Name: _____________________________ (please print)

Signature: __________________________

Section (underline one): Trombetta   Shattuck

ECE 2300 – Final Exam
May 4, 2013

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. **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 170 minutes to work on this exam.

1. ________________/30   2. ________________/20

3. ________________/20   4. ________________/20

5. ________________/40   6. ________________/30

7. ________________/40

Total________________/200

Room for extra work

1. (30 points) When a 2[kΩ] resistor is connected to terminals a and b in the circuit in Figure 1, the current i_O as defined in Figure 2 is -2.119[A]. When that 2[kΩ] resistor is removed, and a current source of 120[mA] is connected between terminals a and b in its place, the voltage v_O as defined in Figure 3 is 750.46[V]. If then a -120[V] voltage source is connected in place of the current source between a and b, what will be the current i_Z as defined in Figure 4?

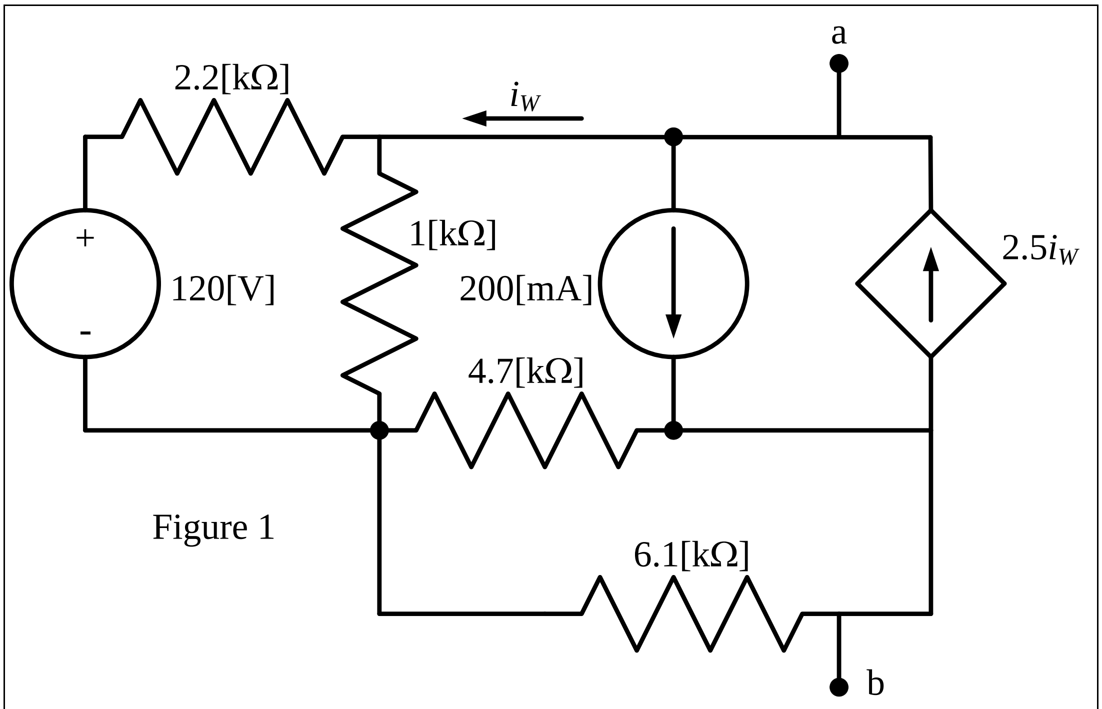


Figure 1

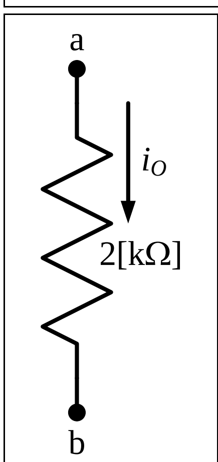


Figure 2

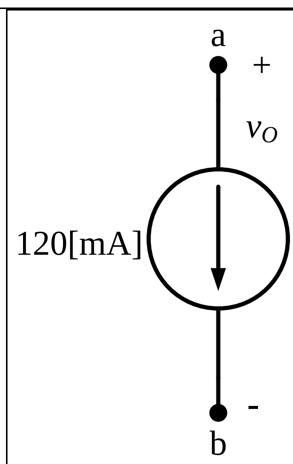


Figure 3

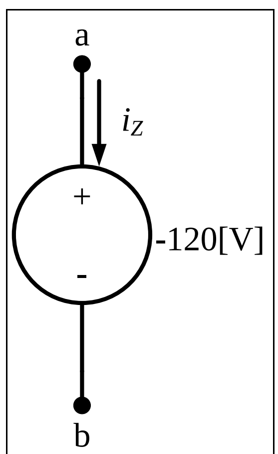
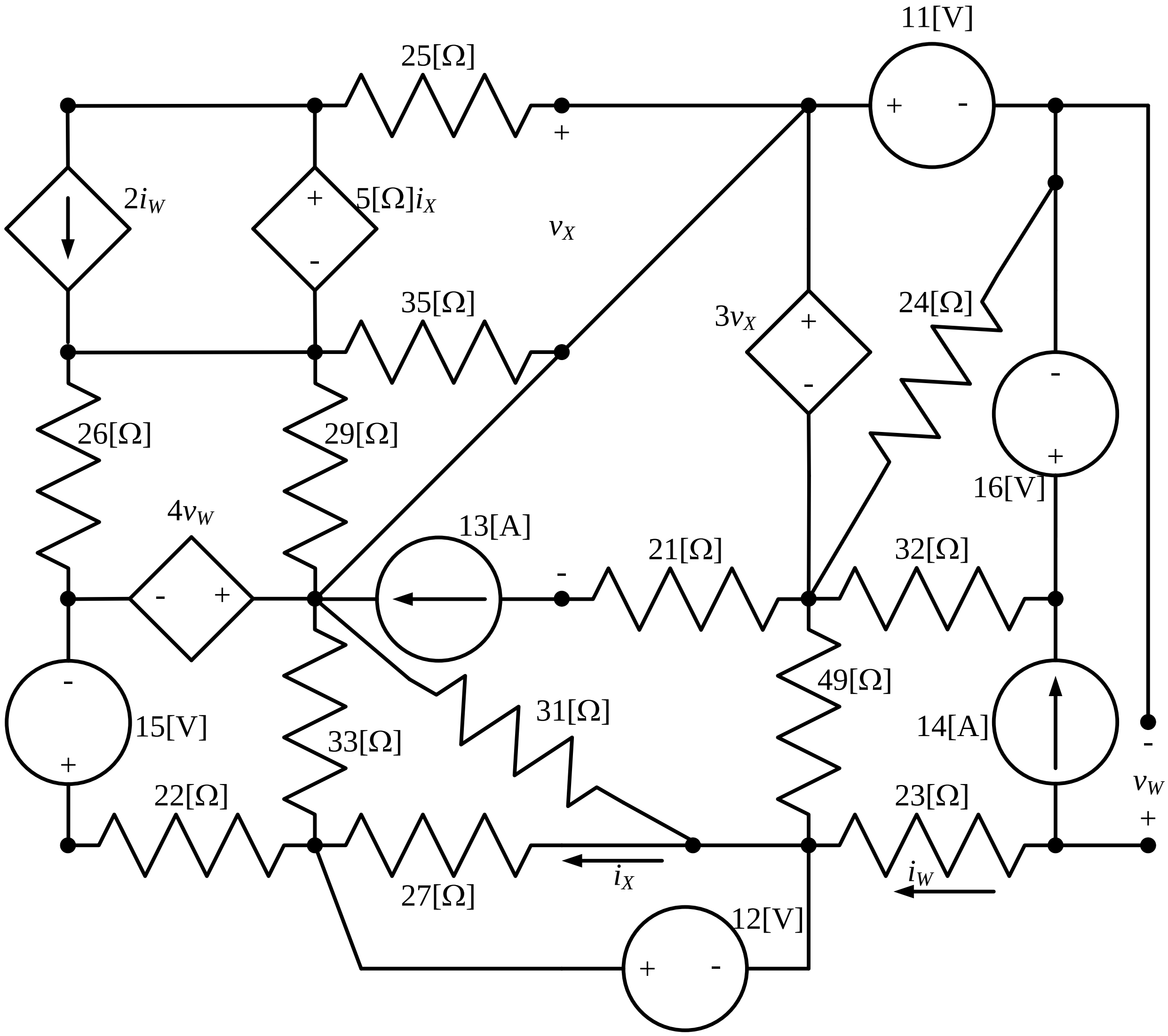


