Name: ______________________________ (please print)

Signature: ___________________________

ECE 2300 – Midterm Exam
July 2, 2016

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.
3. Show all units in solutions, intermediate results, and figures. Units in the quiz will be included between square brackets.
4. If the grader has difficulty following your work because it is messy or disorganized, you will lose credit.
5. Do not use red ink. Do not use red pencil.
6. You will have 90 minutes to work on this exam.

1. ________________/20

2. ________________/40

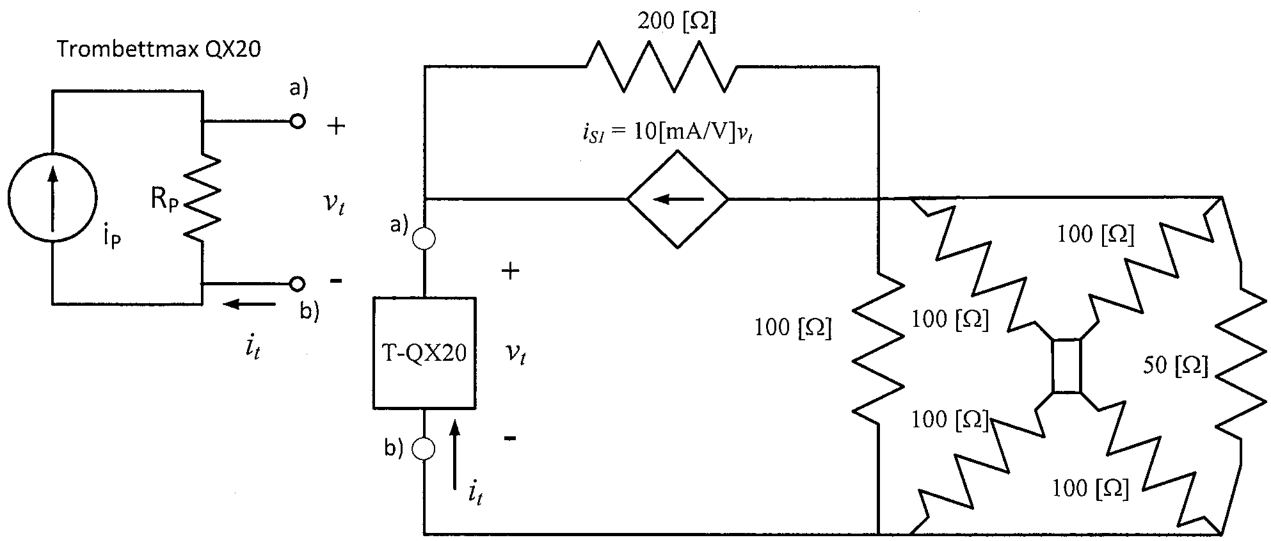
3. ________________/40

Room for extra work

1. (20 points) The Trombettamax T-QX20 can be modeled by a current source in parallel with a resistor, as shown in the diagram to the left. The circuit below shows the T-QX20 inserted into a circuit, with the terminals connected as indicated. The terminal current $i_t(t)$ for the device is

