Name: ______________________________ (please print)

Signature: ___________________________

ECE 2300 – Final Exam
July 26, 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.
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5. Do not use red ink. Do not use red pencil.
6. You will have 170 minutes to work on this exam.

1. ________________/35

2. ________________/30

3. ________________/35

4. ________________/30

5. ________________/35

6. ________________/35

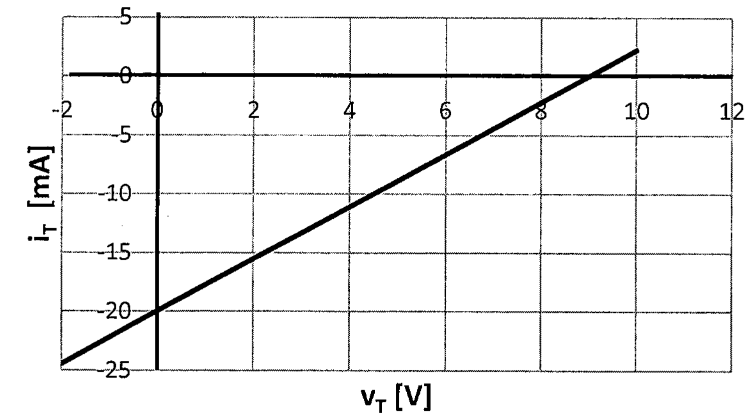
/200

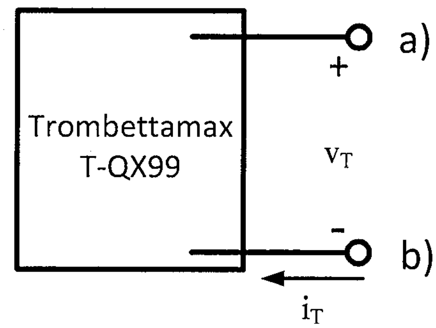
Room for extra work

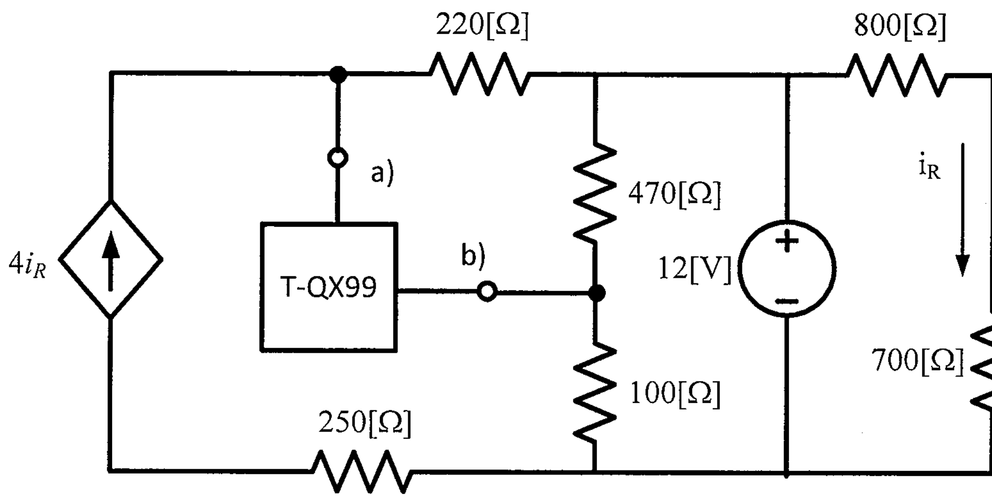
1. (35 points) The Trombettamax T-QX series is being discontinued and is now on sale! The graph below gives the current-voltage characteristics for the final version of the Trombettamax, with polarities defined in the figure. It is inserted into a circuit by connecting at terminals a), b) as shown.

   i) Find the power delivered by device the T-QX99.

   ii) Find the power delivered by the dependent current source.

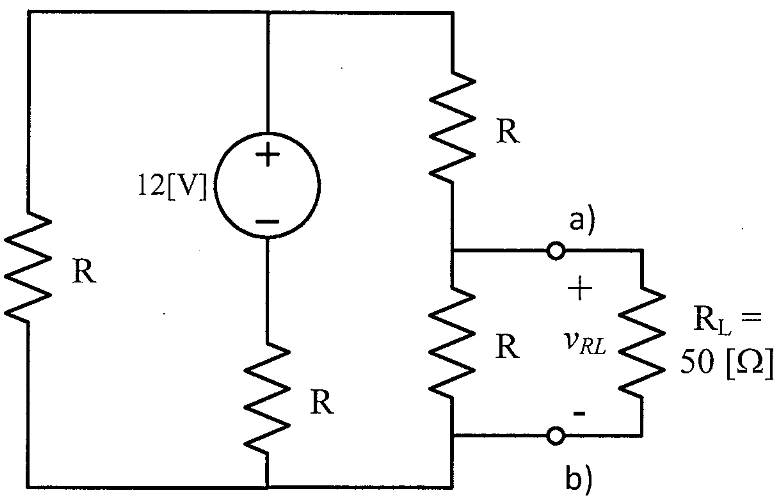






Room for Extra Work

2. (30 points) In the circuit below, the resistance R is unknown. All the resistors have the same value, except for the load resistor R_L, which is 50 [Ω]. When R_L is attached at terminals a), b), the voltage v_{RL} is 1.154 [V]. Find the Thevenin Equivalent of the circuit as seen by the load resistor R_L. Draw the Thevenin Equivalent circuit and label its parameters.