Figure 4

Room for extra work

2. (20 points) In the circuit below, find the power delivered by the dependent current source.

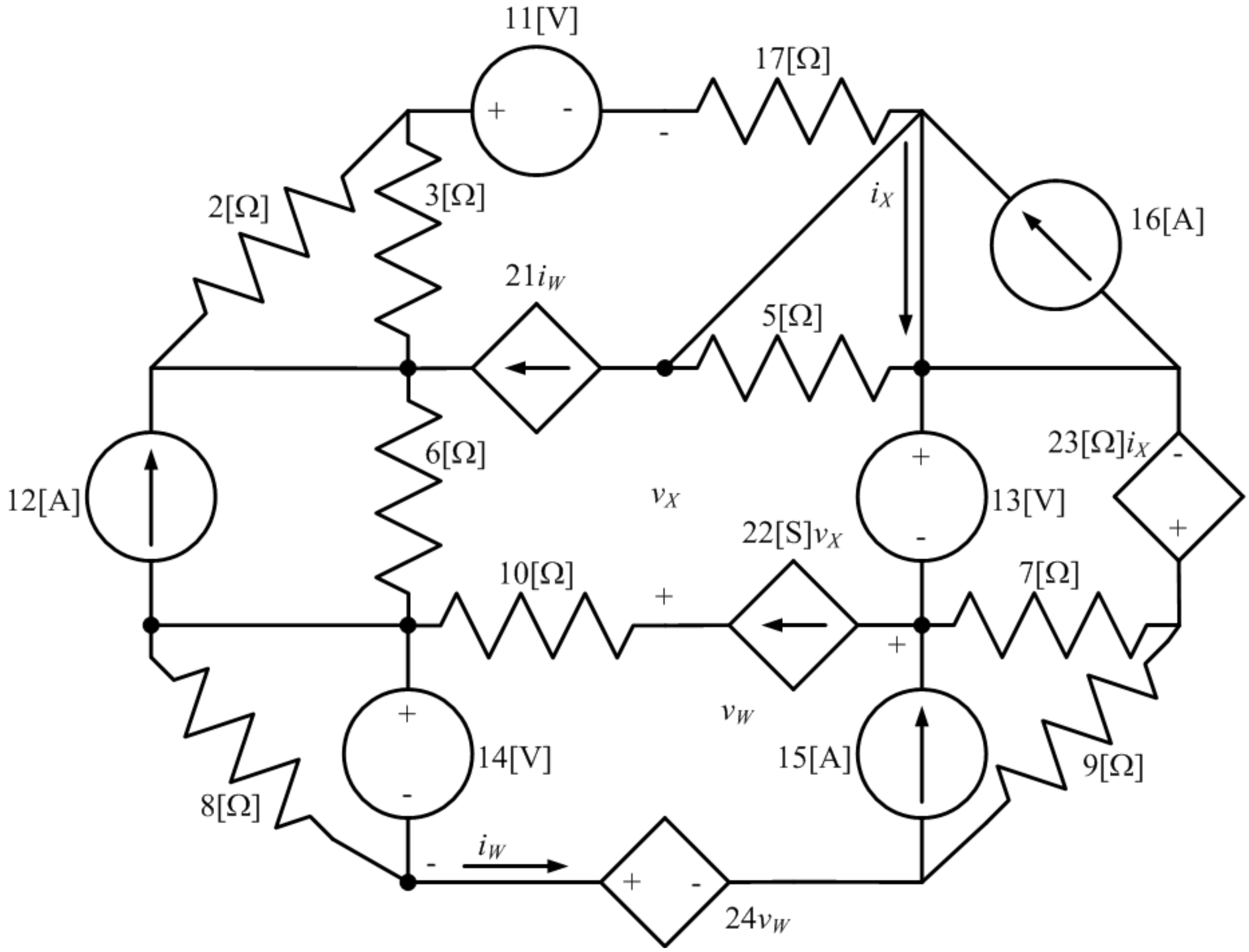


Room for extra work

3. (20 points) There are two separate voltmeters available for use in a laboratory. One voltmeter has a full-scale reading of 200[V], and has an equivalent resistance of 6.8[MΩ]. The second voltmeter has a full-scale reading of 150[V], and has an equivalent resistance of 25[MΩ]. The plan is to increase the range of voltages that can be measured by putting the two voltmeters in series, and placing the series combination across an unknown voltage. Find the largest voltage that can be measured using the two voltmeters in series, assuming that the voltage will be determined by adding the voltages measured on the two voltmeters.

