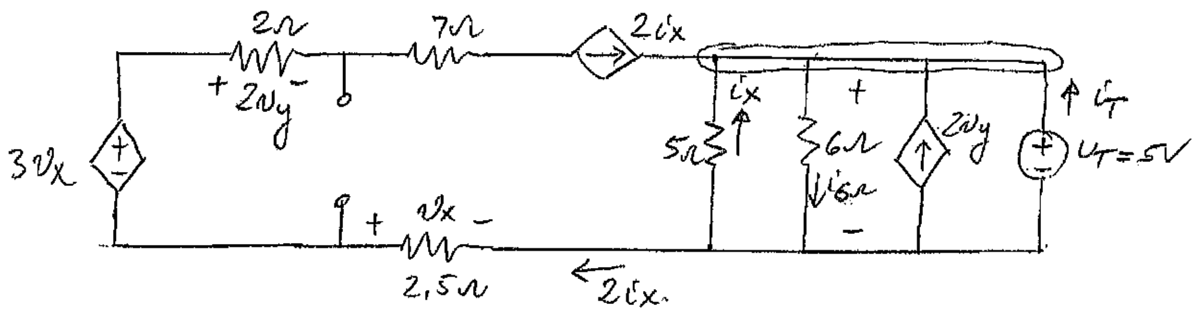
$v_C = -0.6\ [V] \rightarrow v_y = 3v_x + 5 + (v_D - v_C) = -2.4[V]$

Room for extra work

$$i_{SC} - 0.8 - 0.4 - 2\cdot(-2.4) = 0$$

$$i_{SC} = -3.6\ [A]$$

Deactivate all independent sources and connect a test source



$i_x = -1[A]$; $2i_x = -2[A]$; $v_x = -2i_x \cdot 2.5 = +5\ [V]$

$3v_x = 15[V]$ (not needed)

$2v_y = +2i_x \cdot 2 = +4i_x = -4\ [V]$

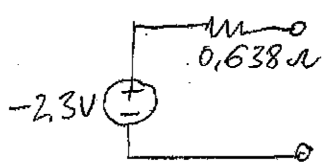
KCL $\quad -i_T - 2v_y + \frac{v_T}{6\Omega} - i_x - 2i_x = 0$

$$i_T = +4 + \frac{5}{6} + 1 + 2 = 7.83\ [A]$$

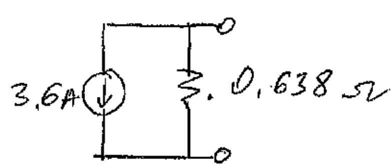
$R_{T1} = \frac{5}{7.83} = 0.638\ [\Omega] = R_{TH}$ → Maximum power will be delivered to R_L if $R_L = 0.638\Omega$

$V_{TH} = R_{TH} \cdot i_{SC} = -2.3\ [V]$

$i_N = i_{SC}$



NORTON →



Thevenin equivalent

Norton equivalent

5. {35 Points} In the circuit shown below (Figure 1) Device is connected at terminals A and B. The Thevenin equivalent seen by this device is given in Figure 2. Information about the device include:

The device can be modeled as a voltage source connected in series with a resistor.
It absorbs power of 28 [W] if connected to a current source of 2 [A] (Figure 3).
It delivers power of 27 [W] to 3 [Ω] resistor (Figure 3).

a. Find the device model and draw it, labeling terminals A, B.
b. Calculate the value of resistor R in the circuit.
c. Find the power delivered to this device by the circuit.

