Name: SOLUTIONS (please print)

Signature: Solutions

ECE 2201 – Exam 2
April 15, 2023

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

1. This exam is closed book, closed notes. You may use any calculator. You may **not** use a cell phone, tablet computer, nor laptop computer. You may have a crib sheet in the form of one 8 ½" x 11" piece of paper, with material written on both sides.
2. Print your name, and provide your signature above.
3. 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. You may separate the pages as you work.
4. Show all units in solutions, intermediate results, and figures. Units in the exam will be included between square brackets.
5. If the grader has difficulty following your work because it is messy or disorganized, you will lose credit.
6. Do not use red ink. Do not use red pencil.
7. You will have 90 minutes to work on this exam.

1. _____/40
2. _____/30
3. _____/30

Total = 100

Room for extra work

1. (40 points) Use the diagrams below to solve.

a) An Electronic Device, as shown in Figure 1, can be modeled as a voltage source in series with a resistance. The relationship between the voltage and the current for the Electronic Device is shown in Figure 2. Find the model for the Electronic Device. Draw the model with clear numerical labels, and labeling terminals A and B.

b) Three identical versions of the Electronic Device are connected in the circuit shown in Figure 3 on the next page. Notice that for each Electronic Device, the polarity is indicated by terminal labels, where A1, A2 and A3 correspond to A in Figure 1, and B1, B2, and B3 correspond to B in Figure 1. Find the power delivered by the 1.5[V] voltage source in Figure 3.