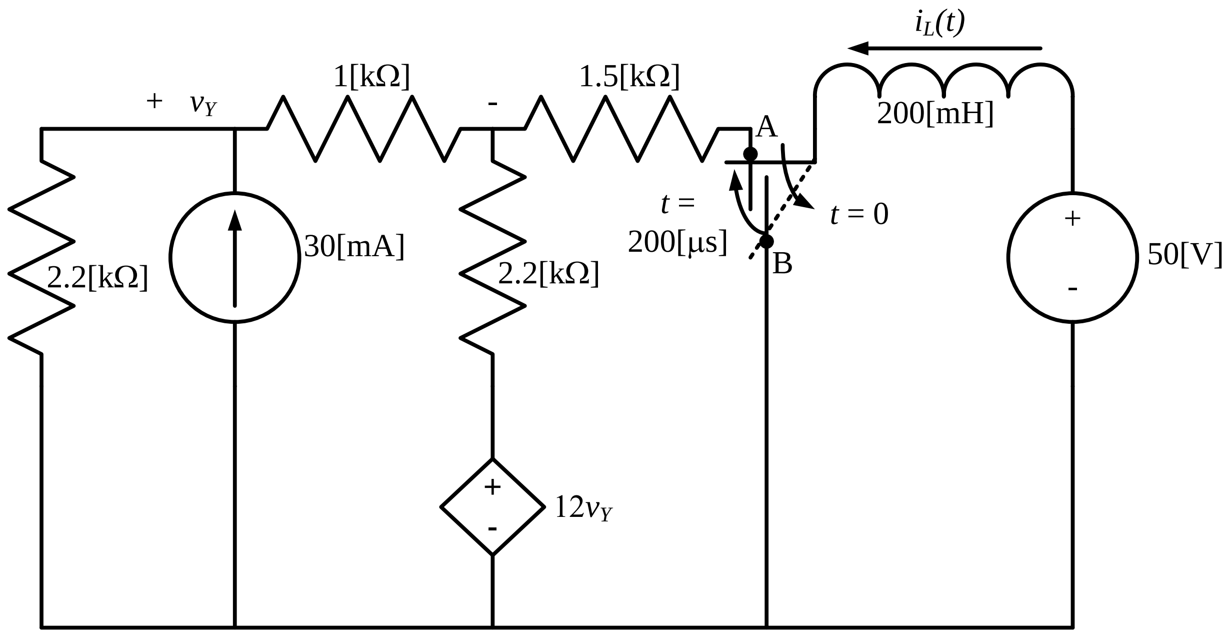
Room for extra work

4. (<u>20 points</u>) Use 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. Do not skip any meshes.</u>



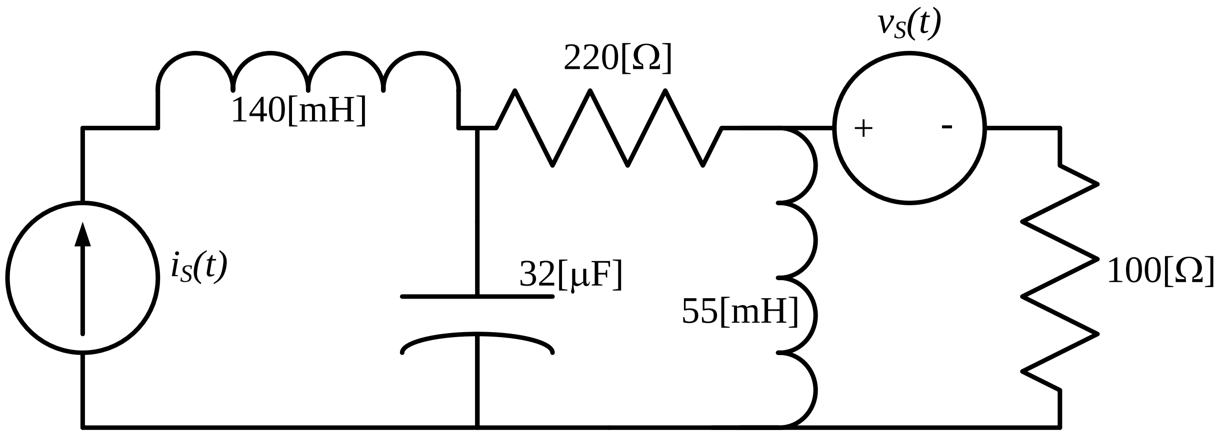
Room for extra work

5. (40 points) In the circuit given below, the switch was in position A for long time before it moved at $t = 0$ to position B. The switch then moved back to A at $t = 200[\mu s]$. Find $i_L(t)$ for $t \geq 200[\mu s]$.



Room for extra work

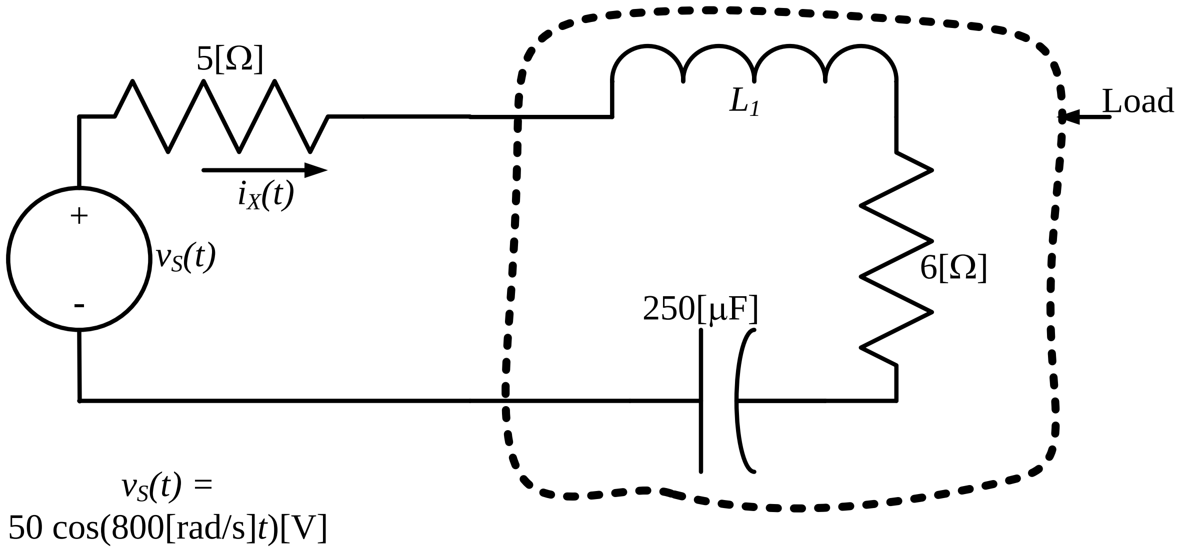
6. (30 points) Find the Thévenin impedance Z_{TH} as seen by the current source, at $\omega = 1500$[rad/s]. Draw a circuit model for Z_{TH}, modeling it either as a resistance in series with an inductor or as a resistance in series with a capacitor.



$v_S(t)$ = 15[V] sin(ωt + 20°)
$i_S(t)$ = 32[mA] cos(ωt - 22°)

Room for extra work

7. (40 points) In the circuit below, the load is enclosed with a dashed line.
a) Find the value of the inductance L_1 that will make the voltage $v_S(t)$ be in phase with the current $i_X(t)$.
b) Find the value of the power factor angle for the load that results from the value of L_1 found in part a).
c) Find the value of the power factor of the load, if L_1 = 3.9[mH]. Indicate whether this is a leading or a lagging power factor.
d) Find the apparent power absorbed by the load, if L_1 = 3.9[mH].



1. (30 points) When a 2[kΩ] resistor is connected to terminals a and b in the circuit in Figure 1, the current i_O as defined in Figure 2 is -2.119[A]. When that 2[kΩ] resistor is removed, and a current source of 120[mA] is connected between terminals a and b in its place, the voltage v_O as defined in Figure 3 is 750.46[V]. If then a -120[V] voltage source is connected in place of the current source between a and b, what will be the current i_Z as defined in Figure 4?

