Name: ______________________________ (please print)

Signature: ___________________________

Section (underline one): Trombetta   Shattuck

ECE 2300 – Exam #2
April 14, 2012

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. 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. **<u>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.</u>**
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 90 minutes to work on this quiz.

1. ________________/30

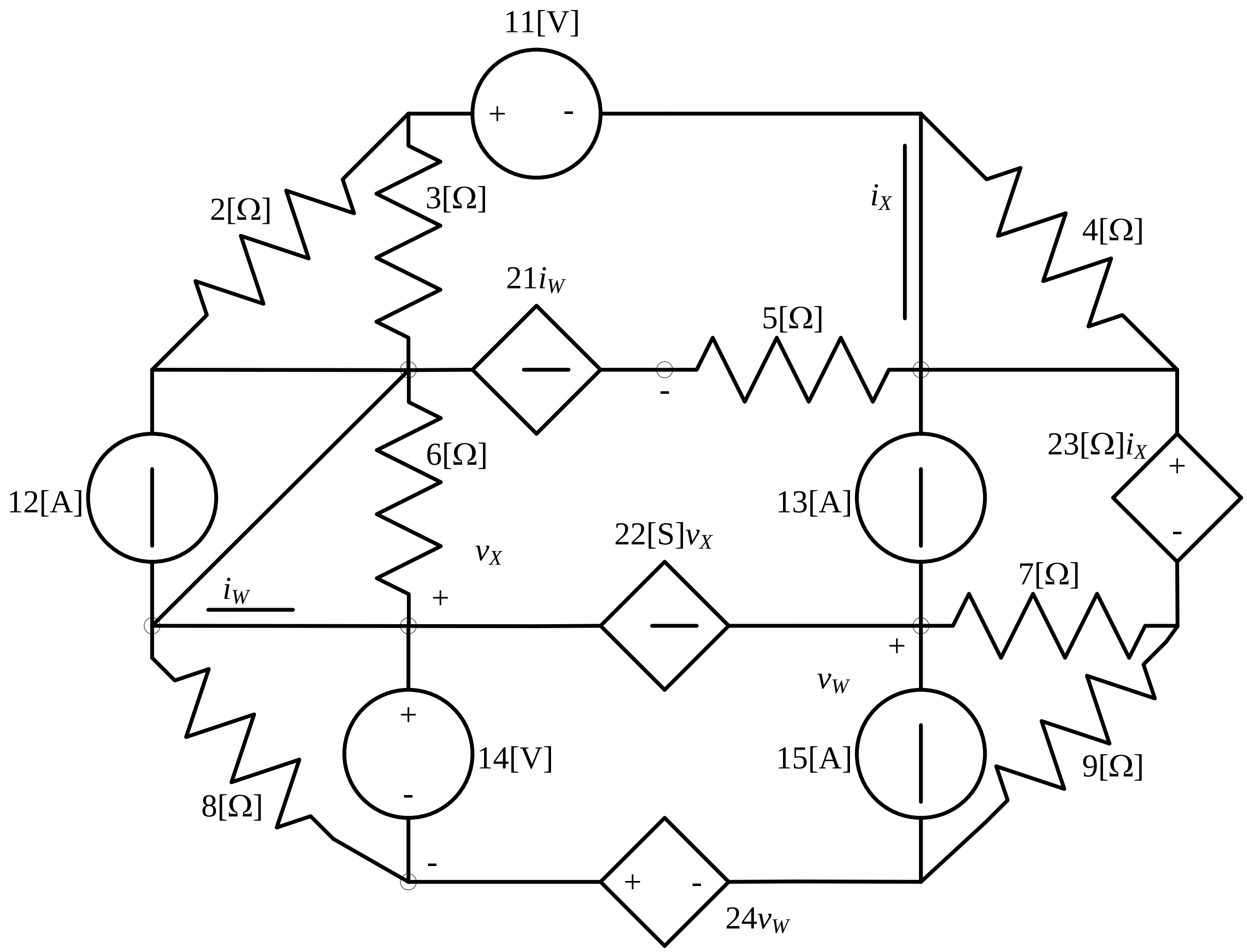
2. ________________/35

3. ________________/35

Total________________/100

Room for extra work

1. (30 points) Use either the node voltage method or the mesh current method to write a complete set of equations that could be used to solve the circuit below. Do not simplify the circuit. Do not attempt to solve the equations. You must define all circuit variables.