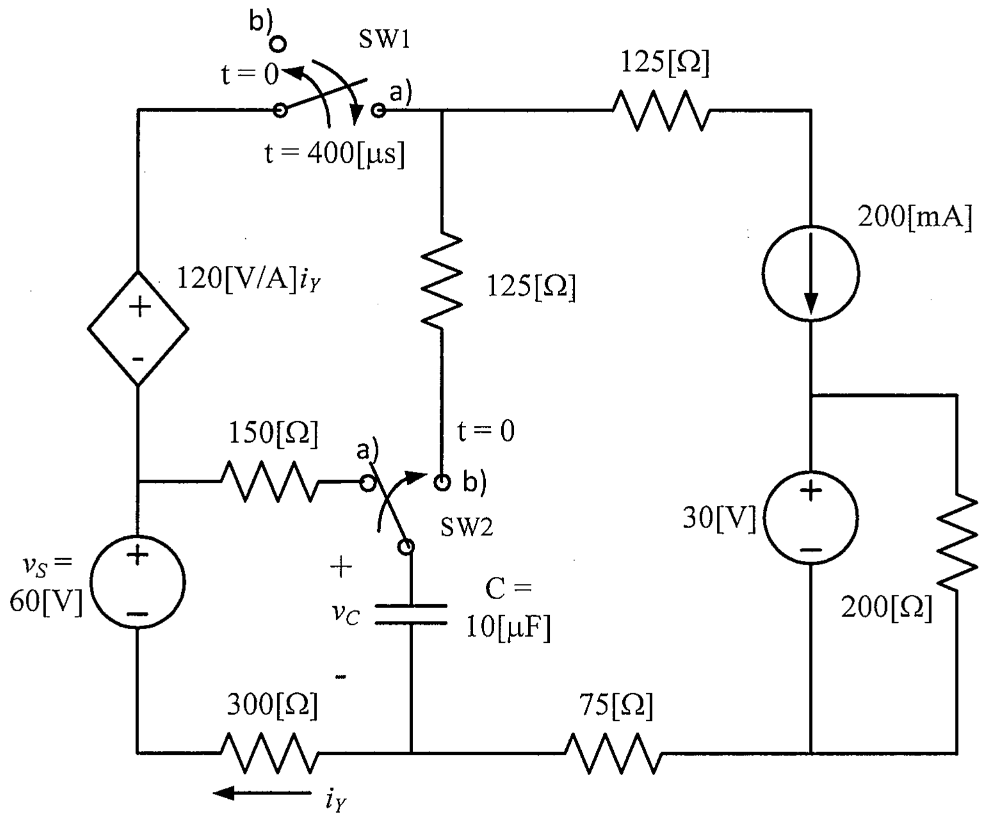


Room for extra work

3. (35 points) In the circuit below, switches S1 and S2 were in position a) for a long time. At t = 0, both switches moved to position b). At t = 400 [μs], switch S1 moved back to a).

i) Find the voltage v_C as a function of time for t > 400 [μs].

ii) Find the current i_Y at t = 450 [μs].

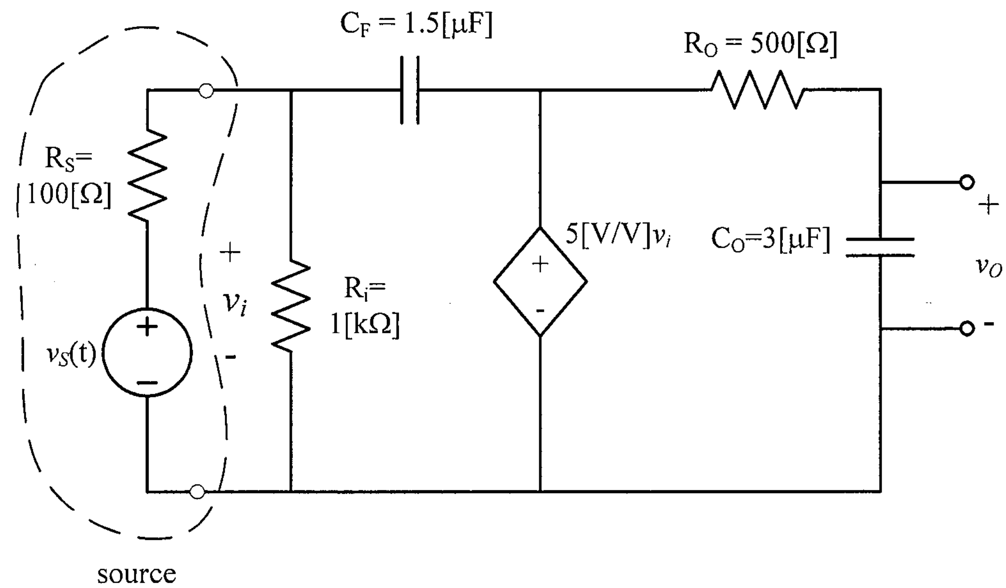


Room for extra work

4. (30 points) The circuit below is a model for a voltage amplifier. The source consists of an ideal voltage source v_S in series with a resistor R_S, as shown.

i) Find the output voltage $v_O(t)$, for $v_S(t)$ = 1[V] cos(1000 [rad/s]t).