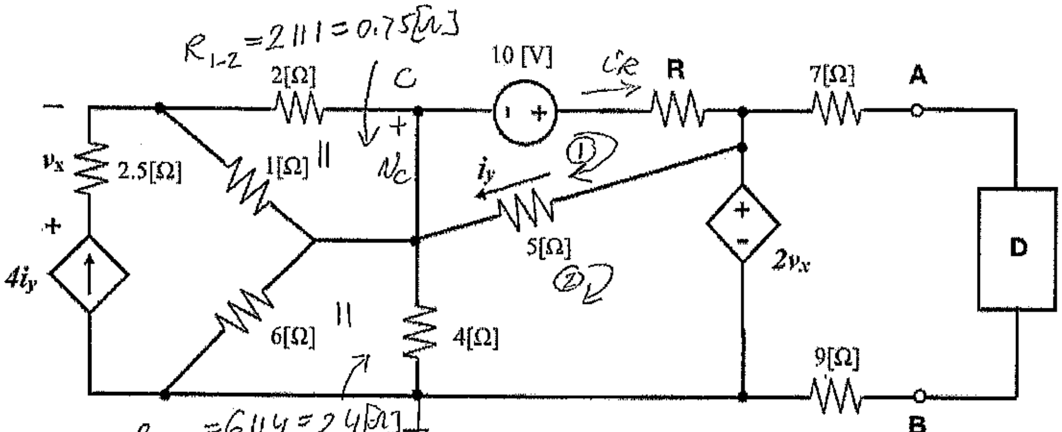


Figure 1.

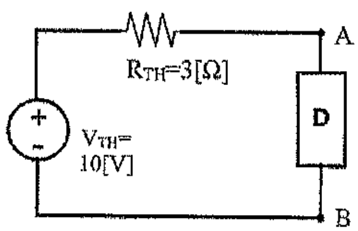


Figure 2.

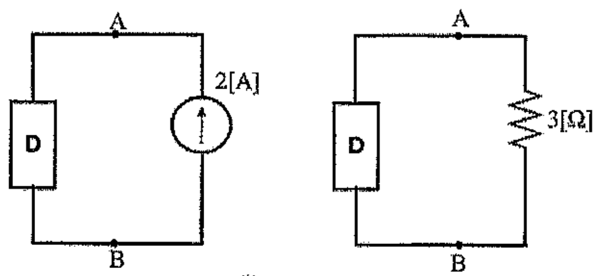


Figure 3.

Disconnect Device D → voltage on AB terminals is $v_{OC} = v_{TH} = 10[V]$

$2v_x = 10[V] \to v_x = 5[V] \to i_{2.5[\Omega]} = 4i_y = \frac{5[V]}{2.5[\Omega]} = 2[A]$

$i_y = 0.5[A]$

KVL in ①

$i_y \cdot 5[\Omega] - 10[V] + i_R \cdot R = 0 \to i_R \cdot R = 7.5[V]$

KCL in Ⓒ $-2[A] - i_y + \frac{v_c[V]}{2.4[\Omega]} + i_R = 0$

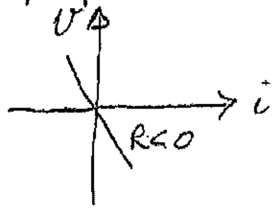
KVL ② $v_c = 10[V] - i_y \cdot 5 = 7.5[V]$

$i_R = -0.625[A]$

$R = -12[\Omega]$

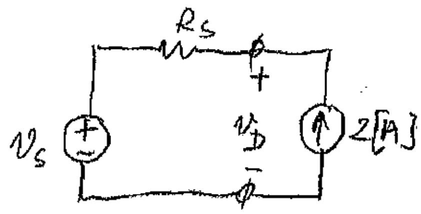
Room for extra work

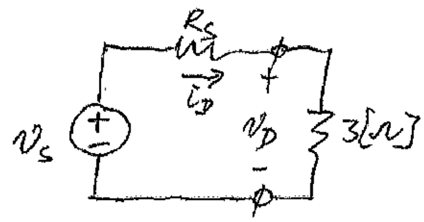
Solving for R gave R<0 – this is not a physical resistor but represents i(v) characteristic



of a device w/ R<0. In this problem it was caused by "unforced" error in drawing 10 source instead of 15 [V].

Device model





$$V_D = \frac{28\,[W]}{2\,[A]} = 14\,[V]$$

(1) $+V_S + 2R_S = V_D = 14\,[V]$

$P_{del,3\Omega} = i_D \cdot V_D = 27\,[$

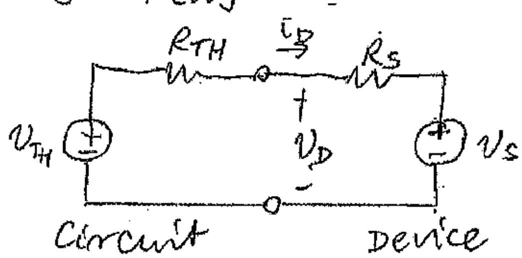
$p = \left(\frac{V_S}{R_S + 3}\right)^2 \cdot \cancel{3} = \cancel{27}\ 9 \Rightarrow$

(2) $V_S - 3R_S = 9$

solve (1) + (2)