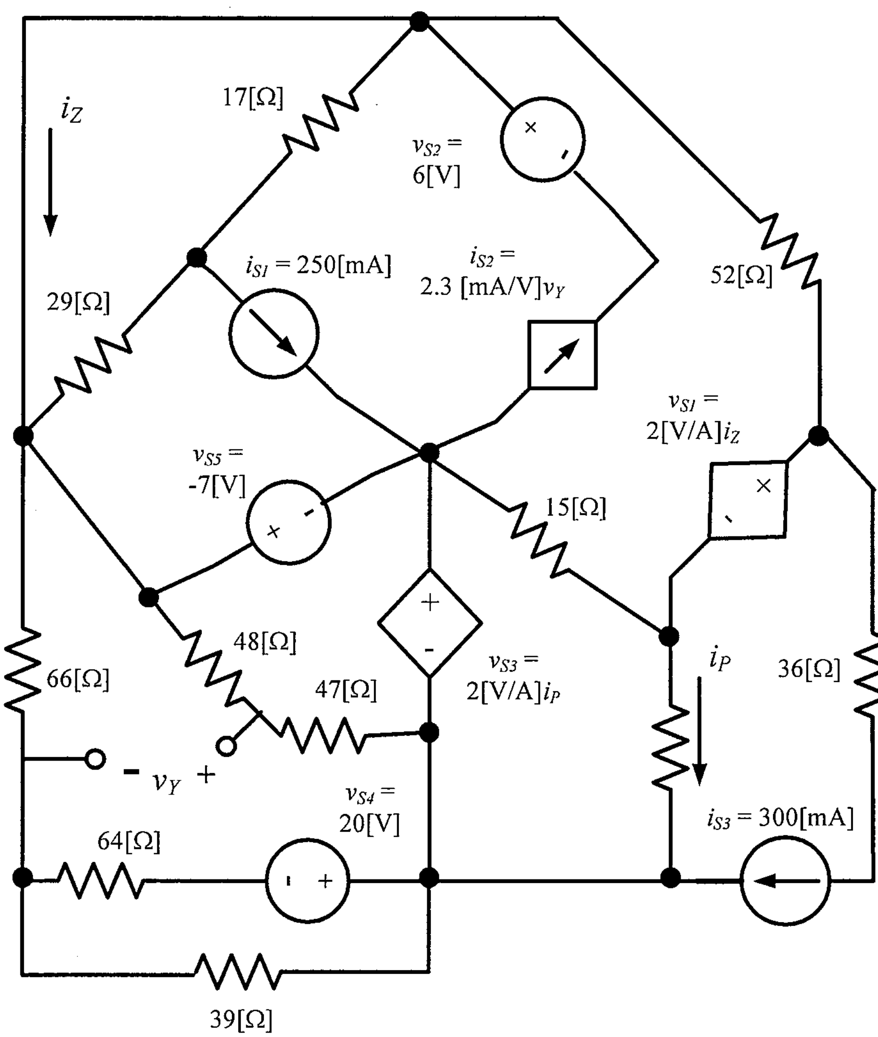
$$i_t(t) = 350e^{-t/20[ms]}[mA] \, .$$

a) Find the energy delivered by the T-QX20 over the time interval 0 to 400 [μs].
b) If the parallel resistance is R_p = - 100 [Ω], find an expression for the current i_p as a function of time.



Room for extra work

2. (40 points) Use the Node Voltage Method to find 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.



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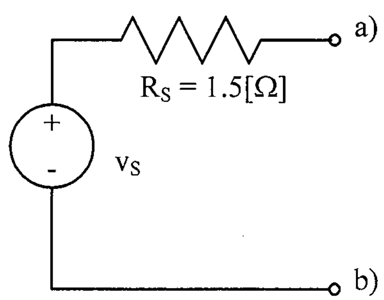
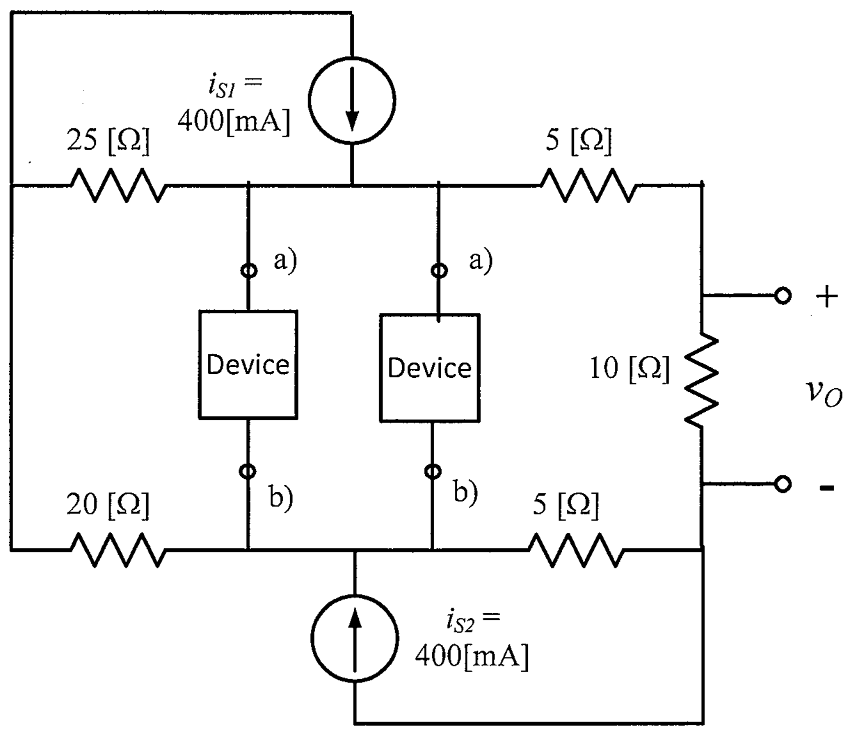
3. (40 points) A device (which is not as good as the Trombettamax T-QX20) can be modeled by a voltage source in series with a resistance, as shown in the figure to the left. The value of the voltage source is unknown. Two identical such devices are inserted into the circuit as shown, with terminals connected as indicated in the circuit diagram. In this configuration, the output voltage v_o is known to be - 5.571 [V].