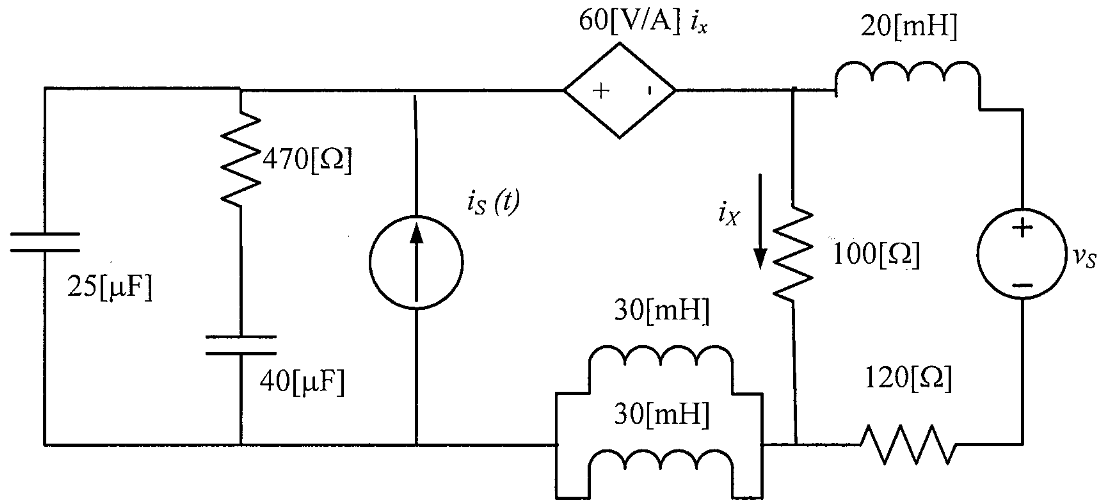
ii) Find the Thevenin Equivalent impedance seen by the source at ω = 1000 [rad/s].



Room for extra work

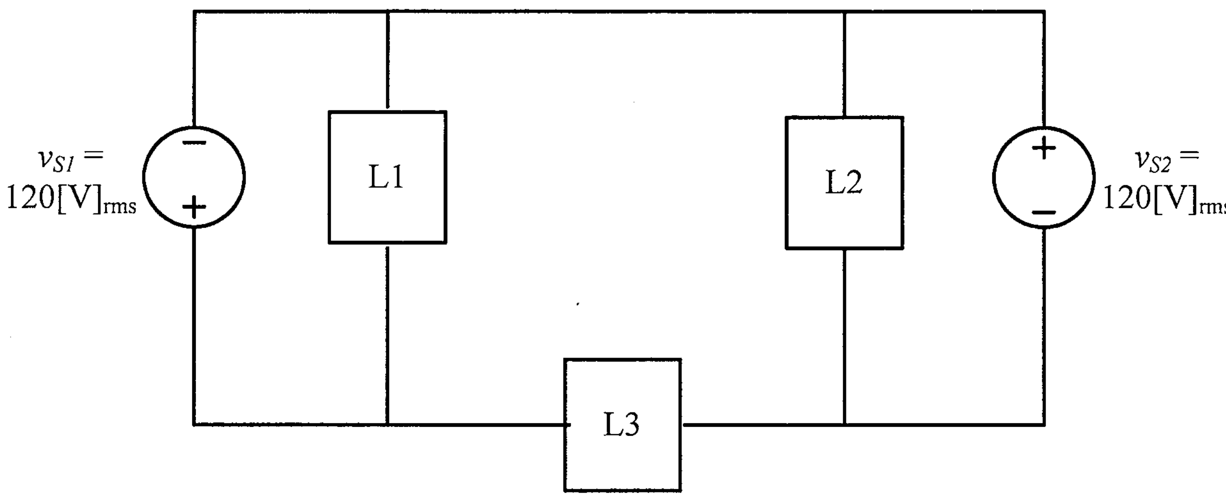
5. (35 points) For the circuit below, find the Norton Equivalent in the time domain seen by the current source i_S. The sources are as follows.

$$i_S(t) = 250 \sin(1000[\text{rad/s}]t) \text{ [mA]}$$
$$v_S(t) = 30 \cos(1000[\text{rad/s}]t) \text{ [V]}$$



Room for extra work

6. (35 points) In the circuit below, load L1 absorbs 2.5 [kW] and 450 [VAR]. Load 2 absorbs 3.5 [kVA] at 0.96 pf lead. Load 3 is a 15 [Ω] resistor in series with a reactance of $-\mathbf{j}15$ [Ω]. Find the power delivered by each of the sources.