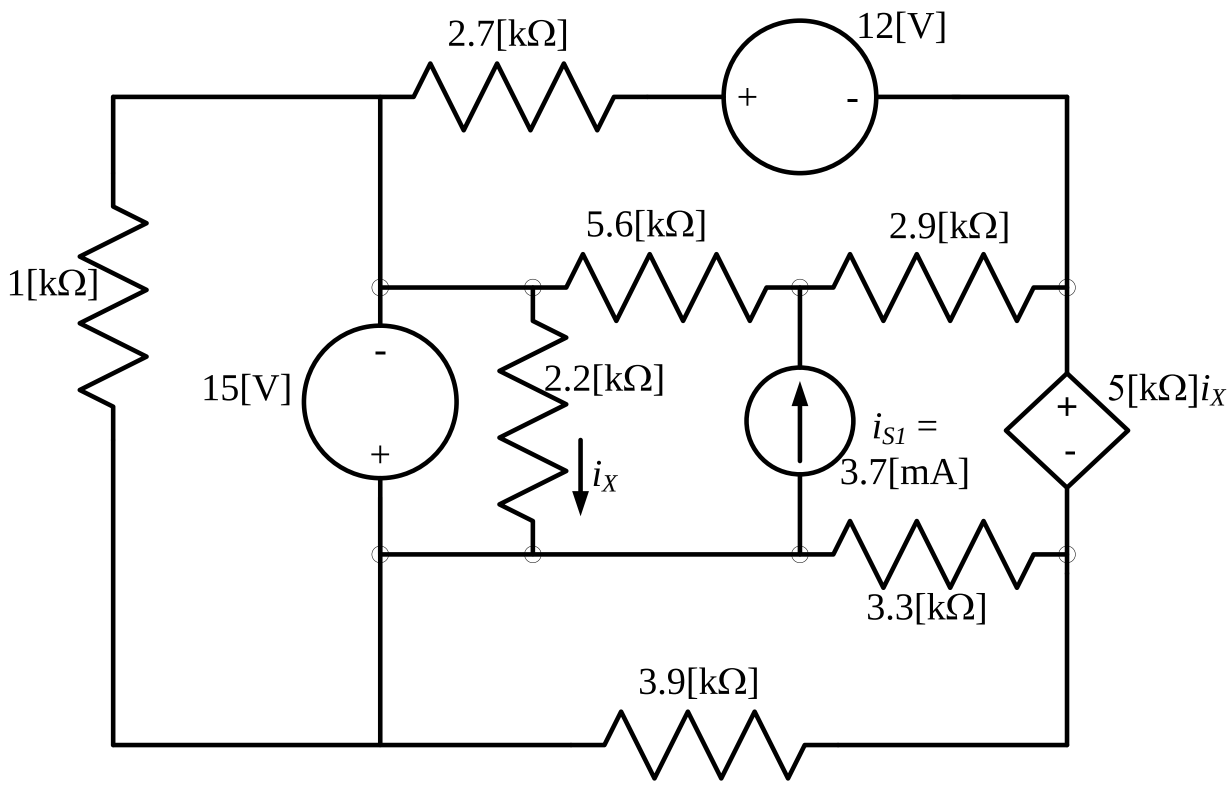


Room for extra work

2. (<u>35 points</u>) For the circuit shown below, do the following.