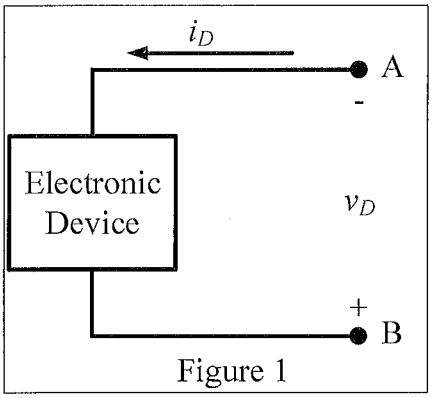


Figure 1

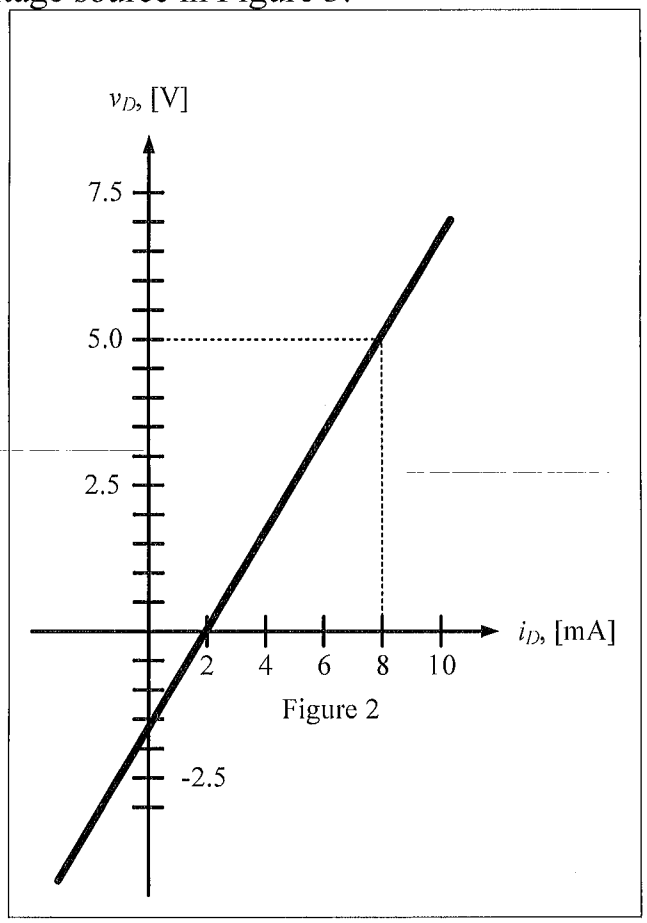