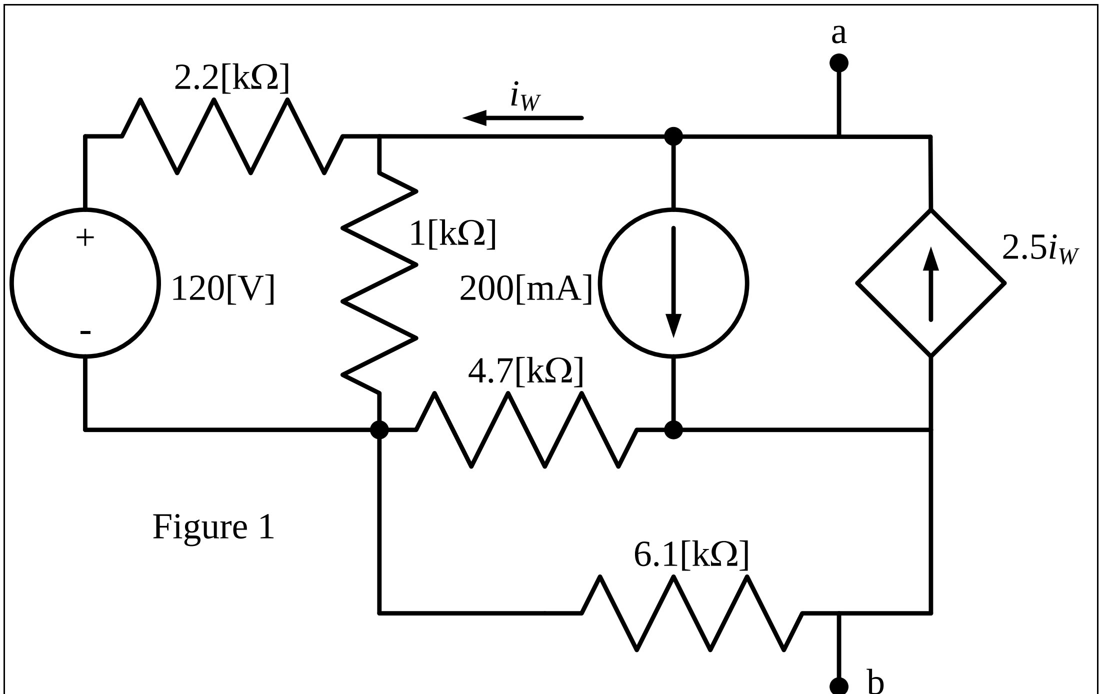


Figure 1

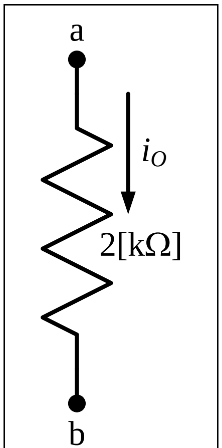


Figure 2

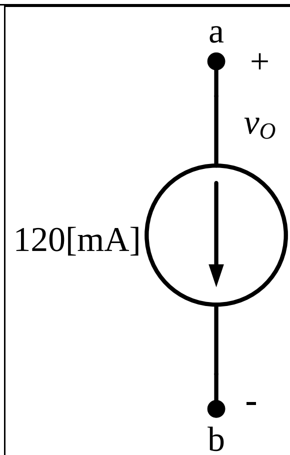


Figure 3

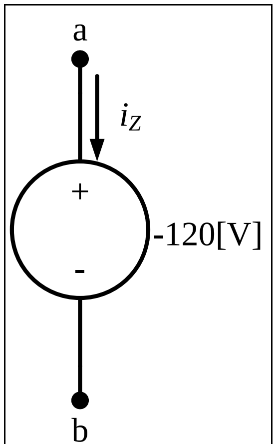
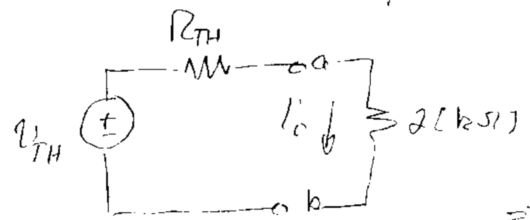


Figure 4

We have all the information we need from Figs. 2, 3, 4:

+4

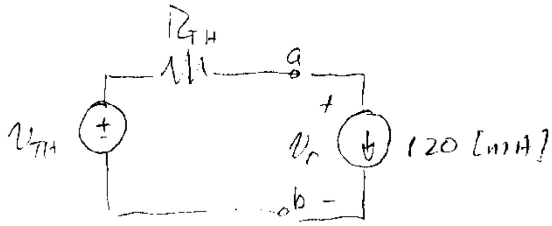


$$-v_{TH} + i_c(R_{TH} + 2000) = 0$$

$$i_c = -2.119\ [A]$$

$$\Rightarrow \quad -v_{TH} - 2.119\,R_{TH} - 4238 = 0 \quad (1)$$

+4



$$-v_{TH} + 0.120\,R_{TH} + 250.46 = 0 \quad (2)$$

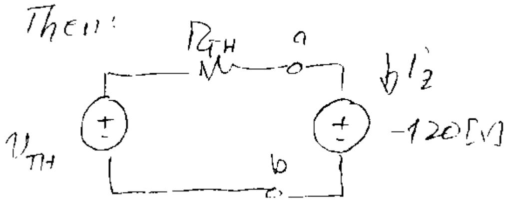
Solving (1) and (2) together gives

+2

$$v_{TH} = 483.1\ [V] \qquad R_{TH} = -2228\ [\Omega]$$

+10

Then:



$$-v_{TH} + i_2 R_{TH} - 120 = 0$$

$$i_2 = \frac{v_{TH} + 120}{R_{TH}}$$

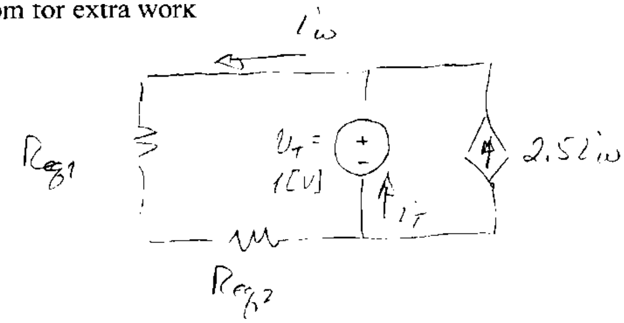
$$\boxed{i_2 = -0.2707\ [A]}$$

We could also have found v_{oc}, R_{TH} or i_{sc}:

Room for extra work

R_{TH}:

+12



$R_{eq1} = 2.2[k\Omega] // 1[k\Omega] = 687.5[\Omega]$

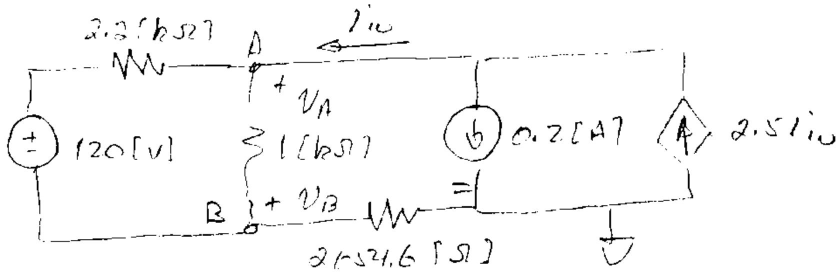
$R_{eq2} = 4.7[k\Omega] // 6.1[k\Omega] = 2654.6[\Omega]$

$$i_w = \frac{1}{R_{eq1} + R_{eq2}} = 0.2992\ [mA] \qquad i_T' = -1.5 i_w' = -0.44882\ [mA]$$

$$R_{TH} = \frac{1}{i_T'} = -2228.1\ [\Omega]$$

v_{oc}:

+12



$$\frac{v_A - v_B - 120}{2200} + \frac{v_A - v_B}{1000} + 0.2 - 2.5 i_w = 0$$

$$\frac{v_B}{2654.6} + \frac{v_B - v_A}{1000} + \frac{v_B - v_A + 120}{2200} = 0$$

$$i_w = -0.2 + 2.5 i_w$$

$v_A = 483.1\ [V]$

$v_B = 353.9\ [V]$

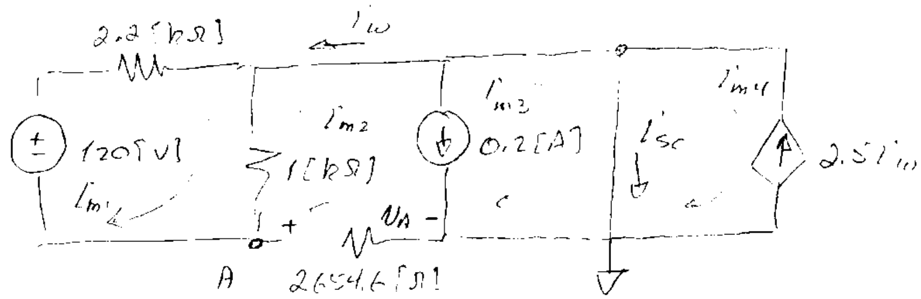
$i_w = 0.133\ [A]$

$$v_{oc} = v_A = 483.1\ [V]$$

next page ↗

i_{SC}:

+12



$$-120 + 2200\, i_{m1} + 1000\,(i_{m1} - i_{m2}) = 0$$

$$1000\,(i_{m2} - i_{m1}) + 2654.6\, i_{m2} = 0$$

$$i_{m2} - i_{m3} = 0.2$$

$$i_W = -i_{m2} \qquad i_{m4} = -2.5\, i_W$$

$$i_{SC} = i_{m3} - i_{m4}$$

i_{m1} =

i_{m2} =

i_{m3} =

i_{m4} =

i_W =

i_{SC} = −0.2168 [A]

– OR –

$$\frac{v_A}{2654.6} + \frac{v_A}{1000} + \frac{v_A + 120}{2200} = 0$$

$$i_W = -\frac{v_A}{1000} - \frac{v_A + 120}{2200}$$

$$i_{SC} = 2.5\, i_W - i_W - 0.2$$

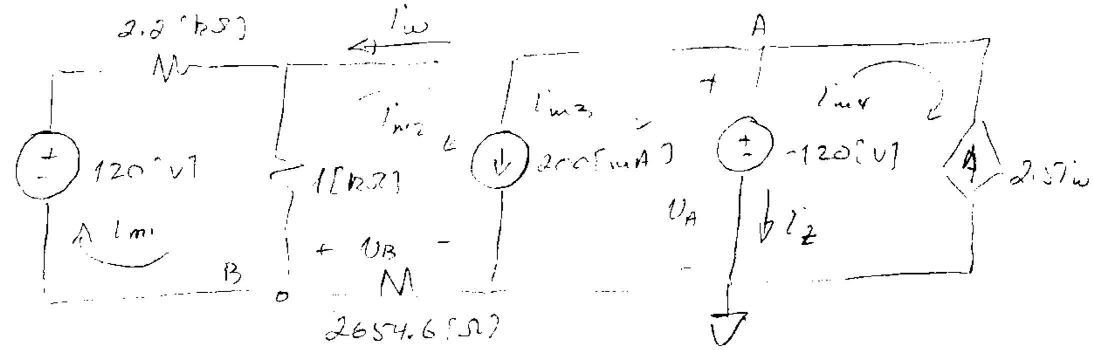
v_A =

i_W =

i_{SC} = −0.2168 [A]

---

i_3: +6



+2 $v_A = -120$ [V]

+8 $i_w = -\frac{v_B - v_A}{1000} - \frac{v_B - v_A + 120}{2200}$

+8 $\frac{v_B}{2654.6} + \frac{v_B - v_A}{1000} + \frac{v_B - v_A + 120}{2200} = 0$

+5 $v_B =$

+7 $i_z = -2.57 i_w + i_w + 0.2 =$

+6 $-120 + 2200 i_{m1} + 1000(i_{m1} - i_{m2}) = 0$

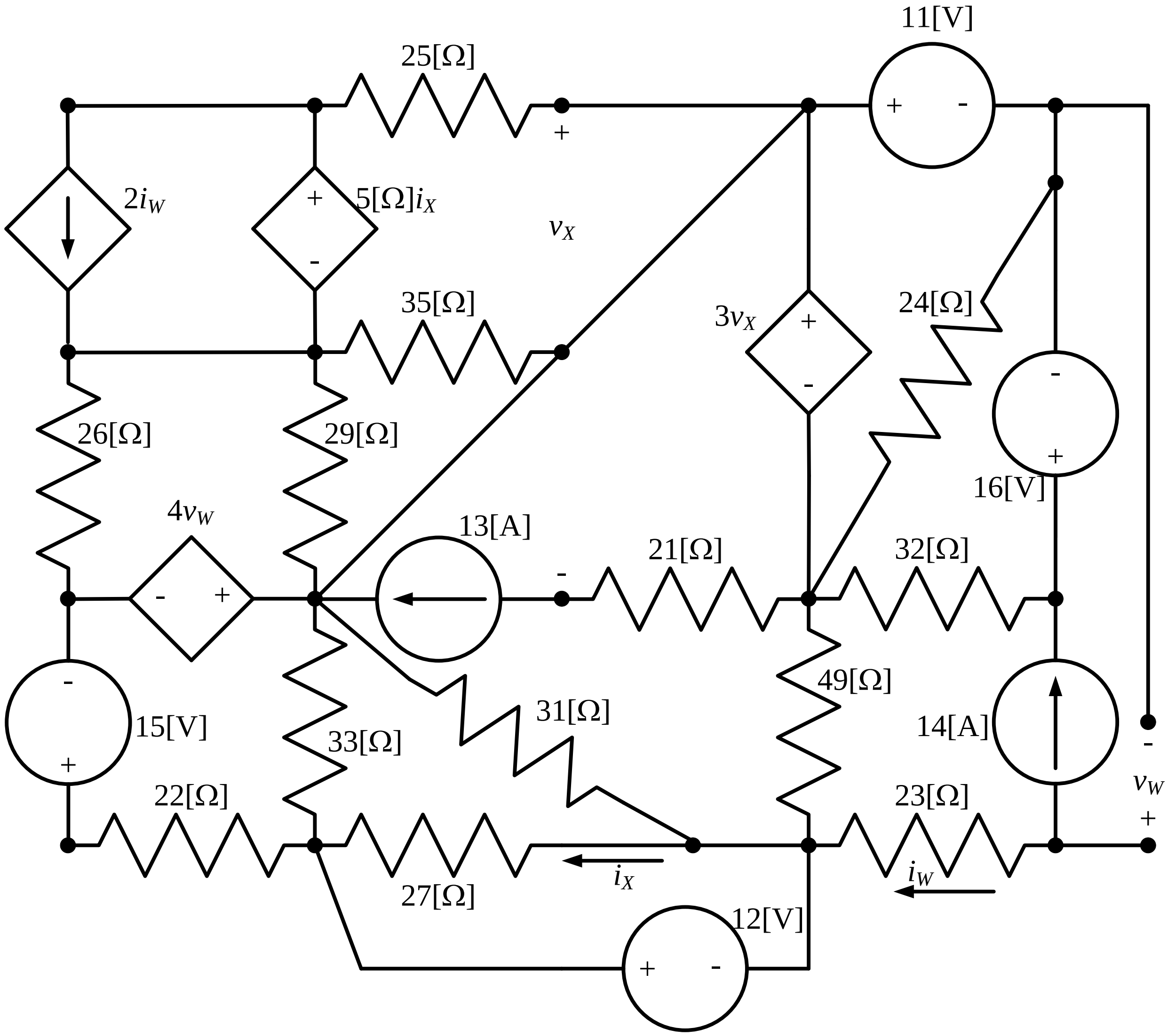
+3 $i_{m2} - i_{m3} = 0.2$ +6 $1000(i_{m2} - i_{m1}) - 120 + 2654.6 i_{m} = 0$