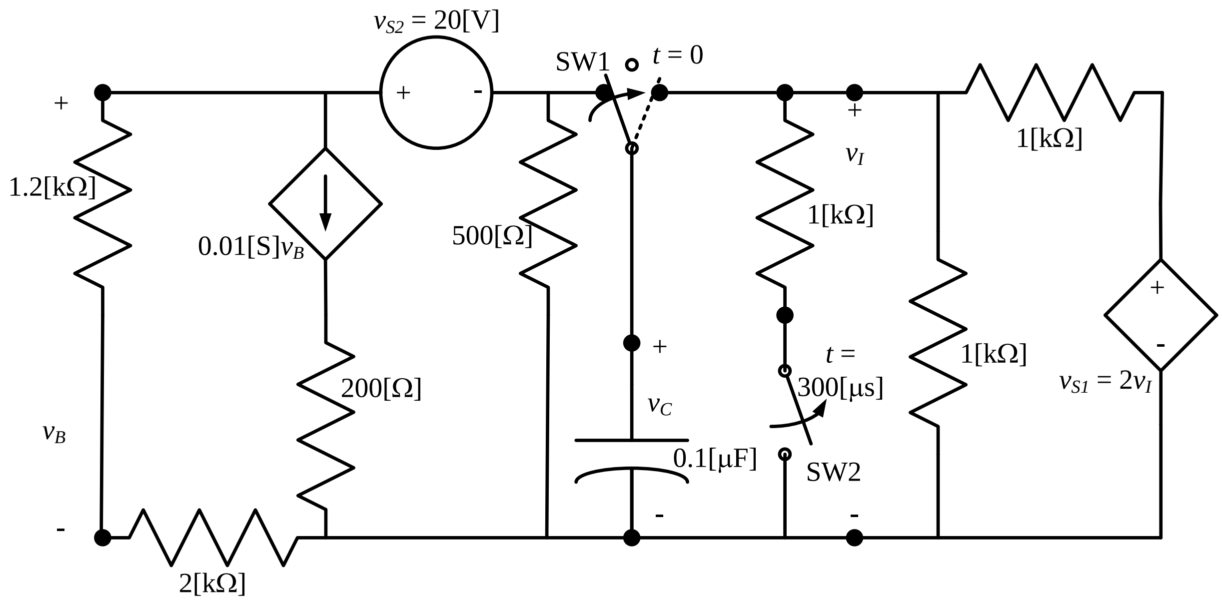
a) Find the Thevenin equivalent circuit as seen by the current source i_{S1}. Draw the equivalent circuit. Clearly label the equivalent circuit parameters, and show how it is connected to the current source.

b) Find the power absorbed by the current source i_{S1} in this circuit.



Room for extra work

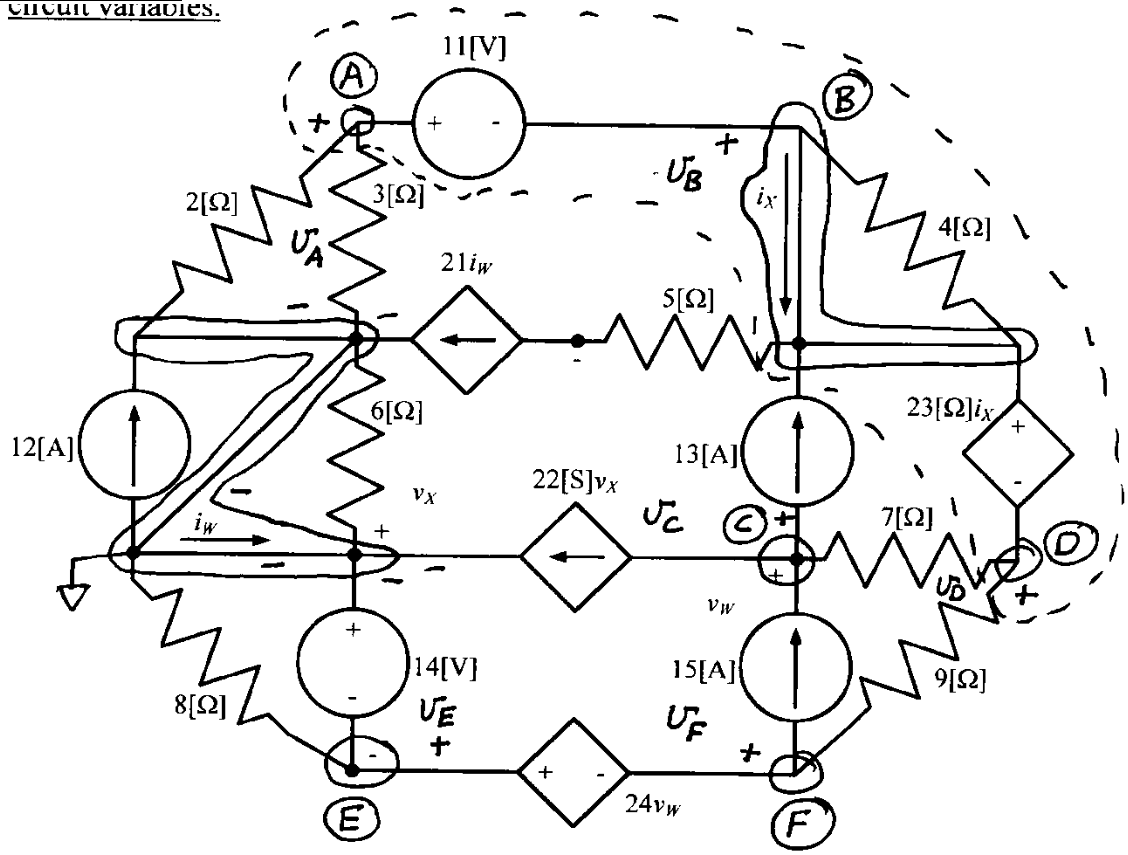
3. (35 points) In the circuit below, the switch SW1 was in the left-most position for a long time, and switch SW2 was closed for a long time. At $t = 0$, switch SW1 moved to the right-most position. At $t = 300$ [μs], switch SW2 opened. Find expressions for $v_C(t)$ for t 0.