Figure 2

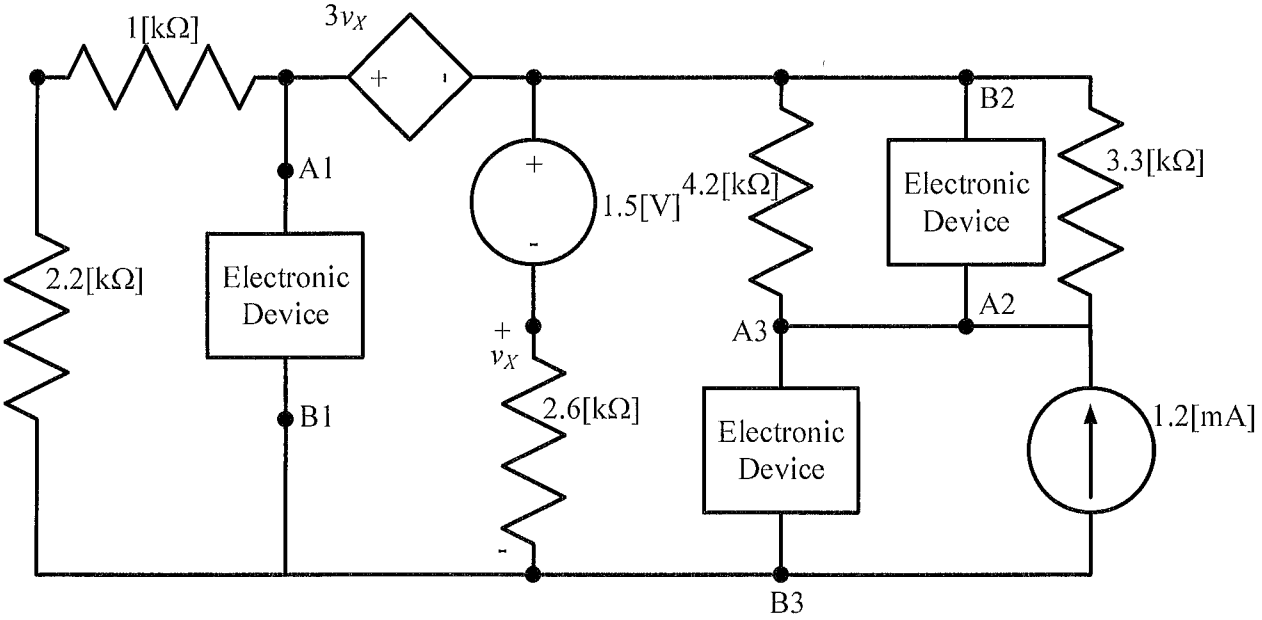
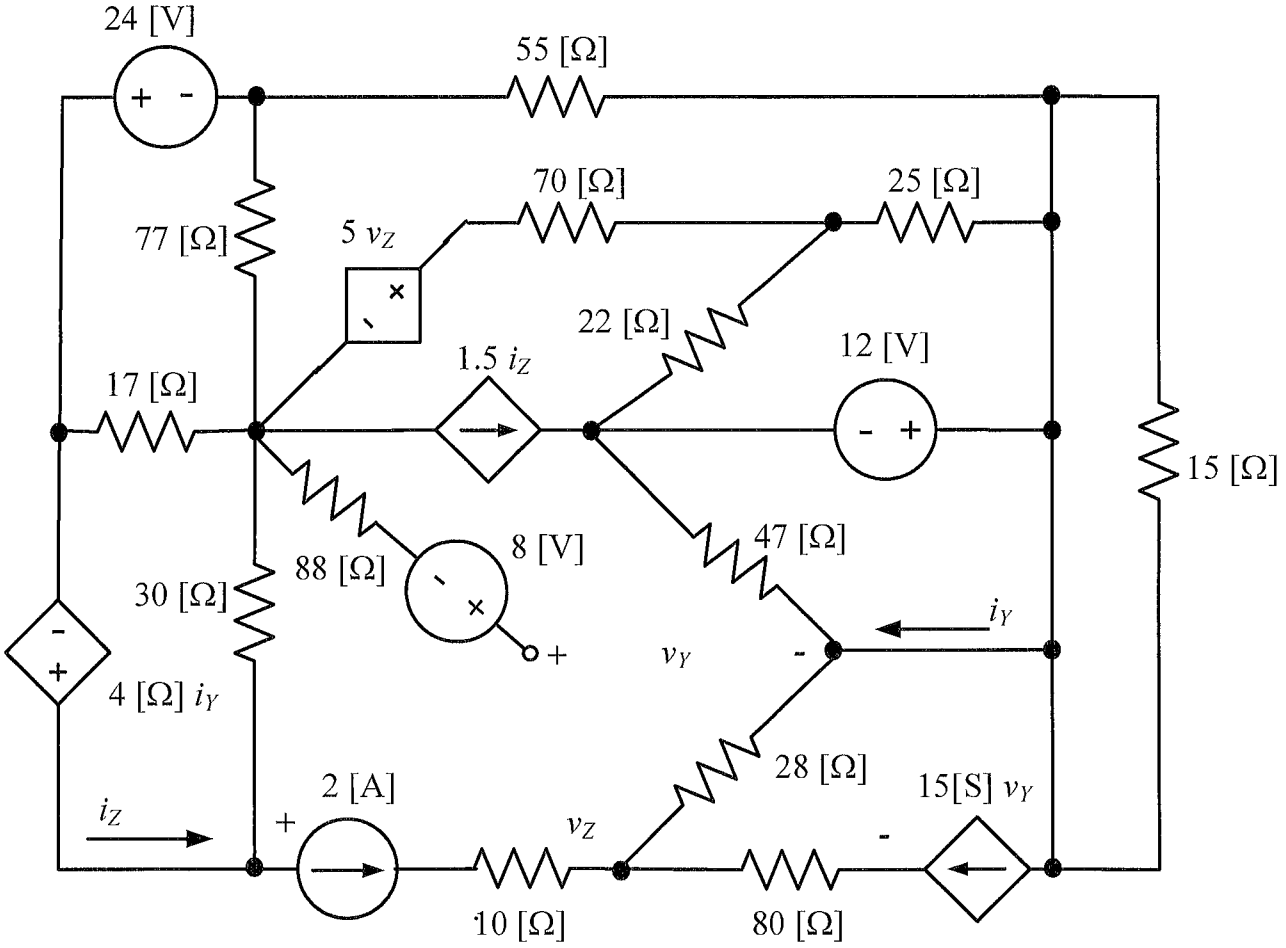