$V_S = 12\,[V]$

$R_S = 1\,[\Omega]$



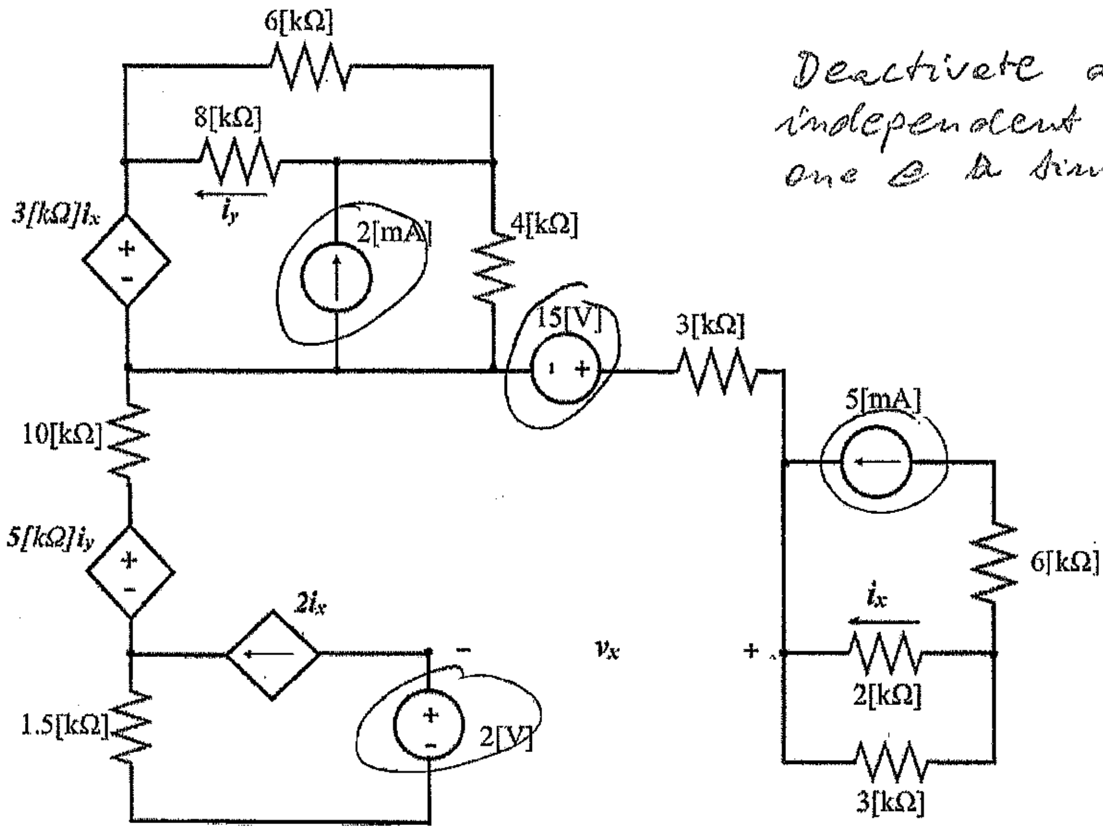
$P_{abs,D} = i_D \cdot V_D =$

$$\left(\frac{V_{TH} - V_S}{R_{TH} + R_S}\right)^2 \cdot R_S + \frac{V_{TH} - V_S}{R_{TH} + R_S} \cdot\cdot$$