Solution:

1. (<u>30 points</u>) Use either the node voltage method or the mesh current method to write a complete set of equations that could be used to solve the circuit below. Do not simplify the circuit. Do not attempt to solve the equations. <u>You must define all circuit variables.</u>

circuit variables.



First, using the node-voltage method. We define the node voltages on the diagram above. We will need to write 10 equations (7-1 +4).

A+B+D $\quad \dfrac{v_A}{3[\Omega]} + \dfrac{v_A}{2[\Omega]} + \dfrac{v_D - v_F}{9[\Omega]} + \dfrac{v_D - v_C}{7[\Omega]} - 13[A] + 21 i_W = 0$

A+B $\quad v_A - v_B = 11[V]$

B+D $\quad v_B - v_D = 23[\Omega] i_X$

see next page

1.) Node Voltage Method Continued.

C $\quad 13[A] + \dfrac{v_C - v_D}{7[\Omega]} + \left(-15[A]\right) + 22[s]\, v_x = 0$

E $\quad v_E = -14[V]$

E+F $\quad v_E - v_F = 24\, v_w$

v_x $\quad v_x - (21\, i_w)\, 5[\Omega] + v_B = 0$

v_w $\quad v_w = v_C - v_E$

i_w $\quad -i_w + \dfrac{0-0}{6[\Omega]} - 22[s]\, v_x + 15[A] + \dfrac{v_F - v_D}{9[\Omega]} + \dfrac{v_E}{8[\Omega]} = 0$

i_x $\quad i_x + \dfrac{v_A}{3[\Omega]} + \dfrac{v_A}{2[\Omega]} + \dfrac{0-0}{4[\Omega]} = 0$

See next page for the Mesh-Current method solution.

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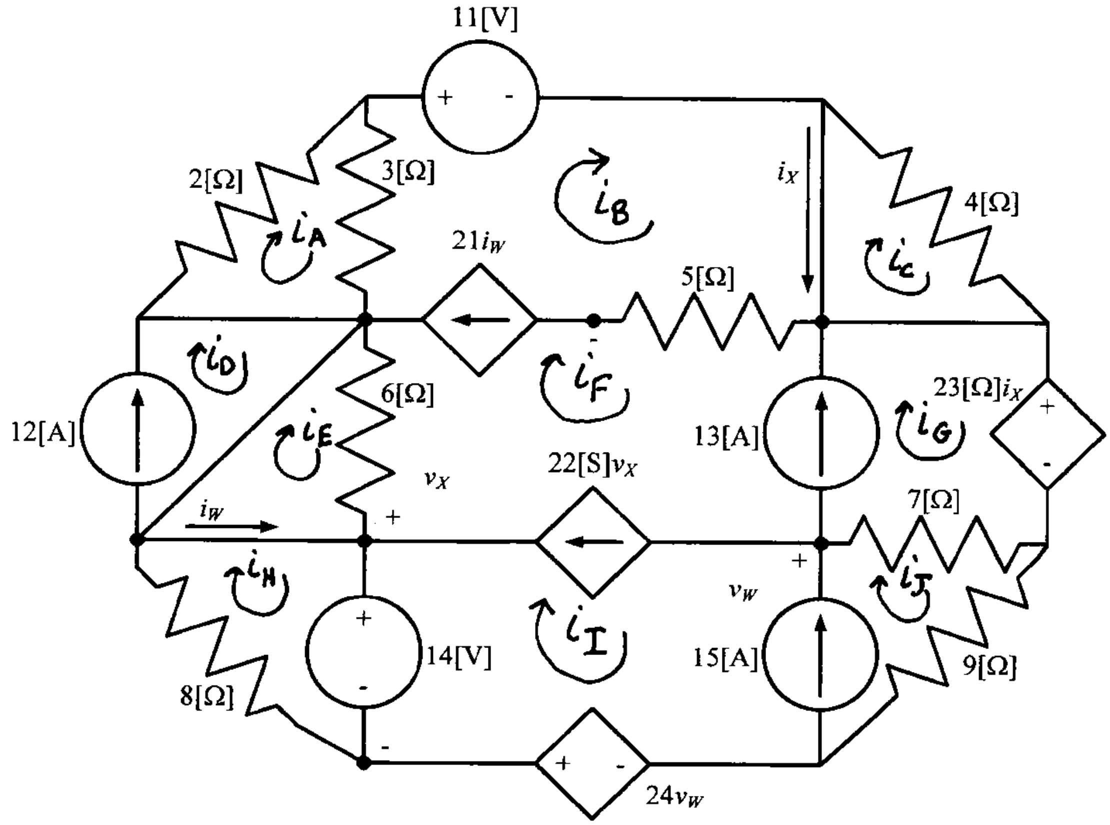