If the current source i_{s2} is removed from the circuit, what is the new output voltage v_o?





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Room for extra work

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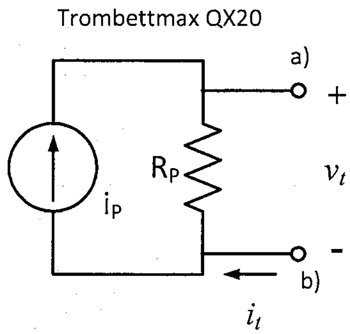
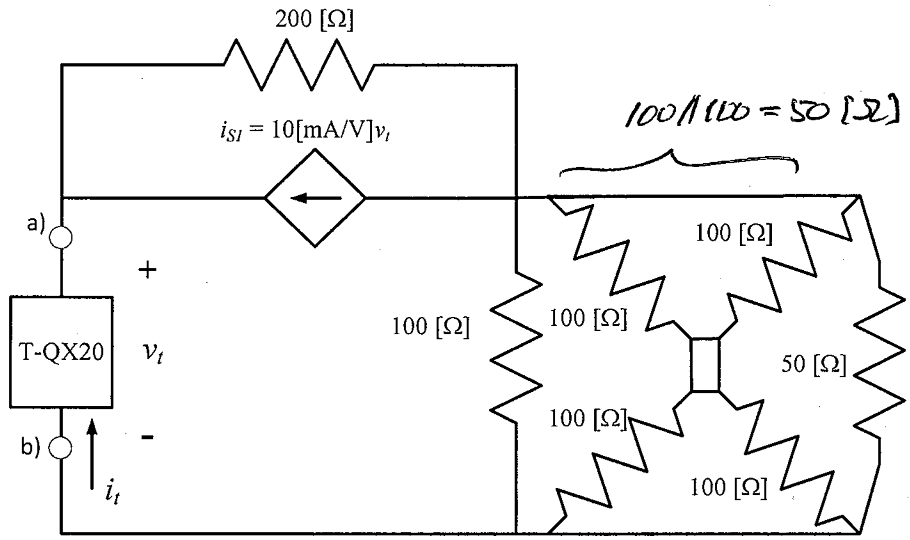




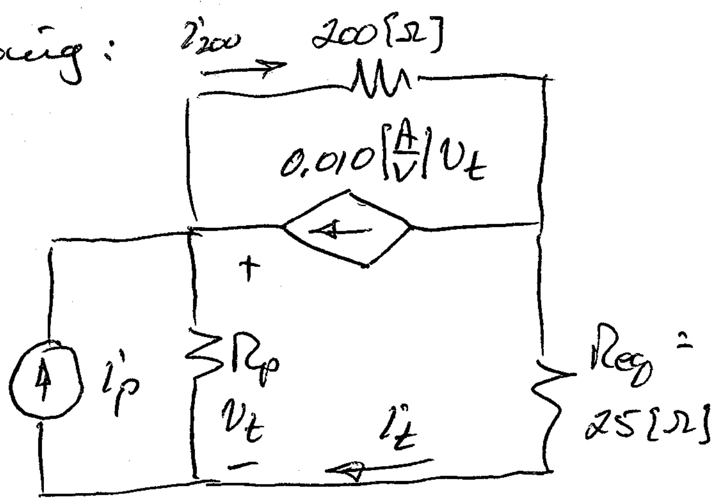
100 // 100 = 50 [Ω]

50 + 50 = 100 [Ω]

R_{eq} = 100// 100 //50 = 25 [Ω]

We have that $P_{del\ by\ QX20} = v_t \cdot i_t$, so we will need to find v_t. We first simplify the resistor network.