Room for Extra Work

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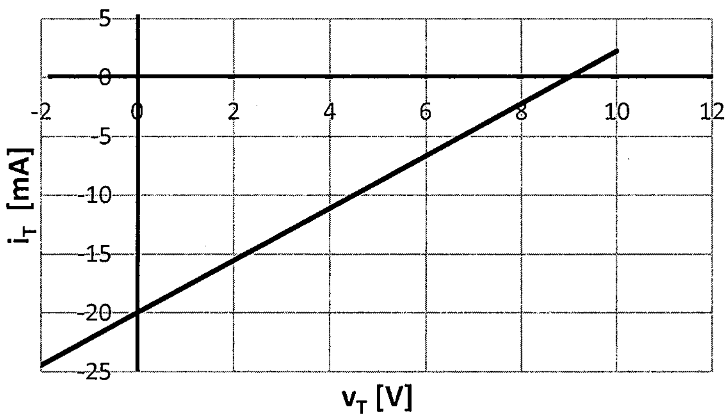
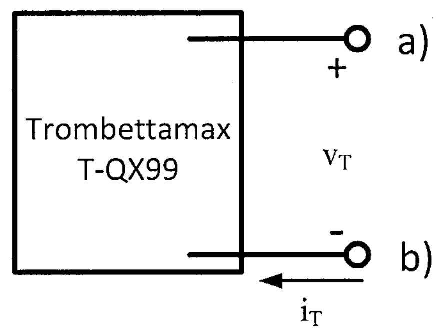
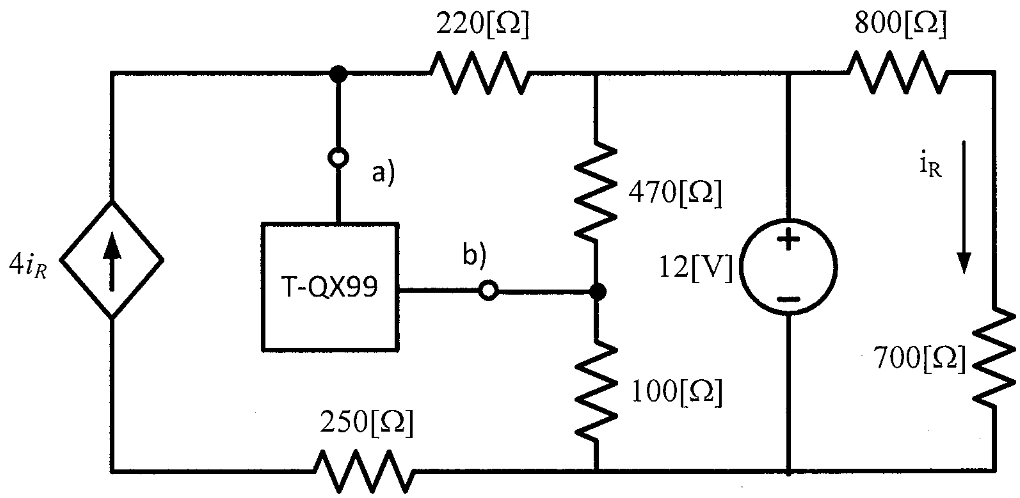
/200

1. (35 points) The Trombettamax T-QX series is being discontinued and is now on sale! The graph below gives the current-voltage characteristics for the final version of the Trombettamax, with polarities defined in the figure. It is inserted into a circuit by connecting at terminals a), b) as shown.

i) Find the power delivered by device D.
ii) Find the power delivered by the dependent current source.

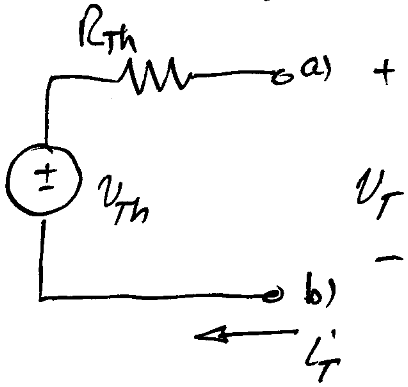






We need a model for the T-QX99 - we'll use a Thevenin Equivalent.

+4



$V_T - V_{Th} + i_T' R_{Th} = 0$

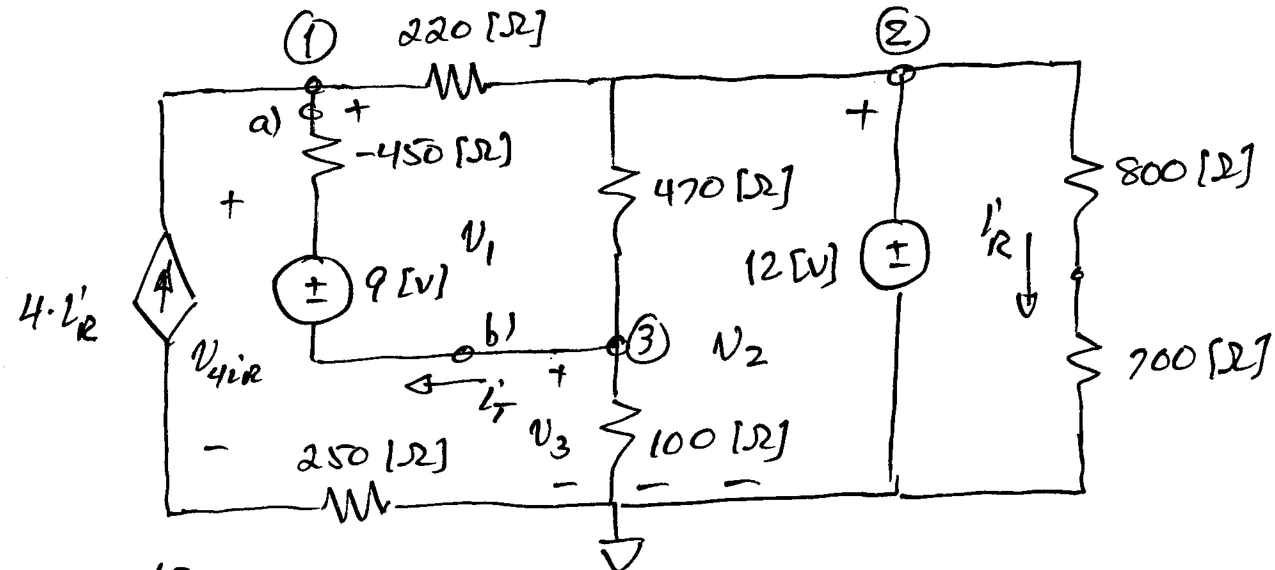
$i_T' = 0 \Rightarrow V_T = V_{Th} = 9\,[V]$

$V_T = 0 \Rightarrow i_T' = \dfrac{9}{R_{Th}} = -0.02\,[A]$

$\Rightarrow R_{Th} = -450\,[\Omega]$ +4

Room for Extra Work

We can insert the model into the circuit:



$i_R' = \frac{12}{1500} = 0.008$ [A] $\qquad V_2 = 12$ [V] $\qquad +12$

① $-4(0.008) + \frac{V_1 - V_3 - 9}{-450} + \frac{V_1 - 12}{220} = 0$

③ $\frac{V_3}{100} + \frac{V_3 - V_1 + 9}{-450} + \frac{V_3 - 12}{470} = 0$

$V_1 = 30.87$ [V]

$V_3 = -2.329$ [V]

i) $P_{del\ by\ Qx99} = (V_1 - V_3) \cdot i_T'$

$= (33.2)(53.78 \times 10^{-3})$

$= 1.785$ [W]

$i_T' = (V_3 - V_1 + 9)/-450$

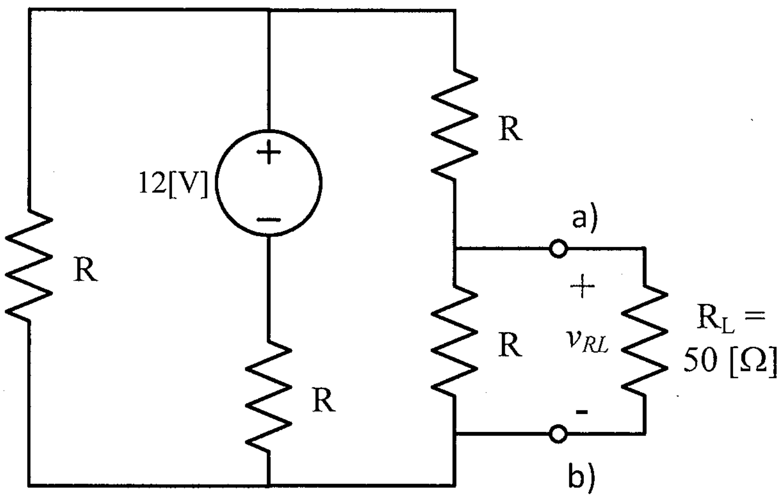
$= 53.78$ [mA]

$+8$

ii) $-V_{4iR} + V_1 + 250(4 \times 0.008) = 0 \Rightarrow V_{4iR} = 38.87$ [V]

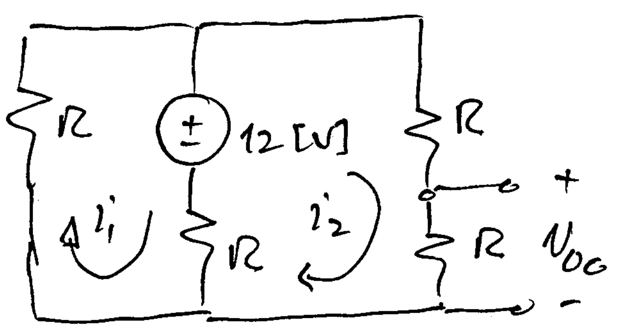
$P_{del\ by\ 4iR} = V_{4iR} \cdot 4(0.008) = 1.244$ [W] $\qquad +7$

2. (30 points) In the circuit below, the resistance R is unknown. All the resistors have the same value, except for the load resistor R_L, which is 50 [Ω]. When R_L is attached at terminals a), b), the voltage v_{RL} is 1.154 [V]. Find the Thevenin Equivalent of the circuit as seen by the load resistor R_L. Draw the Thevenin Equivalent circuit and label its parameters.



There are several ways to approach this. Here's one:

1. We can find V_{Th} without knowing R:



a) $i_1' R + 12 + (i_1' - i_2')R = 0$

b) $(i_2' - i_1')R - 12 + 2Ri_2' = 0$

$\Rightarrow i_1' R = -2Ri_2'$

$\Rightarrow i_1' = -2i_2'$

Substituting back into a) gives

$-2i_2' R + 12 - 3i_2' R = 0 \Rightarrow i_2' = \frac{12}{5R}$

$\therefore V_{oc} = i_2' R = \frac{12}{5} \Rightarrow V_{Th} = 2.4 [V]$

+14

Room for extra work

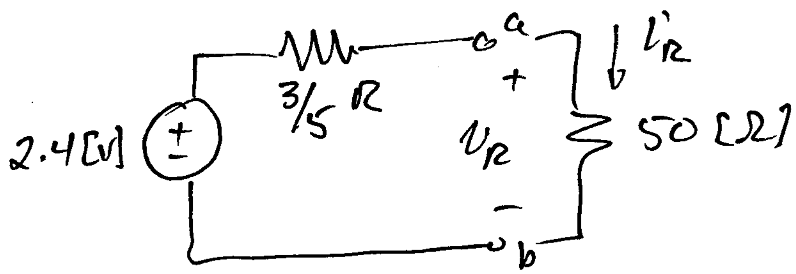
2. We can find R_{Th} in terms of R: If we imagine a test source at a), b) then

$$R_{Th} = (R/\!/R + R)/\!/R = \left(\tfrac{1}{2}R + R\right)/\!/R = \frac{\frac{3}{2}R \cdot R}{\frac{3}{2}R + R}$$

$$\underline{R_{Th} = \tfrac{3}{5}R}$$

+ 7

3. Now we can use the given information.



$V_R = 1.154$ [V]