The alternative was to use the mesh-current method. We define the mesh currents on the diagram above. We will need to write 14 equations (10+4).

(A) $i_A\, 2[\Omega] + (i_A - i_B)\, 3[\Omega] = 0$

see next page

Room for extra work

B+F+G+I+J $(i_B - i_A)\, 3\{\Omega\} + 11\{V\} + 23\{\Omega\}\, i_X +$
$i_J\, 9\{\Omega\} - 24\, v_W - 14\{V\} + (i_F - i_E)\, 6\{\Omega\} = 0$

B+F $i_B - i_F = 21\, i_W$

F+G $i_G - i_F = 13\{A\}$

F+I $i_F - i_I = 22\{S\}\, v_X$

I+J $i_J - i_I = 15\{A\}$

C $i_C\, 4\{\Omega\} = 0$

D $i_D = 12\{A\}$

E $(i_E - i_F)\, 6\{\Omega\} = 0$

H $i_H\, 8\{\Omega\} + 14\{V\} = 0$

i_W $i_W = i_H - i_E$

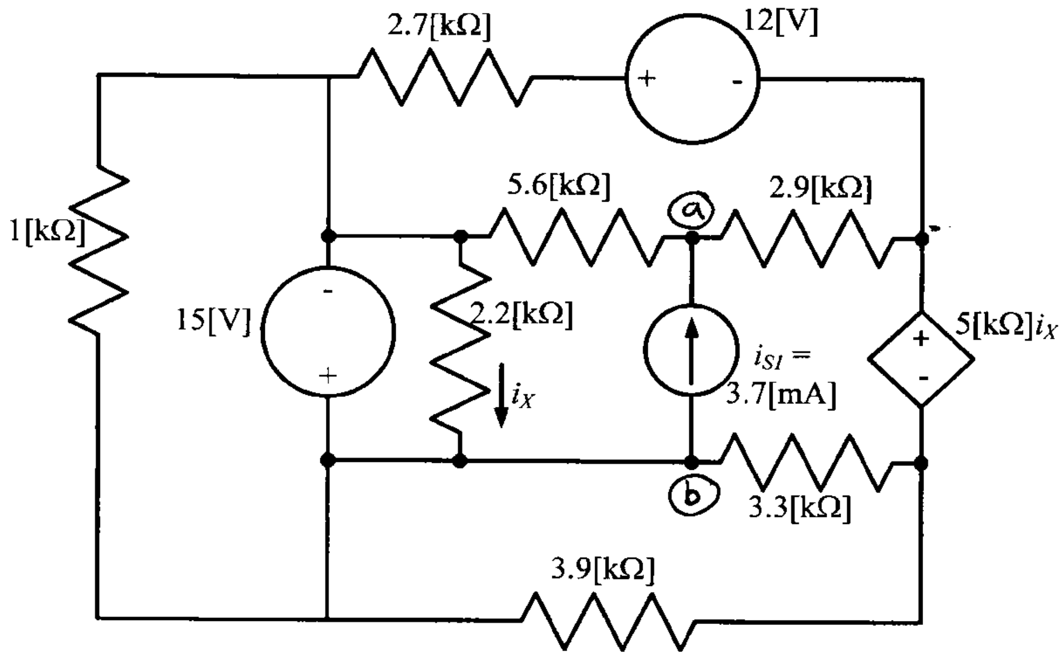
i_X $i_X = i_B - i_C$

v_W $-v_W + (i_J - i_G)\, 7\{\Omega\} + (i_J)\, 9\{\Omega\} - 24\, v_W = 0$

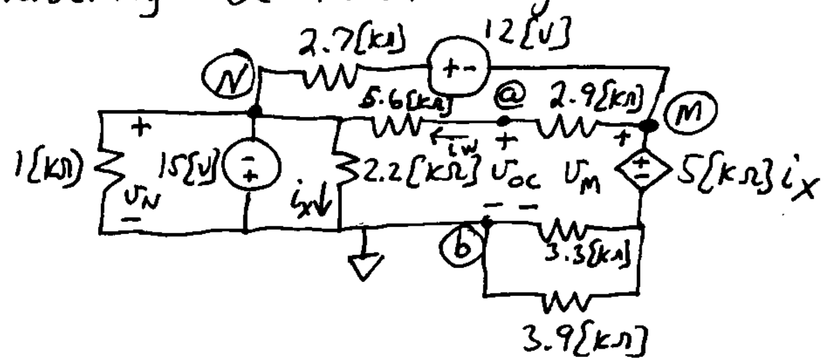
v_X $-v_X + i_A\, 2\{\Omega\} + 11\{V\} + (i_B - i_F)\, 5\{\Omega\} = 0$

2. (35 points) For the circuit shown below, do the following.