$$= \left(\frac{-2}{4}\right)^2 \cdot 1 + \frac{-2}{4} \cdot 12 = -5.$$

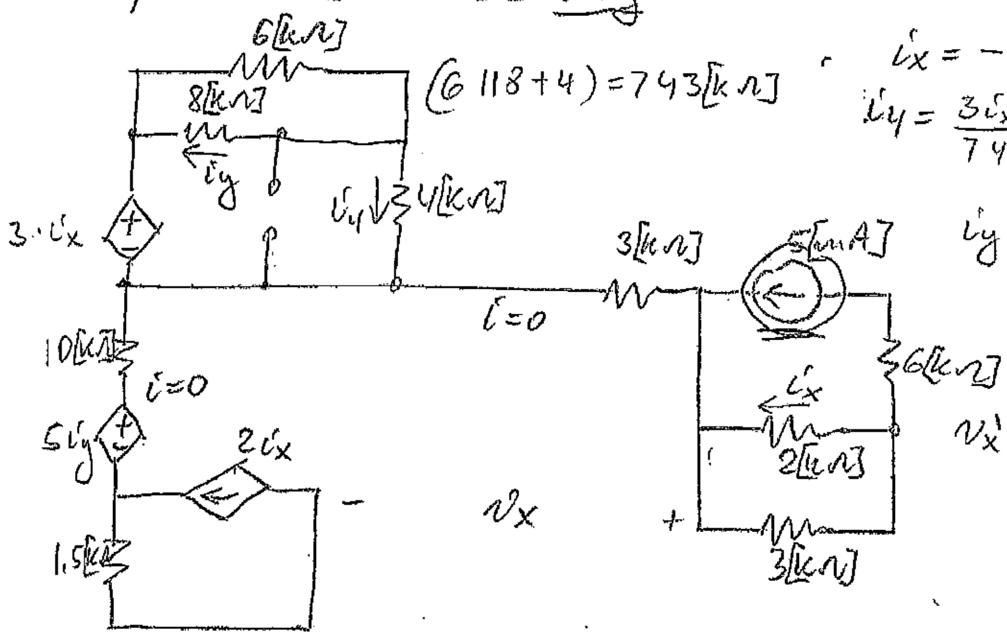
$P_{abs,D} < 0$ so it is

6. {35 Points} For the circuit shown below use superposition principle to find the voltage v_x.



Deactivate all independent sources one @ a time

① keep 5[mA] source only



$(6 \| 8 + 4) = 7.43[k\Omega]$

$i_x = -5[mA] \cdot \frac{2 \cdot 3}{2+3} = -3[mA]$

$i_4 = \frac{3 i_x}{7.43[k\Omega]} = -\frac{9}{7.43} = -1.21$ [mA]

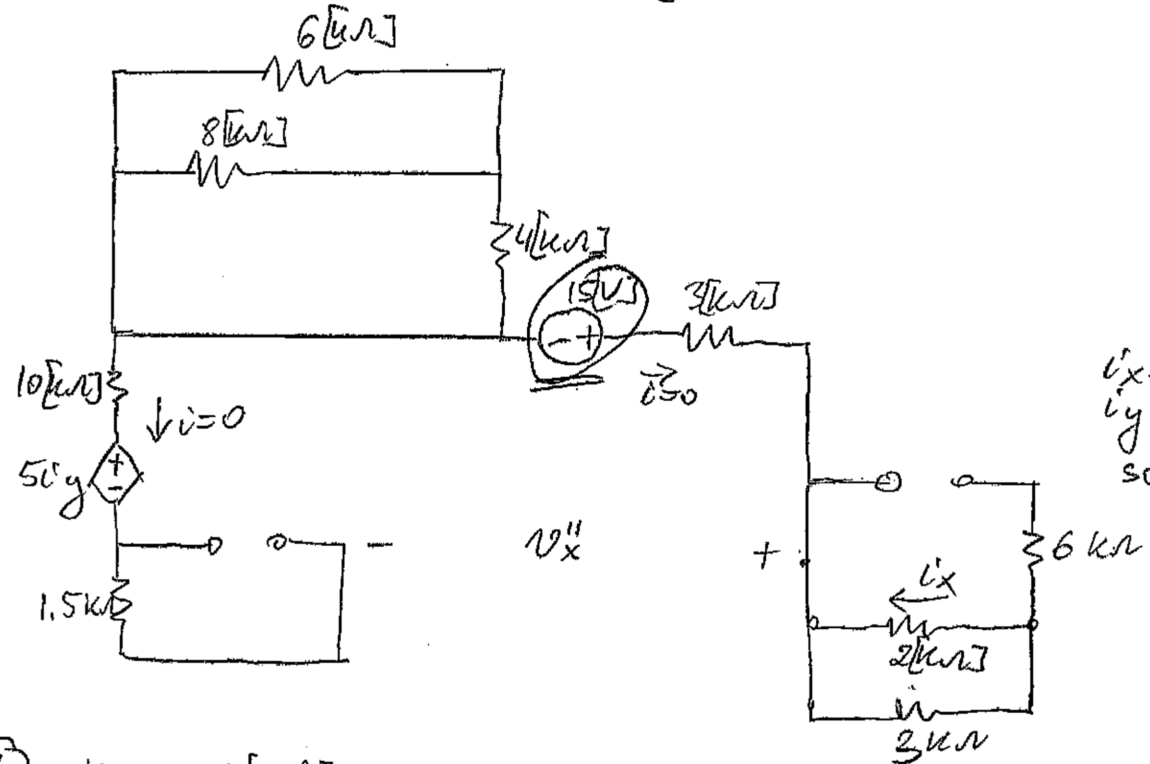
$i_y = 1.21 \cdot \frac{6 \| 8}{8} = 0.52$ [mA]