1[kΩ]
$3v_X$
A1
2.2[kΩ]
Electronic Device
B1
1.5[V]
v_X
2.6[kΩ]
4.2[kΩ]
A3
Electronic Device
B2
Electronic Device
3.3[kΩ]
A2
1.2[mA]
B3

Figure 3

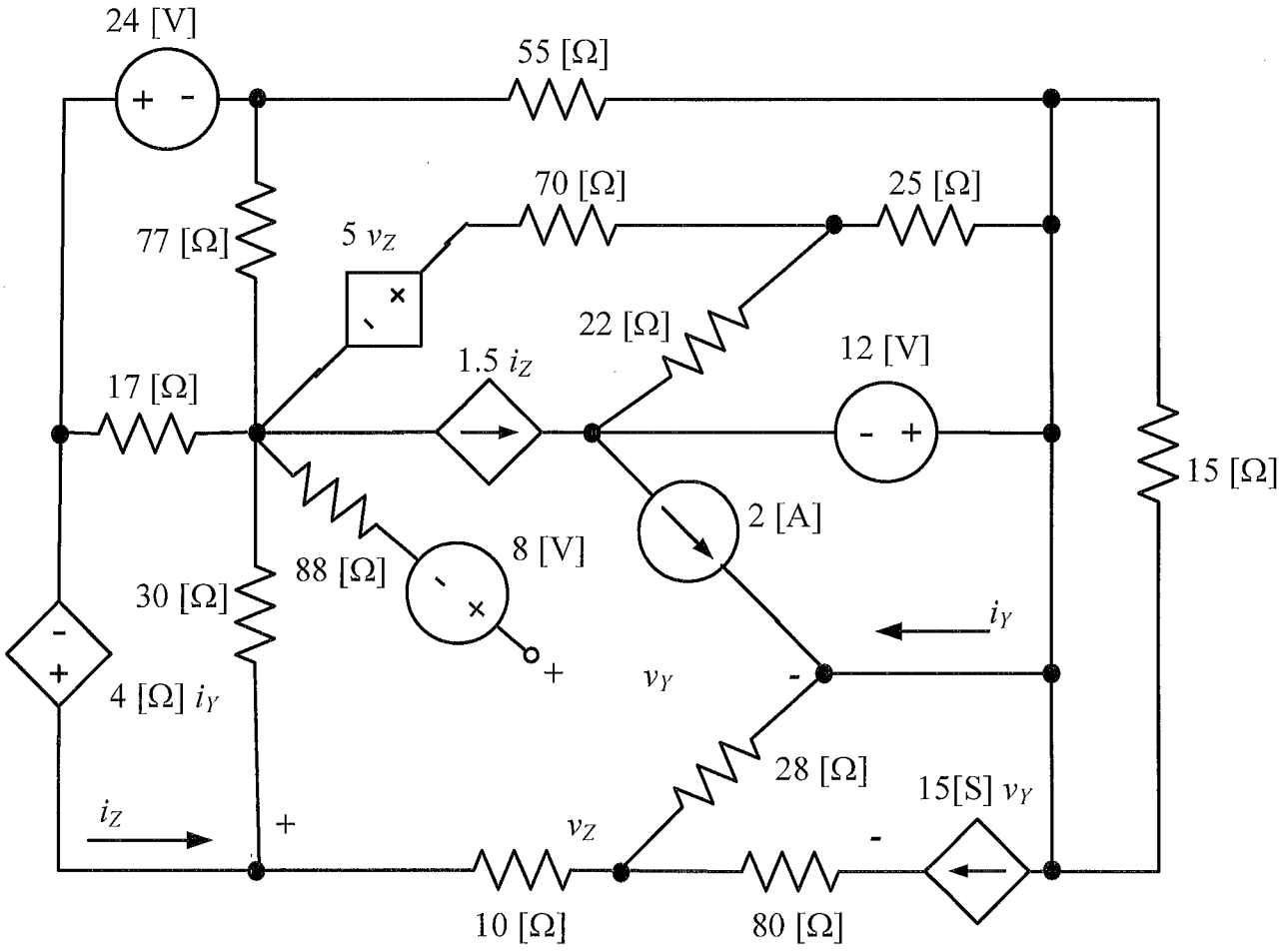
Room for extra work

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 solve or simplify your equations. Define all variables appropriately.



Room for extra work

3. (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 solve or simplify your equations. Define all variables appropriately.



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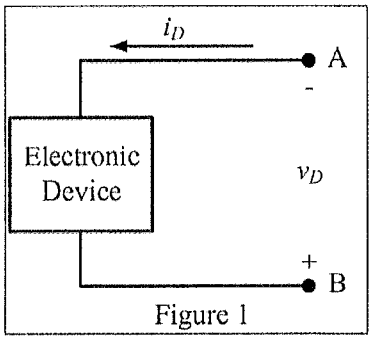


Figure 1

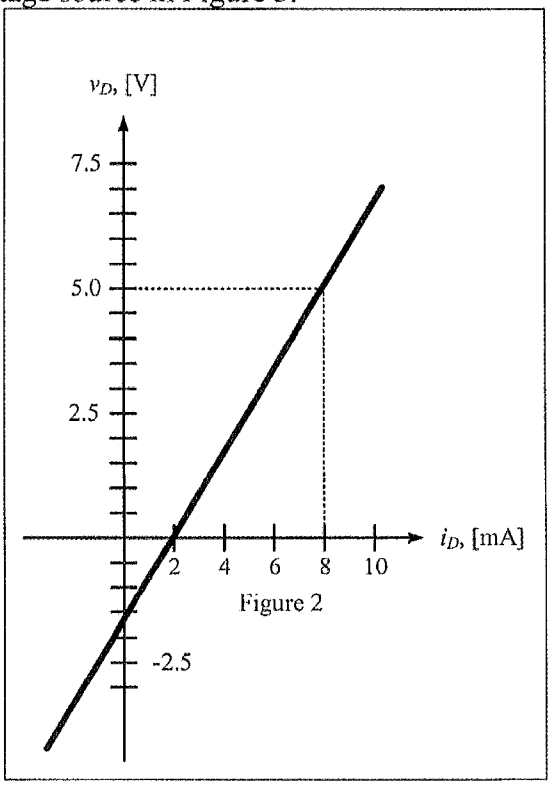
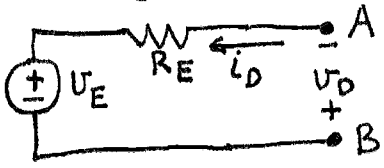


Figure 2

a) We begin by drawing the model for the Electronic Device,



for which we can write KVL, as

$$-v_E - i_D R_E - v_D = 0. \quad \text{(Equ. 1)}$$

See next page

Room for extra work

Option 1

We can plug in two pairs of values as indicated in the plot in Figure 2:

$$-v_E - 8\{mA\}R_E - 5.0\{V\} = 0, \text{ and}$$

$$-v_E - 2\{mA\}R_E + 0 = 0.$$

We can solve these two equations to obtain

$$\boxed{v_E = 1.6667\{V\} \quad \text{and} \quad R_E = -833.33\{\Omega\}.}$$

Option 2

We can find the equation of the line in Figure 2. The slope is $\frac{5\{V\}}{6\{mA\}} = 833.33\{\Omega\}$. The intercept will be $\frac{-5\{V\}}{6\{mA\}} \times 2\{mA\} = -1.6667\{V\}$.