+3 $i_{m4} = -2.57 i_w$ +4 $i_w = -i_{m2}$

soln: +4

+4 $i_z = i_{m3} - i_{m4}$

2. (20 points) In the circuit below, find the power delivered by the dependent current source.



Solution:

$$i_W = -14[A]$$

$$i_X = \frac{-12[V]}{27[\Omega]} = -444.44[mA]$$

$$p_{DEL.BY.2i_W} = -(2i_W)(5[\Omega]i_X) = \boxed{-62.22[W]}$$

3. (<u>20 points</u>) There are two separate voltmeters available for use in a laboratory. One voltmeter has a full-scale reading of 200[V], and has an equivalent resistance of 6.8[MΩ]. The second voltmeter has a full-scale reading of 150[V], and has an equivalent resistance of 25[MΩ]. The plan is to increase the range of voltages that can be measured by putting the two voltmeters in series, and placing the series combination across an unknown voltage. Find the largest voltage that can be measured using the two voltmeters in series, assuming that the voltage will be determined by adding the voltages measured on the two voltmeters.

Call the voltmeter with 200[V] full-scale, voltmeter #1

Call the voltmeter with 150[V] full-scale, voltmeter #2

For Voltmeter #1, full-scale current $= \dfrac{200[V]}{6.8[M\Omega]}$

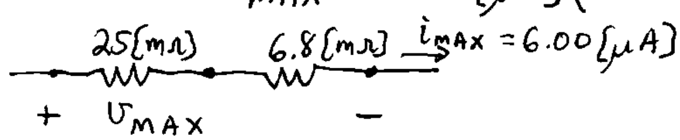
$= 29.41[\mu A]$

For Voltmeter #2, full-scale current $= \dfrac{150[V]}{25[M\Omega]}$

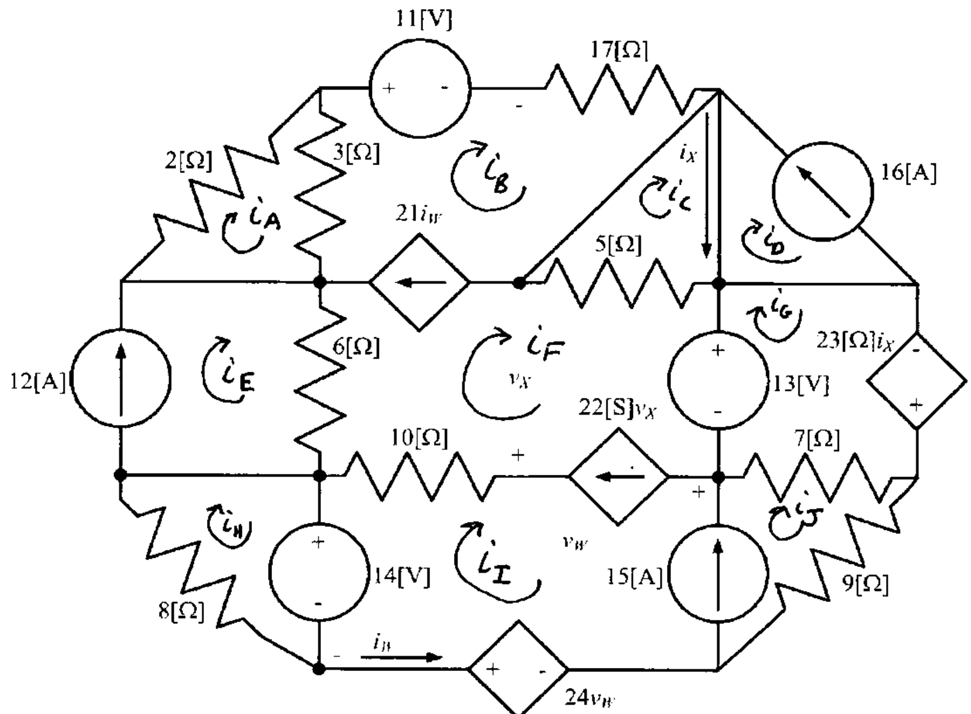
$= 6.00[\mu A]$

If we put them in series, we are limited by the lower full-scale current, 6.00[μA]. So the largest voltage we can read is

$$v_{MAX} = 6.00[\mu A](25+6.8)[M\Omega] = \boxed{190.8[V]}$$



4. (20 points) Use 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. Do not skip any meshes.



10 meshes + 4 dep. source variables = 14 equations

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

(B+F+I+J) $(i_B - i_A) 3[\Omega] + 11[V] + i_B 17[\Omega] + (i_F - i_C) 5[\Omega] + 13[V] + (i_J - i_G) 7[\Omega] +$