Re-drawing:



Room for extra work

KVL: $-v_t + 200 i_{200} + 25 i_t = 0$

KCL: $i_{200} = 0.01 [\frac{A}{V}] v_t + i_t$

$\therefore \quad -v_t + 200 (0.01 v_t + i_t) = 0$

$\Rightarrow \boxed{v_t = -225 i_t} = -225 (0.350 e^{-t/0.02[s]} [A])$

$= -78.75 [V] e^{-t/0.02[s]}$

a)

So $P_{del\ by\ QX20} = -225 (0.350)^2 e^{-2t/0.02[s]} [W]$

$W_{del\ by\ QX20} = \int_0^{400 \times 10^{-6}[s]} (-27.56) e^{-t/0.01[s]} dt = 10.8 [mJ]$

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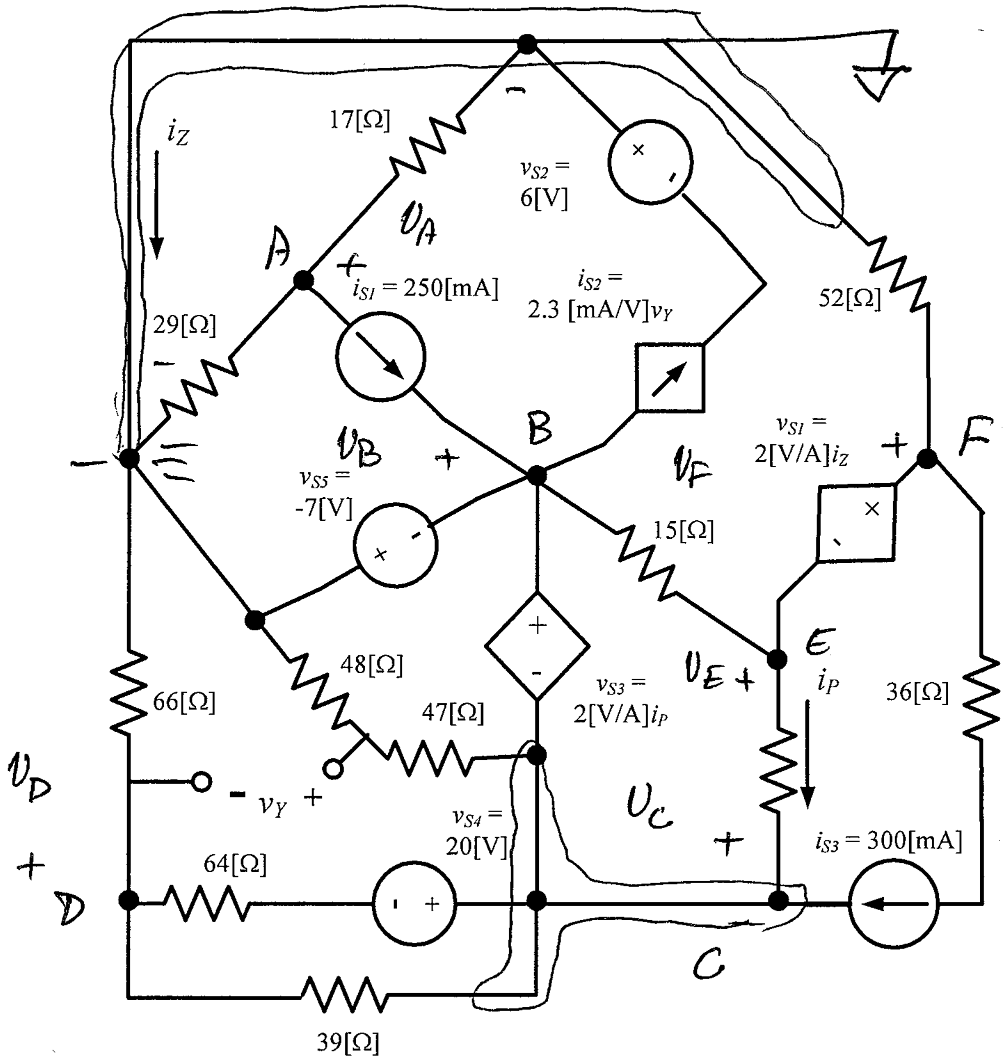
b) We need an expression for i_p:

$$i_p = i_t + \frac{v_p}{R_p} = i_t - \frac{225 i_t}{R_p} = 3.25 i_t$$

So $\boxed{i_p(t) = 1.138 e^{-t/0.02[s]}} [A]$

2. (40 points) Use the Node Voltage Method to find 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.