So, $v_D = 833.33\{\Omega\}\, i_D - 1.6667\{V\}$. We can write Equ. 1 as

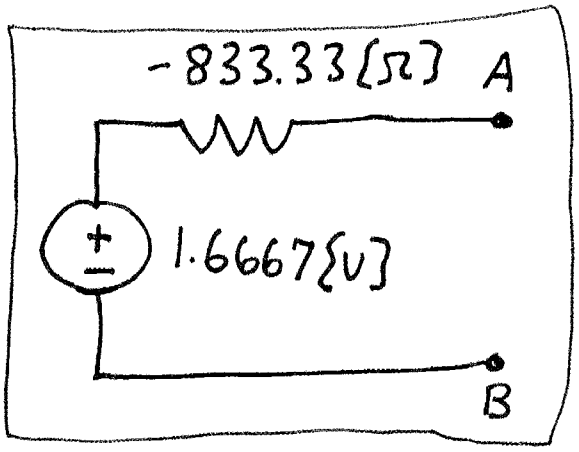
$v_D = -R_E\, i_D - v_E$. From these two equations, we have

$$\boxed{R_E = -833.33\{\Omega\} \text{ and } v_E = 1.6667\{V\}.}$$

see next page

Room for extra work

a) So, the model is



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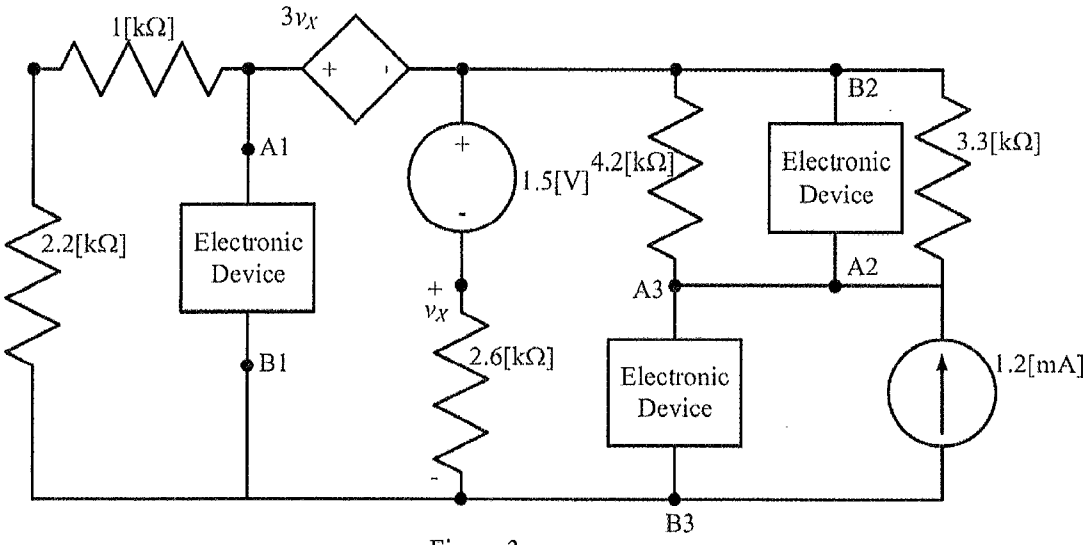
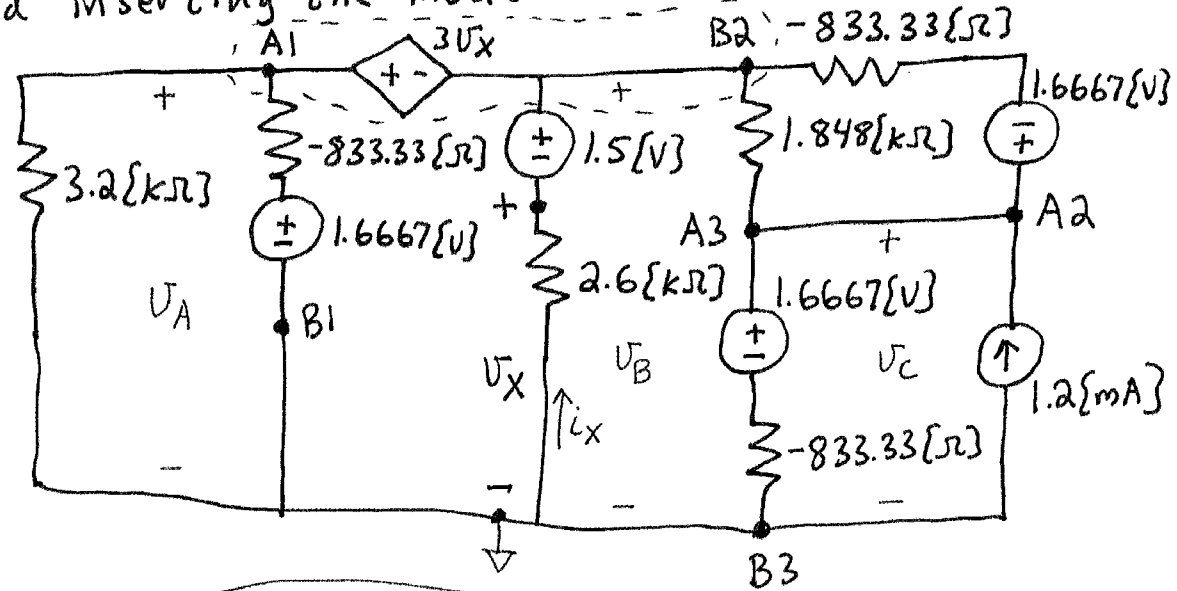