a) Find the Thevenin equivalent circuit as seen by the current source i_{S1}. Draw the equivalent circuit. Clearly label the equivalent circuit parameters, and show how it is connected to the current source.
b) Find the power absorbed by the current source i_{S1} in this circuit.



We choose to find v_{OC}. Remove i_{S1}, and redraw, labelling v_{OC} in the diagram.



$v_N = -15[V]$

$3.3[k\Omega] || 3.9[k\Omega] = 1.788[k\Omega]$

$$i_X = \frac{-15[V]}{2.2[k\Omega]}$$

$i_X = -6.818[mA]$

see next page

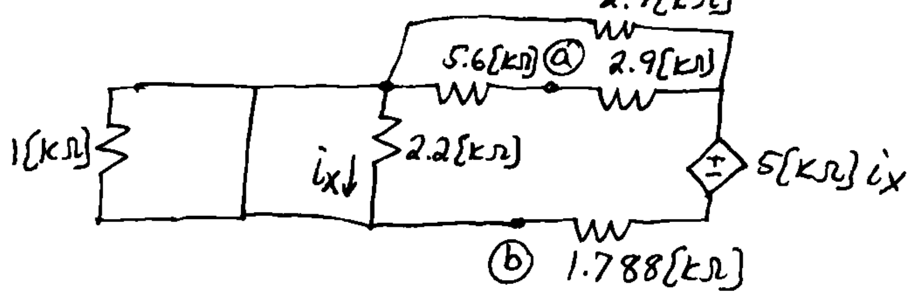
$$\frac{v_M + 15[V]}{8.5[k\Omega]} + \frac{v_M + 12[V] + 15[V]}{2.7[k\Omega]} + \frac{v_M - 5[k\Omega]\,i_X}{1.788[k\Omega]} = 0$$

Solving: $v_M = -29.44[V]$

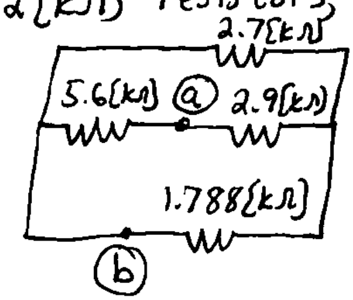
$$i_W = \frac{v_M + 15[V]}{8.5[k\Omega]} = -1.699[mA]$$

$$v_{OC} = -15[V] + i_W\,5.6[k\Omega] = -24.51[V]$$

Next, to get R_{EQ}, we set the independent sources $= 0$, and redraw



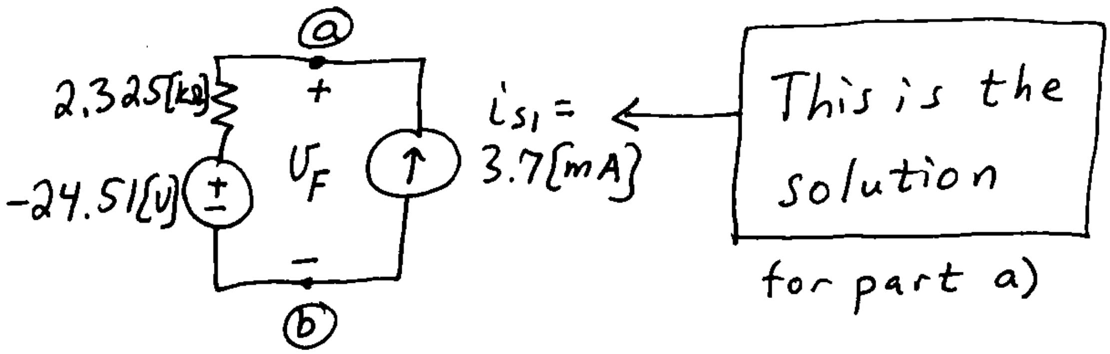
$i_X = 0$, so $5[k\Omega]i_X = 0$, and shorting the $1[k\Omega]$ and $2.2[k\Omega]$ resistors, we have $R_{EQ} =$