$+ i_J 9[\Omega] - 24 v_W - 14[V] + (i_F - i_E) 6[\Omega] = 0$

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

(F+I) $i_F - i_I = 22[S]\, v_X$

(I+J) $i_J - i_I = 15[A]$

See next page

(C) $(i_C - i_F)\,5[\Omega] = 0$

(D) $i_D = -16[A]$

(E) $i_E = 12[A]$

(G) $-13[V] - 23[\Omega]\,i_X + (i_G - i_J)\,7[\Omega] = 0$

(H) $i_H\,8[\Omega] + 14[V] = 0$

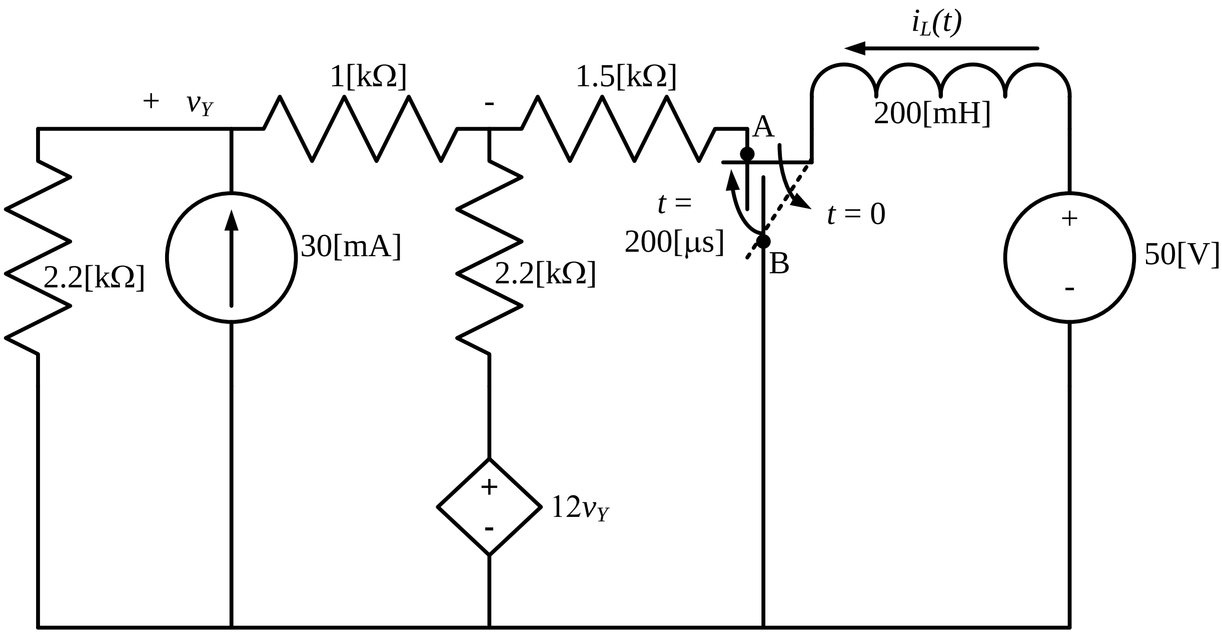
(i_W) $i_W = -i_I$

(i_X) $i_X = i_C - i_D$

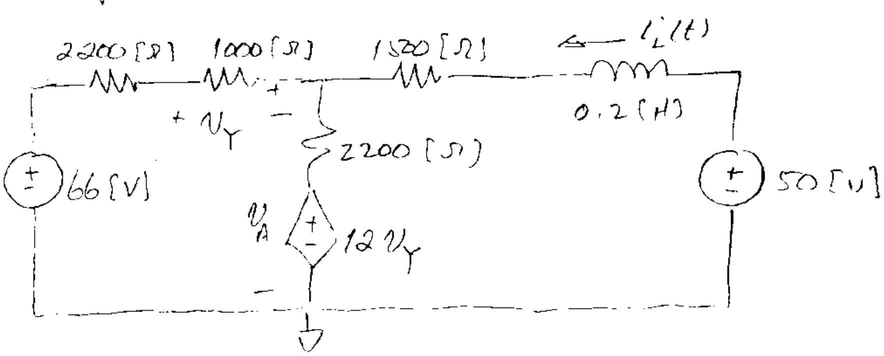
(v_X) $-v_X + (i_F - i_I)\,10[\Omega] + (i_F - i_E)\,6[\Omega] + (i_B - i_A)\,3[\Omega] + 11[V] = 0$

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

5. (40 points) In the circuit given below, the switch was in position A for long time before it moved at $t = 0$ to position B. The switch then moved back to A at $t = 200[\mu s]$. Find $i_L(t)$ for $t \geq 200[\mu s]$.



Re-draw for $t<0$: Use source transformation on 30[mA]:



$$\frac{v_A - 12v_Y}{2200} + \frac{v_A - 66}{3200} + \frac{v_A - 50}{1500} = 0$$

$$v_Y = -\frac{v_A - 66}{3200} \cdot 1000$$

$v_A = 53.04[V]$

$v_Y = 4.050[V]$

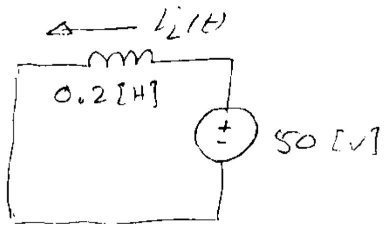
TO PAGE 12

+6 $\quad i_L(0^-) = i_L(0^+) = -\dfrac{v_A - 50}{1500} = -2.027\,[mA]$

Note that since the switch returns to this position after the 2nd switching event, this is also the final, steady state value for i_L:

$$i_L(t \to \infty) = i_{L,ss} = -2.027\,[mA]$$

$0 < t < 200\,[\mu s]$



$$i_L(t) = \frac{1}{L}\int_0^t 50\,[V]\,dt + i_L(0^+)$$

$$= 250t \Big|_0^t - 2.027\,[mA]$$

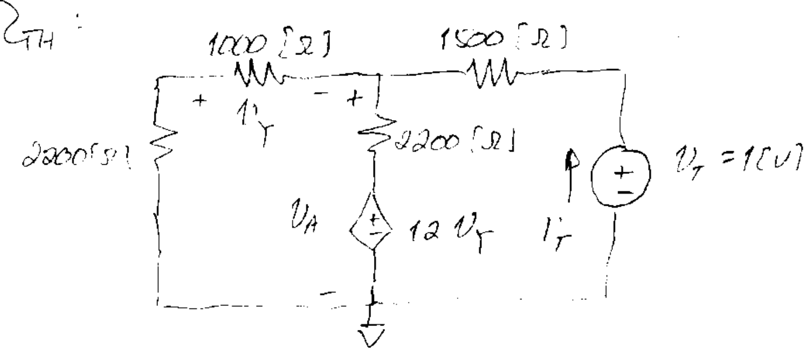
$$= 250t - 2.027\,[mA]$$

$$i_L(t = 200[\mu s]^+) = 250(200 \times 10^{-6}) - 2.027\,[mA]$$

+10 $\quad = 47.97\,[mA]$

+11 Also, $i_L(\infty) = i_{L,ss} = -2.027\,[mA]$ from above.

R_{TH}:



next page

$$\frac{v_A - 12v_Y}{2200} + \frac{v_A}{3200} + \frac{v_A - 1}{1500} = 0 \qquad v_A = 0.2124\,[V]$$

$$v_Y = -v_A \cdot \frac{1000}{3200} \qquad v_Y = -0.0664\,[V]$$

$$i_T = -\left(\frac{v_A - 1}{1500}\right) = 0.5251\,[mA]$$

+2

+2

$$\Rightarrow R_{TH} = 1905\,[\Omega] \qquad \tau_L = \frac{L}{R_{TH}} = 0.1050\,[ms]$$

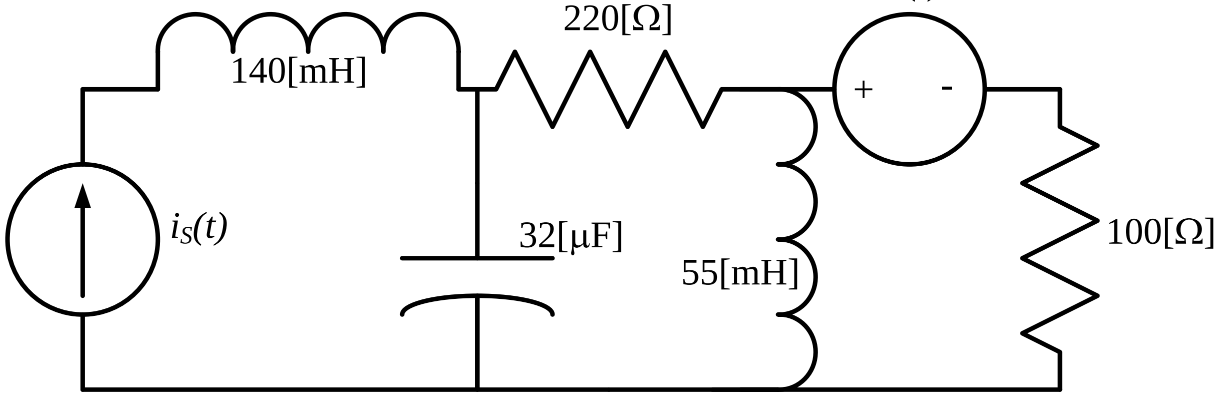
$$\therefore \quad i_L(t) = -2.027\,[mA] + (47.97 + 2.027)\,[mA]\, e^{-\frac{(t - 0.2\,[ms])}{0.1050\,[ms]}}$$