A: $\frac{v_A}{17} + 0.250\,[A] + \frac{v_A}{29} = 0$ B: $v_B = 7\,[V]$

C: $v_C = -2\,[\frac{V}{A}]\,i_P + 7\,[V]$ D: $\frac{v_D}{66} + \frac{v_D - v_C + 20}{64} + \frac{v_D - v_C}{39} = 0$

E, F: $\frac{v_F}{52} + 0.3\,[A] + \frac{v_E - v_C}{23} + \frac{v_E - v_B}{15} = 0$

$v_F - v_E = 2\,[\frac{V}{A}]\,i_Z$

Auxiliary Eqns.

Room for extra work

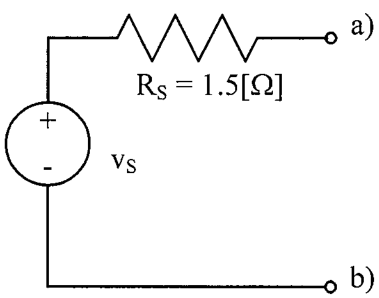
$$i_g' = \frac{v_A}{17} + 0.023 \left[\frac{A}{V}\right] v_Y + \frac{v_F}{52}$$

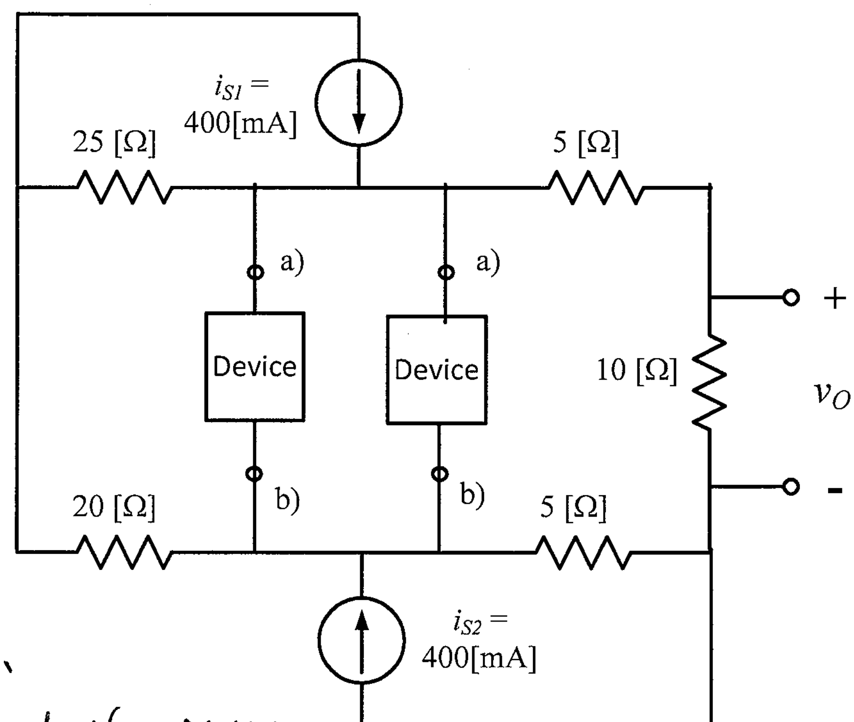
$$v_y = \frac{v_C}{(47+48)} \cdot 48 - v_D$$

$$i_p' = \frac{v_E - v_C}{23}$$

3. (40 points) A device (which is not as good as the Trombettamax T-QX20) can be modeled by a voltage source in series with a resistance, as shown in the figure to the left. The value of the voltage source is unknown. Two identical such devices are inserted into the circuit as shown, with terminals connected as indicated in the circuit diagram. In this configuration, the output voltage v_o is known to be - 5.571 [V].