Figure 3

b) We have series resistors $1\{k\Omega\} + 2.2\{k\Omega\} = 3.2\{k\Omega\}$ and parallel resistors $4.2\{k\Omega\} \| 3.3\{k\Omega\} = 1.848\{k\Omega\}$. We can redraw Figure 3 with these simplifications, and inserting the model for the Electronic Device.



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We can choose the node-voltage method. After defining the variables, we write

$$\frac{V_B + 1.6667\{V\} - V_C}{-833.33\{\Omega\}} + \frac{V_B - V_C}{1.848\{k\Omega\}} + \frac{V_B - 1.5\{V\}}{2.6\{k\Omega\}} +$$

$$+ \frac{V_A - 1.6667\{V\}}{-833.33\{\Omega\}} + \frac{V_A}{3.2\{k\Omega\}} = 0$$

$$V_A - V_B = 3V_X$$

$$0 = \frac{V_C - V_B}{1.848\{k\Omega\}} + \frac{V_C - 1.6667\{V\} - V_B}{-833.33\{\Omega\}} - 1.2\{mA\} + \frac{V_C - 1.6667\{V\}}{-833.33\{\Omega\}}$$

$$V_B - V_X - 1.5\{V\} = 0$$

$$i_X = \frac{-V_X}{2.6\{k\Omega\}}$$

Solving, we get

$$i_X = 104.63\{\mu A\}$$
$$V_X = -272.03\{mV\}$$
$$V_A = 411.89\{mV\}$$
$$V_B = 1.228\{V\}$$
$$V_C = 1.9416\{V\}$$