$5 i_y = 2.59 [V]$

$v_x' = -2i_x\, 1.5[k\Omega] - 5i_y = -11.56[V]$

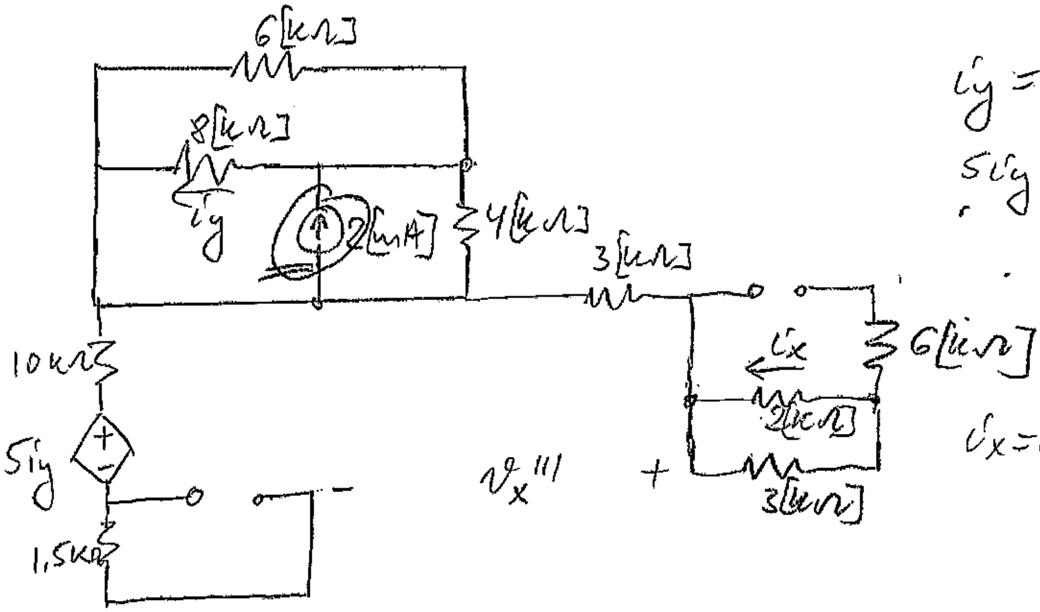
Room for extra work

(2.) Keep 15[V] source only



$i_x = 0$
$i_y = 0$
so $v_x'' = 15[V]$

(3) Keep 2[mA]



$i_y = 2 \cdot \frac{6 \| 8 \| 4}{8} = 0.462$ [mA]