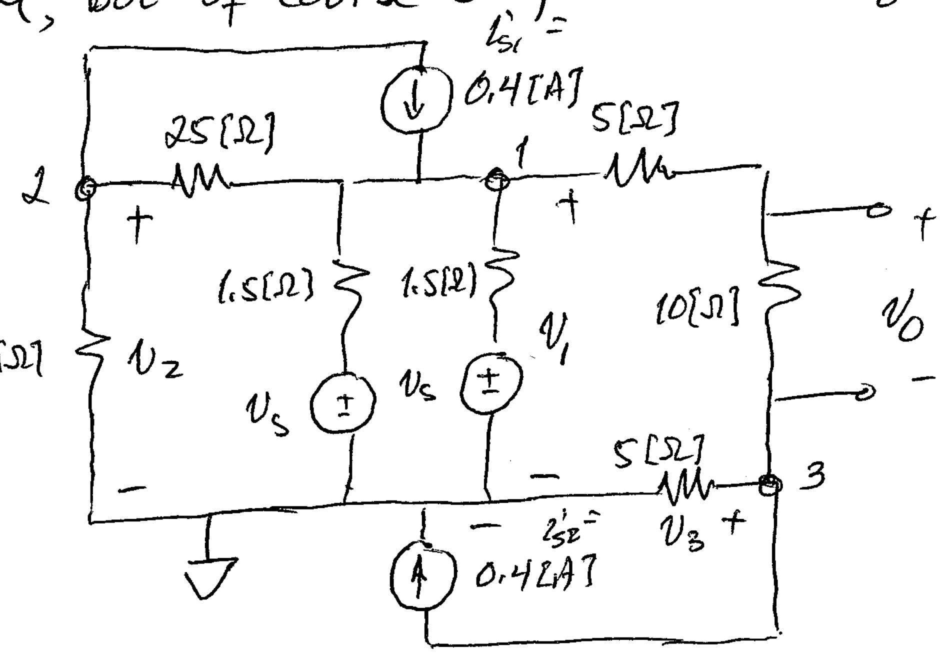
If the current source i_{S2} is removed from the circuit, what is the new output voltage v_o?





We need to find V_s ...

We'll solve this using both NVM and MCM, but of course only one was required.



Room for extra work

$$2\,\frac{V_1-V_S}{1.5} - 0.4 + \frac{V_1-V_2}{25} + \frac{V_1-V_3}{15} = 0$$

$$\frac{V_2-V_1}{25} + 0.4 + \frac{V_2}{20} = 0$$

$$\frac{V_3}{5} + 0.4 + \frac{V_3-V_1}{15} = 0$$

$V_1 = -13.142$ [V]

$V_2 = -10.285$ [V]

$V_3 = -4.7855$ [V]

$V_S = -13.645$ [V]

$$\frac{V_1-V_3}{15}\cdot 10 = -5.571 \text{ [V]}$$

Now we remove i_{S2} ... Node 3 is no longer an essential node:

$$2\left(\frac{V_1+13.645}{1.5}\right) - 0.4 + \frac{V_1-V_2}{25} + \frac{V_1}{20} = 0$$

$$\frac{V_2-V_1}{25} + 0.4 + \frac{V_2}{20} = 0$$

$V_1 = -12.786$ [V]

$V_2 = -10.127$ [V]