+5

+3

$$\boxed{i_L(t) = -2.027\,[mA] + 50\,[mA]\, e^{-\frac{(t - 0.2\,[ms])}{0.1050\,[ms]}} \quad t \geq 0.2\,[ms]}$$

6. (30 points) Find the Thévenin impedance Z_{TH} as seen by the current source, at ω = 1500[rad/s]. Draw a circuit model for Z_{TH}, modeling it either as a resistance in series with an inductor or as a resistance in series with a capacitor.

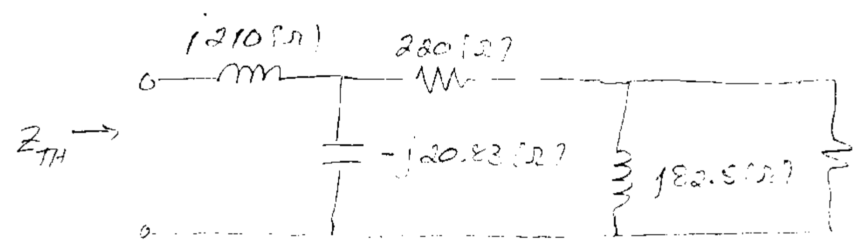


$v_S(t)$ = 15[V] sin(ωt + 20°)
$i_S(t)$ = 32[mA] cos(ωt - 22°)

We can simply reduce the network at the terminals of the current source. The voltage source is a short in that case. Transforming to phasor domain gives:

+10

+2 L
+2 L
+2 C +2 R
+2 sources



$L \to j\omega L$

$C \to -j/\omega C$

$Z_1 = 220 + j82.5 \parallel 100$

$= (260.5 + j49.09)[\Omega] = 265.08\angle 10.67°[\Omega]$

$Z_2 = -j20.83 \parallel Z_1 = 1.646 - j21.01\,[\Omega]$

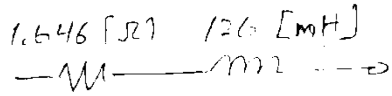
$= 21.07\angle -85.52°\,[\Omega]$

TO PAGE 14 →

Finally $Z_{TH} = j210[\Omega] + Z_2 = 1.646 + j189.0 \; [\Omega]$

$189.2 \angle 89.50 \; [\Omega]$

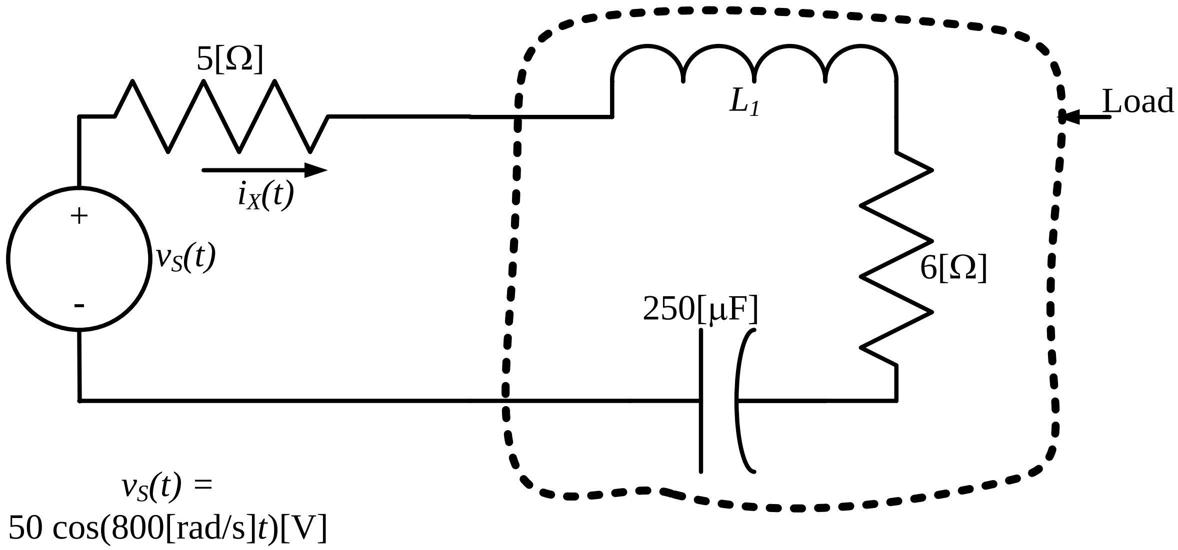
Model: Z_{TH}:



Positive imaginary part means we have an inductor, and

$\omega L = 189 \Rightarrow L = \frac{189}{1500} = 126 \, [mH]$

7. (40 points) In the circuit below, the load is enclosed with a dashed line.
a) Find the value of the inductance L_1 that will make the voltage $v_S(t)$ be in phase with the current $i_X(t)$.
b) Find the value of the power factor angle for the load that results from the value of L_1 found in part a).
c) Find the value of the power factor of the load, if L_1 = 3.9[mH]. Indicate whether this is a leading or a lagging power factor.
d) Find the apparent power absorbed by the load, if L_1 = 3.9[mH].



a) For the voltage and current to be in phase, the impedance of the load must be purely real.

$$Z_{LOAD} = j\,800[\tfrac{rad}{s}]L_1 + 6[\Omega] + \frac{1}{j(800)(250\times10^{-6})}[\Omega]$$

So, setting the imaginary part = 0, we have

$$800[\tfrac{rad}{s}]\,L_1 - 5[\Omega] = 0$$

$$L_1 = \frac{5}{800}[H] = \boxed{6.25[mH]}$$

b) For a purely real load, the power factor angle = $\boxed{0}$

see next page

c) for $L_1 = 3.9 \{mH\}$,

$$Z_{LOAD} = (6 + 3.12j - 5j)\{\Omega\} = (6 - 1.88j)\{\Omega\}$$

$$= (6.288 \angle -17.40°)\{\Omega\}$$

So $pf = \cos(-17.40°) = \boxed{0.954 \text{ leading}}$

d) $$\bar{I}_{x,rms} = \frac{50/\sqrt{2}}{11 - 1.88j}\{A_{rms}\} = 3.168 \angle 9.699° \{A_{rms}\}$$

$$S_{abs.by.load} = |\bar{I}_{x,rms}|^2 Z_{LOAD} = (3.168)^2 (6.288 \angle -17.40°)\{VA\}$$

Apparent Power $= |S|$, so

$$|S_{abs.by.load}| = \boxed{63.1 \{VA\}}$$