$5 i_y = 2.3[V]$

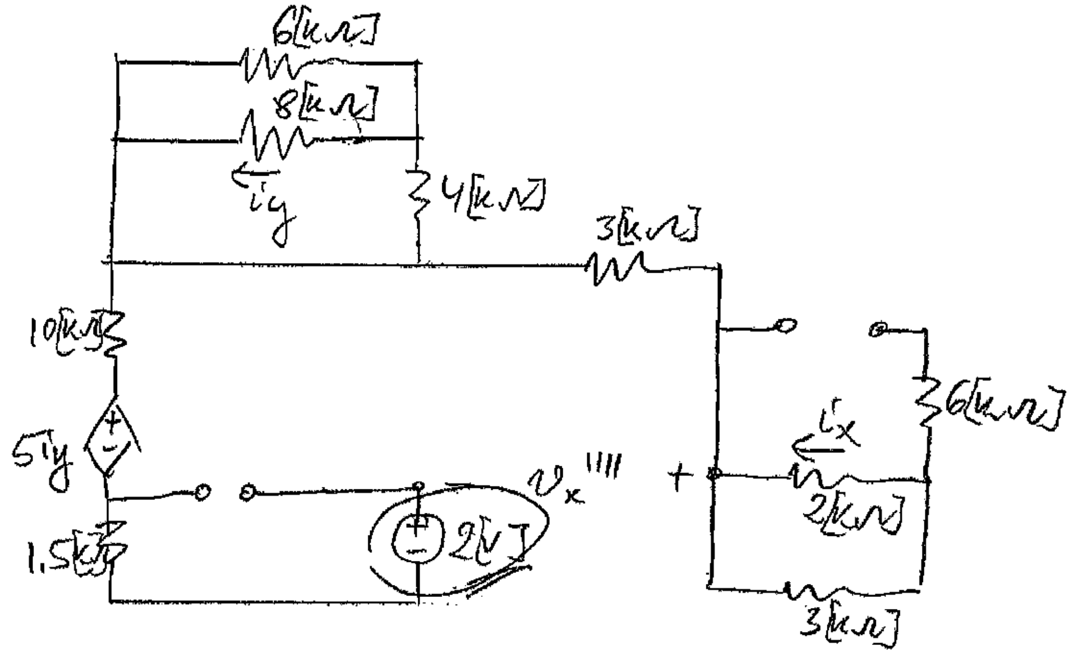
$v_x''' = 2.3[V]$

$i_x = 0$

Room for extra work

(4) keep 2[V] only → $i_x' = 0$, $i_y' = 0$

so $v_x'''' = 2[V]$ → we can redraw it to show



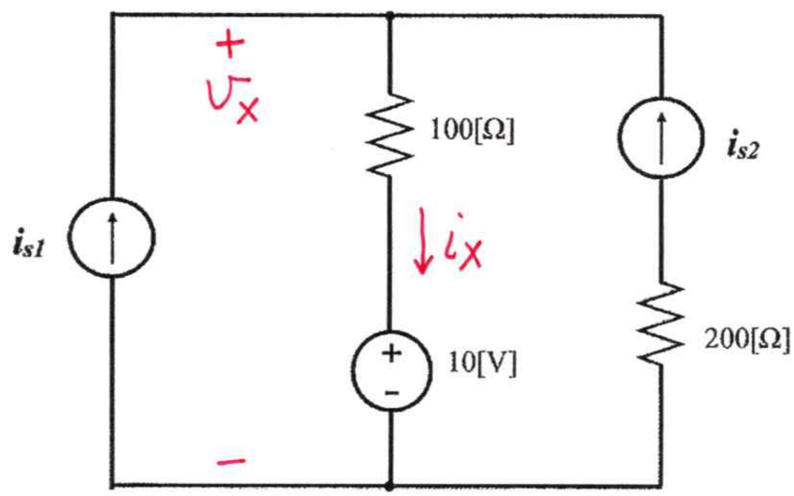
$$v_x = v_x' + v_x'' + v_x''' + v_x'''' = -11.56 + 15 + 2.3 + 2 =$$

$$= 7.74\ [V]$$

2. {25 Points} In the circuit below, the current sources provide the following currents for t ≥ 0. For t < 0, $i_{S1} = i_{S2} = 0$.

$$i_{S1}(t) = 30[mA]e^{-2\left[\frac{1}{ks}\right]t} \qquad i_{S2}(t) = 50[mA]e^{-2\left[\frac{1}{ks}\right]t}$$

Find the energy delivered by the source i_{S1} in the time interval 0 to 0.1 [ks].



$$p_{DEL.BY.i_{S1}} = v_x i_{S1}$$

$$i_x = i_{S1} + i_{S2} = 80\{mA\}e^{-2\{\frac{1}{ks}\}t}; \text{ for } t \geq 0.$$