$$\left(\left((2.7 \| 1.788) + 2.9\right) \| 5.6\right)[k\Omega]$$

$$R_{EQ} = 2.325[k\Omega]$$

see next page



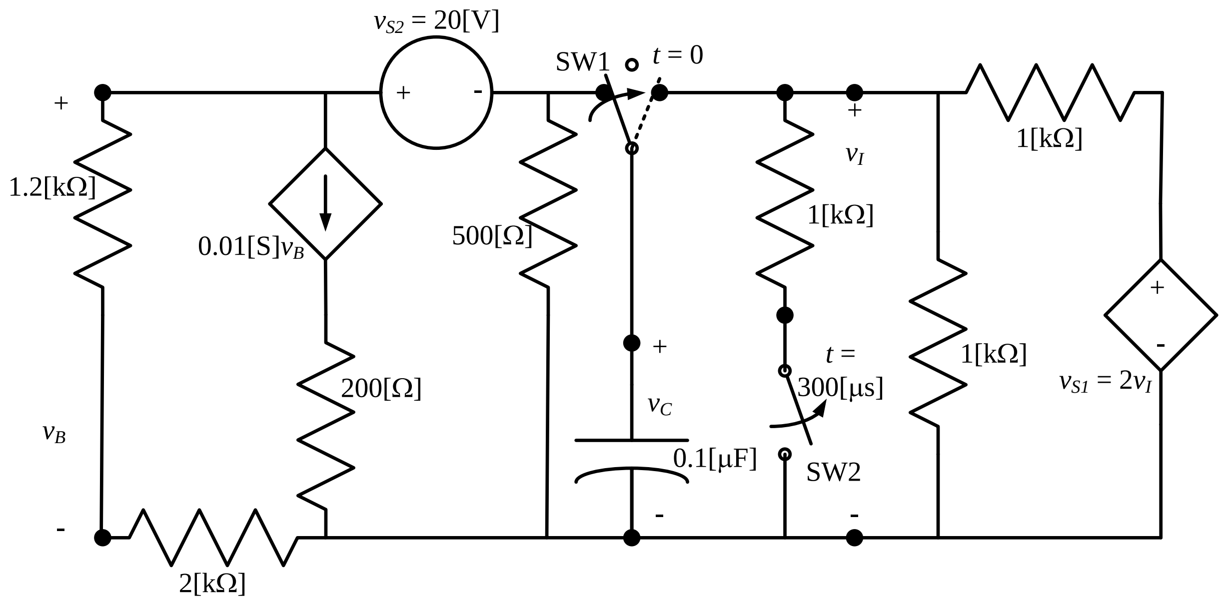
b) $v_F = -24.51[V] + (3.7[mA])(2.325[k\Omega])$

$v_F = -15.91[V]$

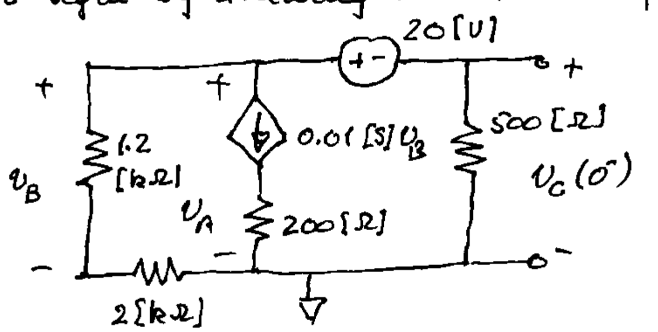
$p_{ABS.\,BY\,i_{S1}} = -v_F\, i_{S1} = -(-15.91[V])(3.7[mA])$

$= \boxed{58.86[mW]}$

3. (35 points) In the circuit below, the switch SW1 was in the left-most position for a long time, and switch SW2 was closed for a long time. At $t = 0$, switch SW1 moved to the right-most position. At $t = 300$ [μs], switch SW2 opened. Find expressions for $v_C(t)$ for t 0.