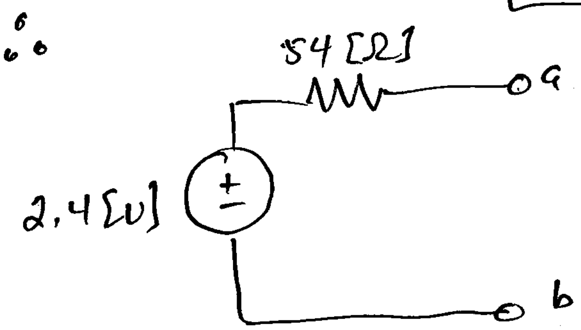
$\Rightarrow i_R = 23.077$ [mA]

$$1.154 - 2.4 + \tfrac{3}{5}R(0.023077) = 0$$

$$\Rightarrow \underline{R = 90\ [\Omega]}$$

+ 7

∴



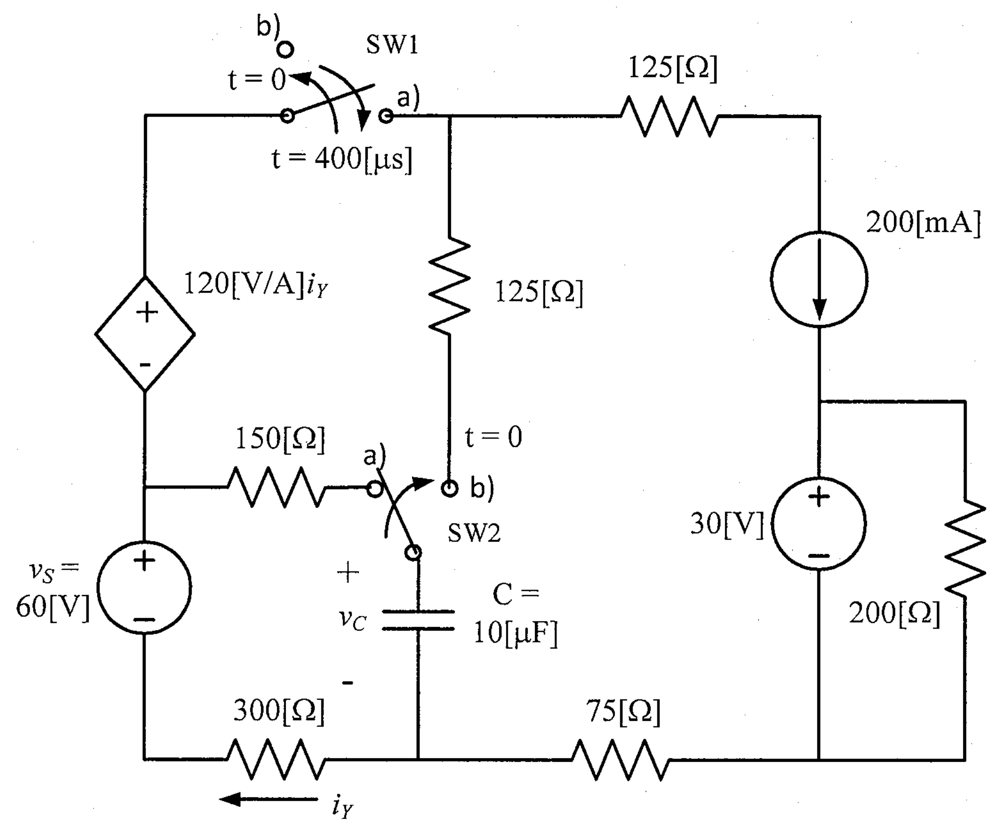
$\Rightarrow \underline{R_{Th} = 54\,[\Omega]}$

+ 2

3. (35 points) In the circuit below, switches S1 and S2 were in position a) for a long time. At t = 0, both switches moved to position b). At t = 400 [μs], switch S1 moved back to a).

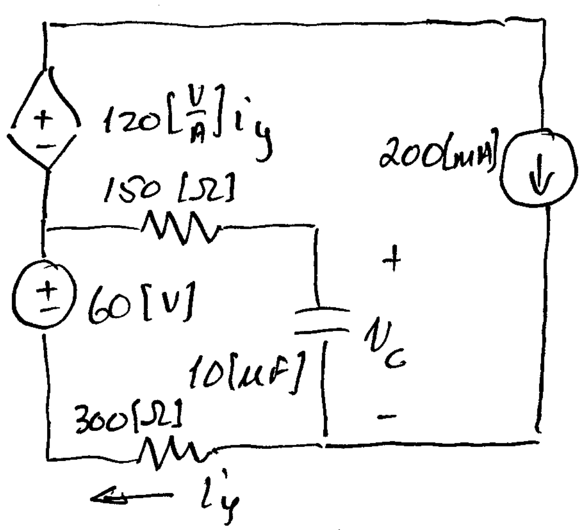
i) Find the voltage v_C as a function of time for t > 400 [μs].

ii) Find the current i_Y at t = 450 [μs].



We re-draw for t < 0:

+3



$v_c \rightarrow$ open ckt

$\Rightarrow i_y = 0.2\ [A]$

KVL: $v_c + 300\, i_y - 60 = 0$

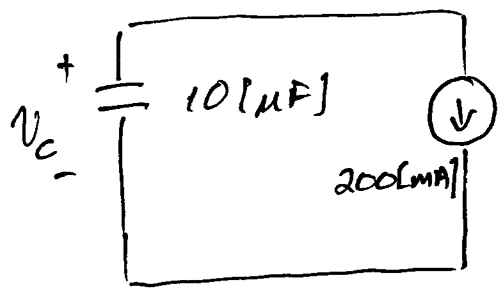
$\Rightarrow v_c = v_c(0^-) = 0 = v_c(0^+)$

+3

We have ignored components in series with 200 [mA]

Room for extra work

Now re-draw for $0 < t < 400[\mu s]$:



+3

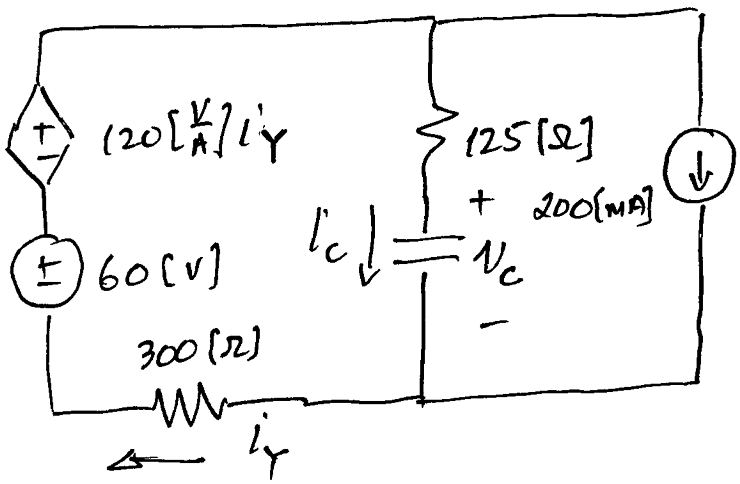
$$V_c(t) = \frac{-1}{C}\int_0^t 0.2\,[A]\,dt + V_c(0^+)$$

$$= -10^5 \cdot 0.2t + 0 = -2\times10^4 t\ [V]$$

$$t = 400\,[\mu s] \Rightarrow V_c(400[\mu s]^+) = -8\ [V]$$

+5

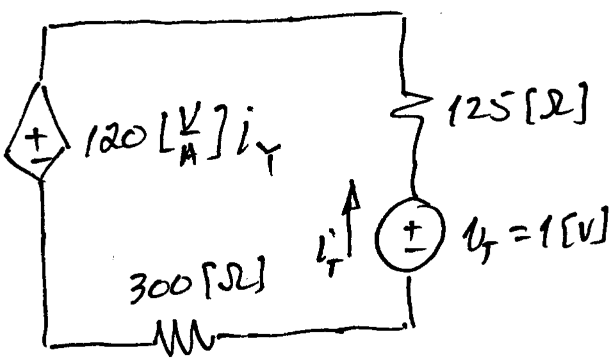
Finally, for $t > 400\,[\mu s]$ we have:



+3

Applying a test source...

+4



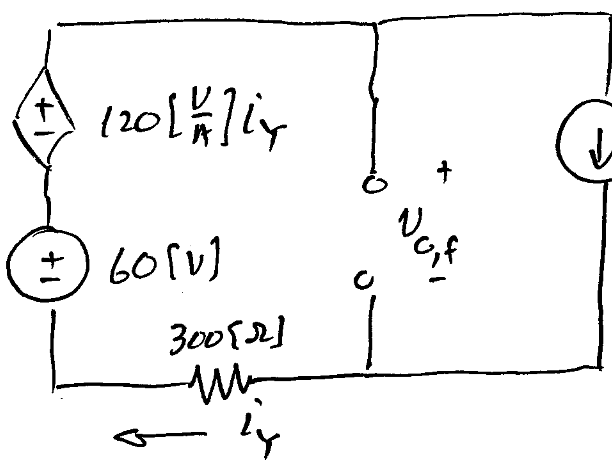
$$i_T = \frac{V_T - 120\, i_Y}{425} \qquad i_Y = -i_T$$

$$\Rightarrow i_T = \frac{1[V]}{305[\Omega]} \Rightarrow R_{Th} = 305\ [\Omega]$$

$$\tau = R_{Th} \cdot C = 3.05\ [ms]$$ +1

Now we need $V_c(t \to \infty) = V_{c,f}$ ...

Room for extra work



$i_Y' = 200\,[mA]$

KVL:

$-60 - 120(0.2) + v_{C,f} + 300(0.2) = 0$

$v_{C,f} = 24\,[V]$ +3

So... $v_C(t) = 24 + (-8-24)\, e^{-(t-400[\mu s])/3.05[ms]}$ [V] $t \geq 400\,[\mu s]$