$$V_0 = V_1\cdot\frac{10}{20} = -6.393 \text{ [V]}$$

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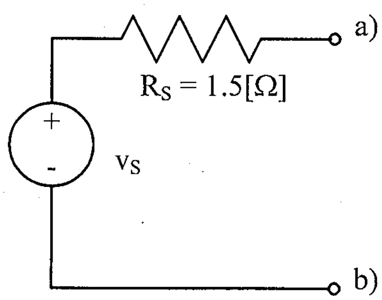
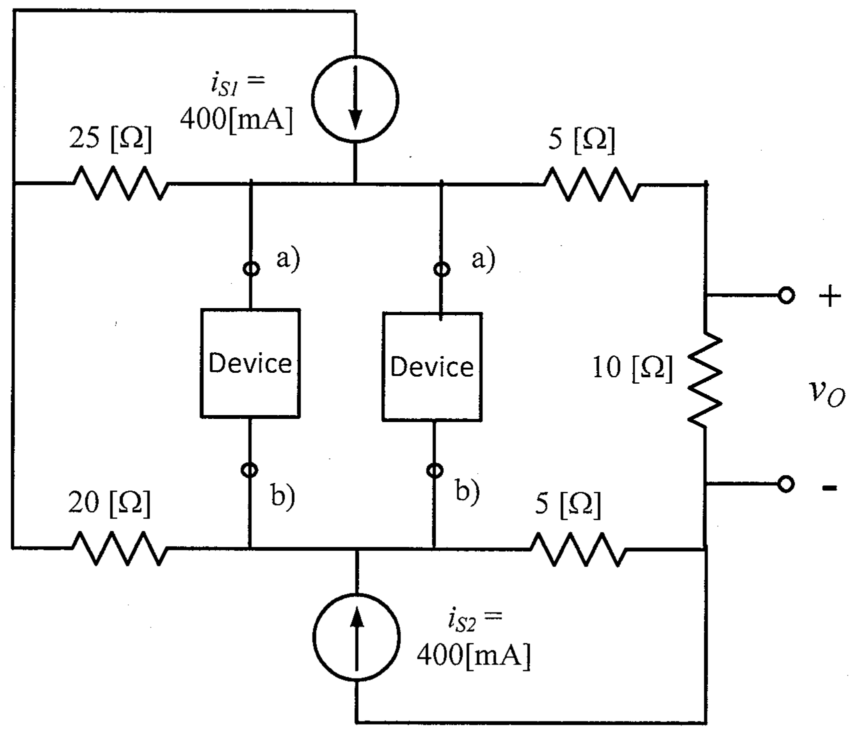
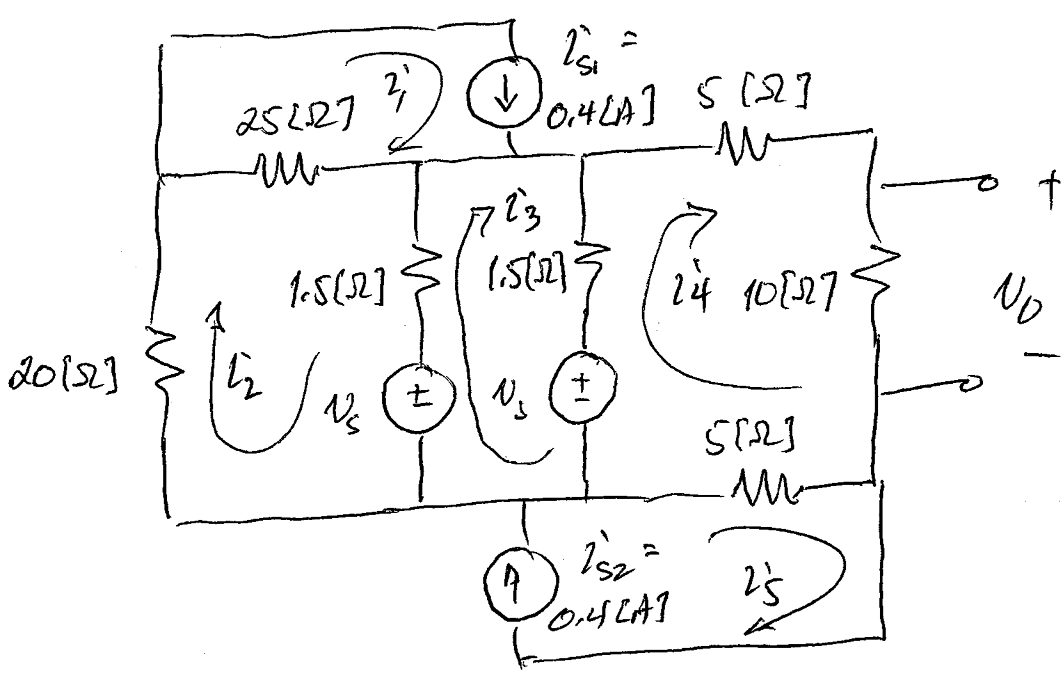




Re-do with MCM



Room for extra work

$i_1' = 0.4$ [A] $i_5' = 0.4$ [A]

$25(i_2' - 0.4) + 1.5(i_2' - i_3') + v_s + 20 i_2' = 0$

$1.5(i_3' - i_4') + 1.5(i_3' - i_2') + \cancel{v_s} - \cancel{v_s} = 0$

$15 i_4' + 5(i_4' - 0.4) - v_s + 1.5(i_4' - i_3') = 0$

$10 i_4' = -5.571$ [V]

$i_2' = 0.5143$ [A] $i_3' = -0.0214$ [A] $i_4' = -0.5571$ [A]

$v_s = -13.945$ [V] (a bit different from NUM...)

Now with i_{s2}' removed...

$25(i_2' - 0.4) + 1.5(i_2' - i_3') - 13.945 \text{ [V]} + 20 i_2' = 0$

$1.5(i_3' - i_2') + 1.5(i_3' - i_4') = 0$

$20 i_4' + 13.945 \text{ [V]} + 1.5(i_4' - i_3') = 0$

$i_2' = -0.5127$ [A] $i_3' = -0.0704$ [A] $i_4' = -0.6535$ [A]

$v_0 = 10 i_4 = -6.535$ [V]