We begin by drawing the circuit for $t < 0$:



We are in steady state so the capacitor is an open circuit.

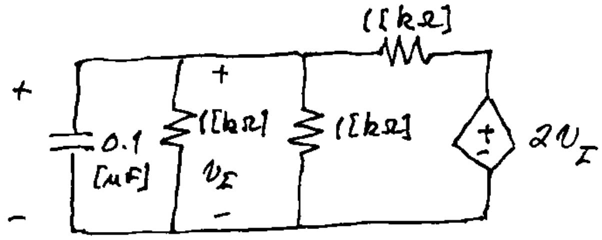
Node voltage: $$0.01\, v_B + \frac{v_A}{3200} + \frac{v_A - 20}{500} = 0$$

$$v_B = v_A \cdot \frac{1200}{3200} \quad \Rightarrow \quad v_A = 6.598 \text{ [V]}$$

$$\Rightarrow v_C(0^-) = v_C(0^+) = v_A - 20 = -13.40 \text{ [V]}$$

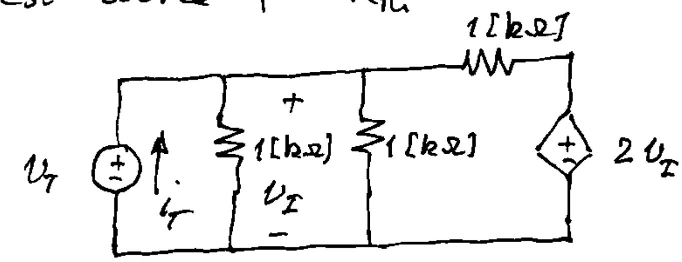
Re-draw for $0 < t < 300\,[\mu s]$:

There are no independent sources so this is a natural response.



$$v_C(t) = v_C(0^+)\,e^{-t/\tau_c} \qquad \tau_c = R_{Th}\cdot C$$

We need a test source for R_{Th}:



$$i_T = \frac{v_T}{1000} + \frac{v_T}{1000} + \frac{v_T - 2v_T}{1000} \qquad (v_I = v_T)$$

$$= v_T\left(\frac{1}{1000} + \frac{1}{1000} + \frac{1}{1000} - \frac{2}{1000}\right) = \frac{1}{1000}$$

$$\therefore\ R_{Th} = \frac{v_T}{i_T} = 1000\,[\Omega] \Rightarrow \tau_c = 1\,[ms]$$

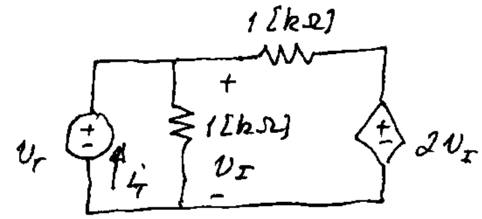
So

$$\underline{v_C(t) = -13.40\,e^{-t/0.001[s]}\,[V] \quad 0 \le t \le 300\times10^{-6}\,[s]}$$

Re-draw for $t > 300\,[\mu s]$. We will show the test source as well:

$t > 300$ [μs]

Again a natural response...



$$i_T = \frac{v_I}{1000} + \frac{v_T - 2v_I}{1000} \qquad (v_I = v_T)$$

$$= v_T\left(\frac{1}{1000} + \frac{1}{1000} - \frac{2}{1000}\right) = 0 \quad !$$

$$\text{So } R_{Th} = \infty \Rightarrow \tau_C = \infty \quad !$$

What this means is that this is not a natural response problem. There is no current through the capacitor at $t > 300$ [μs] so the voltage does not change. Formally,

$$i_C \longrightarrow C \qquad + \; v_C \; -$$

$$i_C = C\frac{dv_C}{dt} = 0 \Rightarrow v_C = \text{constant}$$

So

$$v_C(300[\mu s]^-) = v_C(300[\mu s]^+) = -13.40\, e^{-t/0.001\,[s]}\Big|_{t=300\,[\mu s]}$$

$$= -13.40\, e^{-300\times10^{-6}/1000\times10^{-6}}$$

$$= -13.40\, e^{-0.3} = -9.927\ [V] \qquad t \geq 300\ [\mu s]$$

Summarizing:

$$v_C(t) = -13.40\, e^{-t/0.001[s]}\ [V] \qquad 0 \leq t \leq 300\ [\mu s]$$

$$v_C(t) = -9.927\ [V] \qquad t \geq 300\ [\mu s]$$