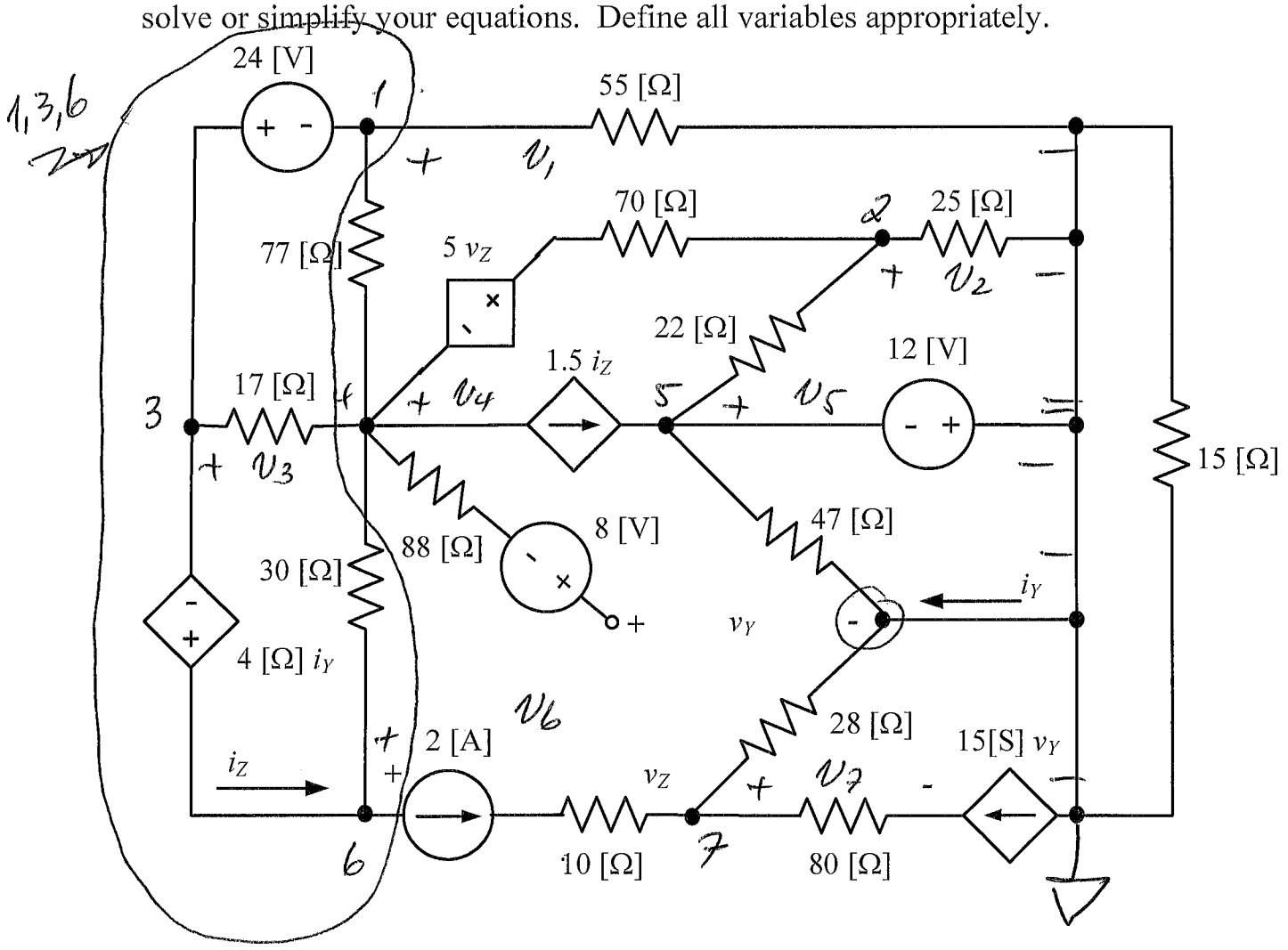
See next page

So,

$$p_{\text{DEL. BY. 1.5[V]}} = (1.5[V])(i_x)$$

$$= \boxed{156.95\,[\mu W]}$$

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 solve or simplify your equations. Define all variables appropriately.



We have chosen a reference, and labeled the non-reference essential nodes 1–7, and defined the node voltages.

Nodes 1, 3, 6 constitute a double supernode. We have indicated one possible closed surface at which to write a KCL.

Room for extra work

+4 1,3,6: $\frac{v_1}{55} + \frac{v_1 - v_4}{77} + \frac{v_3 - v_4}{17} + \frac{v_6 - v_4}{30} + 2 = 0$

+1 +1 constraints: $v_1 - v_3 = -24 \quad v_3 - v_6 = -4[\Omega]\, i_Y'$

+3 2: $\frac{v_2}{25} + \frac{v_2 - 5v_2 - v_4}{70} + \frac{v_2 - v_5}{22} = 0$

+4 4: $\frac{v_4 - v_2 + 5v_2}{70} + 1.5 i_2' + \frac{v_4 - v_1}{77} + \frac{v_4 - v_6}{30} = 0$

+1 5: $v_5 = -12\,[V]$

+3 7: $-2 - 15[S]\, v_7 + \frac{v_7}{28} = 0$

auxiliaries:

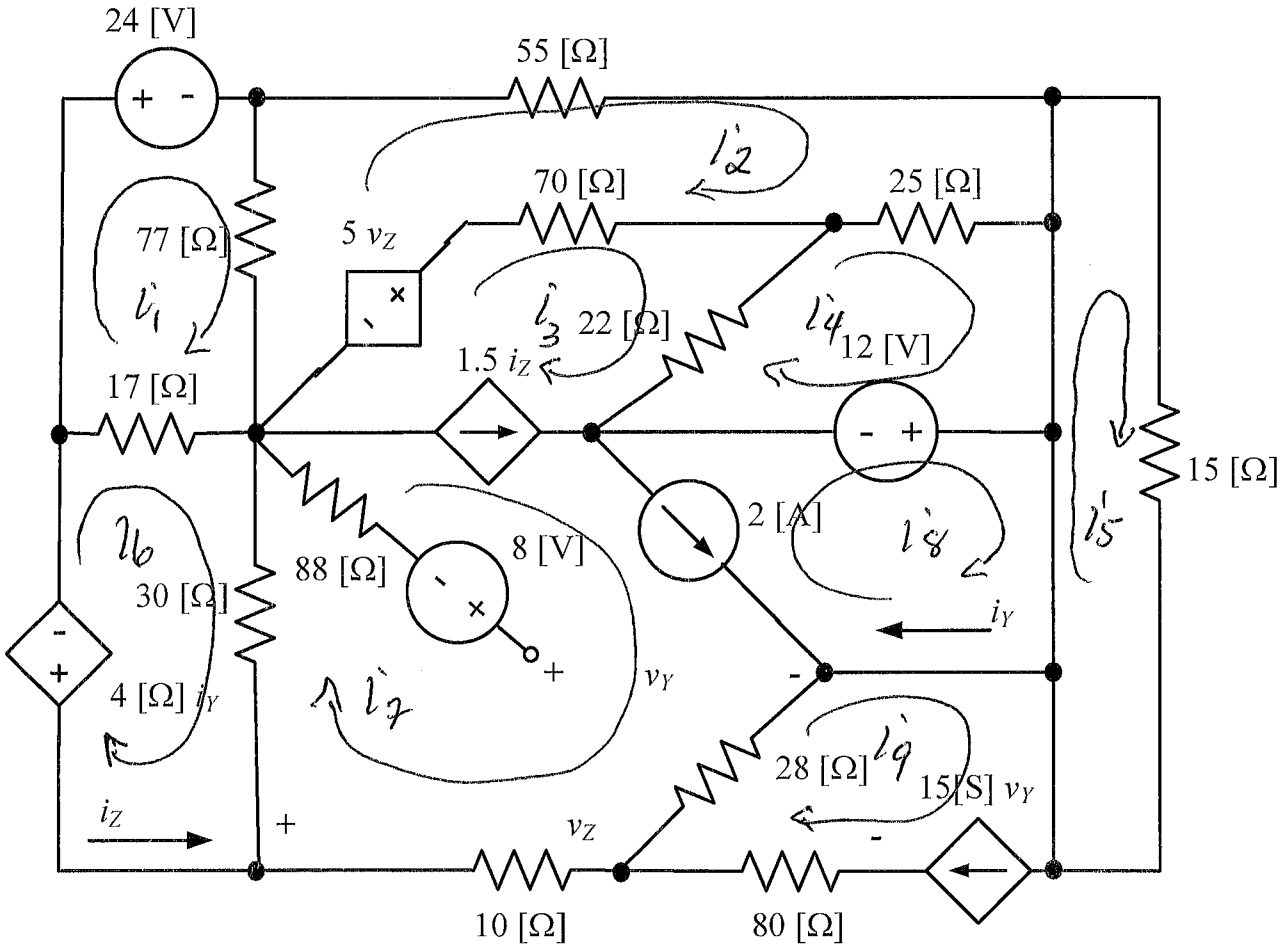
+3 i_Y': $-i_Y' - \frac{v_5}{47} - \frac{v_7}{28} = 0$

+3 v_7: $-v_7 + 8 + v_4 = 0$

+3 i_2': $-i_2' + 2 + \frac{v_6 - v_4}{30} = 0$

+4 v_2: $v_2 + 80(15[S])\, v_7 + v_7 - v_6 = 0$

3. (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 solve or simplify your equations. Define all variables appropriately.



Mesh currents i_1 — i_9 have been defined.

Note: Labeling the mesh currents "1", "2", "3", etc. is not acceptable. They must be indicated "i_1", "i_2", etc.

i_3, i_7, and i_8 constitute a double supermesh

Room for extra work

i_1: $24 + 77(i_1 - i_2) + 17(i_1 - i_6) = 0$

i_2: $55\, i_2 + 25(i_2 - i_4) + 70(i_2 - i_3) + 5V_{2,1} + 77(i_2 - i_1) = 0$

i_3, i_7, i_8: $70(i_3 - i_2) + 22(i_3 - i_4) - 12 + 28(i_7 - i_9) + 10i_7 + 30(i_7 - i_6) - 5V_2 = 0$

i_4: $25(i_4 - i_2) + 12 + 22(i_4 - i_3) = 0$

i_5: $15\, i_5 = 0$

i_6: $17(i_6 - i_1) + 30(i_6 - i_7) + 4[\Omega]\, i_Y = 0$

i_9: $i_9 = 15[S]\, V_Y$

constraints:

$i_7 - i_8 = 2[A]$

$i_7 - i_3 = 1.5 i_2$

auxiliaries:

i_Y: $i_Y = i_6 - i_9$

V_Y: $-V_Y + 8 - 5V_2 + 70(i_3 - i_2) + 25(i_4 - i_2) = 0$

i_2: $i_2 = -i_6$

V_2: $V_2 + 80 i_9 + 10 i_7 = 0$