$$v_x = i_x 100\{\Omega\} + 10\{V\}$$

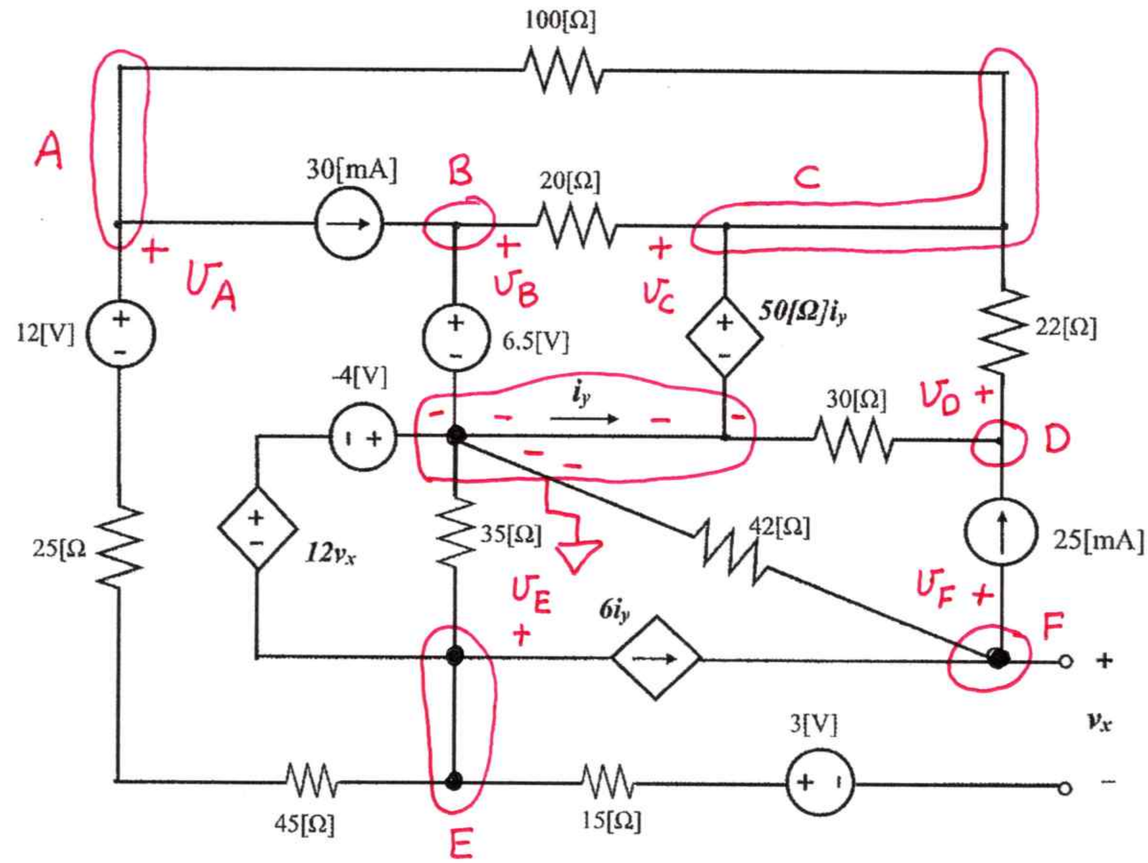
$$v_x = 8\{V\}e^{-2\{\frac{1}{ks}\}t} + 10\{V\}; \text{ for } t \geq 0.$$

$$w_{DEL.BY.i_{S1}} = \int_0^{0.1\{ks\}} p_{DEL.BY.i_{S1}}\, dt$$

$$= \int_0^{0.1\{ks\}} \left(8\{V\}e^{-2\{\frac{1}{ks}\}t} + 10\{V\}\right)\left(30\{mA\}e^{-2\{\frac{1}{ks}\}t}\right)dt$$

$$\boxed{w_{DEL.BY.i_{S1}} = 46.97\{J\}}$$

1. {35 Points} Use the **Node Voltage Method** to write a set of equations that could be used to solve the circuit below. Do not simplify the circuit, and do not attempt to solve the equations.



There are 7 essential nodes and 2 dependent source variables, so we will write 7 - 1 + 2 = 8 equ.

(A) $$30\{mA\} + \frac{v_A - 12\{V\} - v_E}{25\{\Omega\} + 45\{\Omega\}} + \frac{v_A - v_C}{100\{\Omega\}} = 0$$

(B) $$v_B = 6.5\{V\}$$

(C) $$v_C = 50\{\Omega\}\, i_y$$

(D) $$\frac{v_D}{30\{\Omega\}} + \frac{v_D - v_C}{22\{\Omega\}} - 25\{mA\} = 0$$

(See next page.)

Problem 1. continued

(E) $v_E = -12\, v_X - (-4[V])$

(F) $\frac{v_F}{42[\Omega]} + 25[mA] - 6\, i_Y = 0$

(i_Y) $-i_Y + \frac{v_C - v_B}{20[\Omega]} + \frac{v_C - v_A}{100[\Omega]} + \frac{v_C - v_D}{22[\Omega]} + \frac{-v_D}{30[\Omega]} = 0$

(v_X) $v_X - 3[V] + v_E - v_F = 0$

This is 8 equations in 8 unknowns, and we can solve.