i) $v_C(t) = 24 - 32 e^{-(t-0.4[ms])/3.05[ms]}$ [V] $t \geq 400\,[\mu s]$ +5

ii) We can find $i_C'(t) = C \frac{dv_C}{dt}$

$i_C'(t) = 10^{-5} \frac{d}{dt}\left(-32 e^{-(t-0.4)/3.05}\right)$

$= 104.9\,[mA]\, e^{-(t-0.4[ms])/3.05[ms]}$ +3

$i_C'(t = 450[\mu s]) = 103.2\,[mA]$

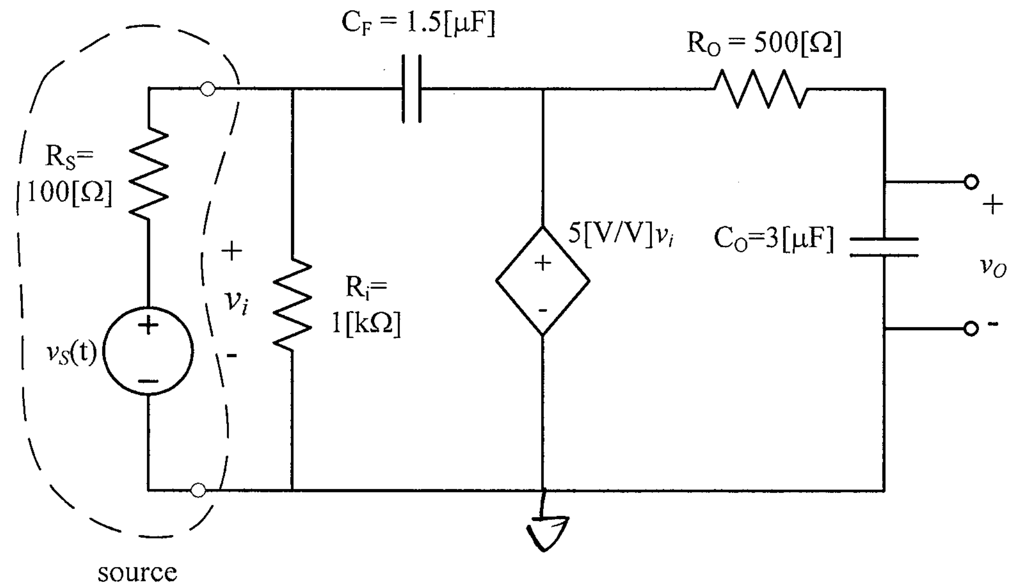
$i_Y'(450[\mu s]) = i_C'(450[\mu s]) + 0.2 = 303.2\,[mA]$ +2

30

4. (~~35~~ points) The circuit below is a model for a voltage amplifier. The source consists of an ideal voltage source v_S in series with a resistor R_S, as shown.

i) Find the output voltage $v_O(t)$, for $v_S(t) = 1[V]\cos(1000\,[rad/s]t)$.

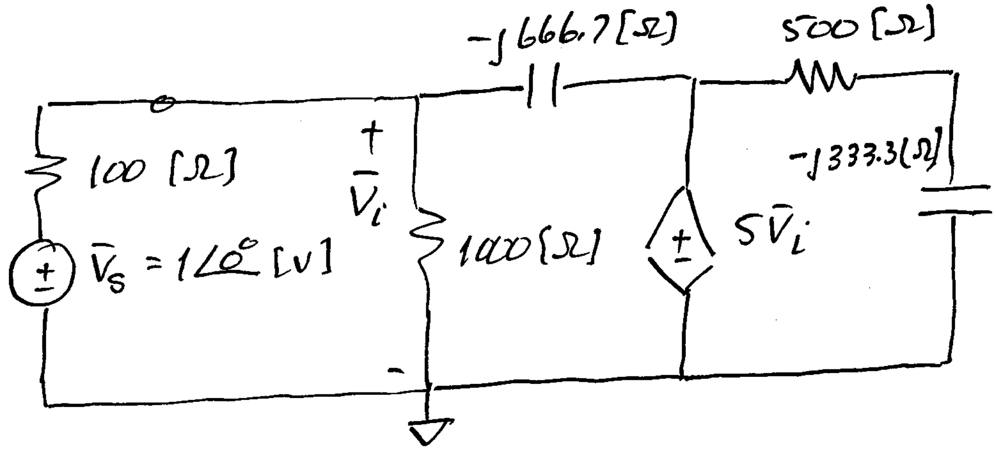
ii) Find the Thevenin Equivalent impedance seen by the source at $\omega = 1000$ [rad/s].



Re-draw in phasor domain:

$$C_F \rightarrow 1/j\omega C_F = -j\,666.7\,[\Omega]$$

$$C_O \rightarrow 1/j\omega C_O = -j\,333.3\,[\Omega]$$



+5

i)

$$\frac{\bar{V}_i - \bar{V}_s}{100} + \frac{\bar{V}_i}{1000} + \frac{\bar{V}_i - 5\bar{V}_i}{-j666.7} = 0 \qquad \bar{V}_o = 5\bar{V}_i \cdot \frac{-j333.3}{-j333.3 + 500}$$

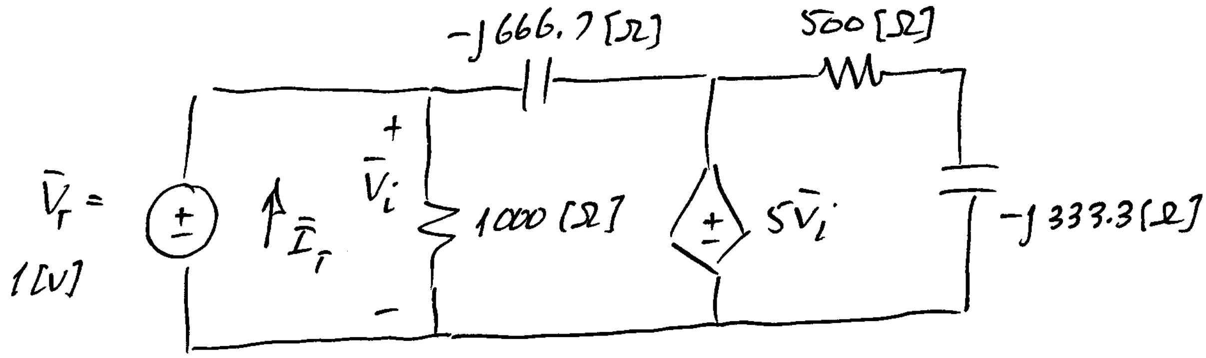
+8

Room for extra work

$\bar{V}_i = 798.1 \angle 28.61^\circ$ [mV] $\Rightarrow$ $\bar{V}_o = 2.213 \angle -27.7^\circ$ [V] + 3

$\Rightarrow$ $v_o(t) = 2.213$ [V] $\cos(1000t - 27.7^\circ)$ +4

ii) Replace the source (V_s and R_s) with a test source.



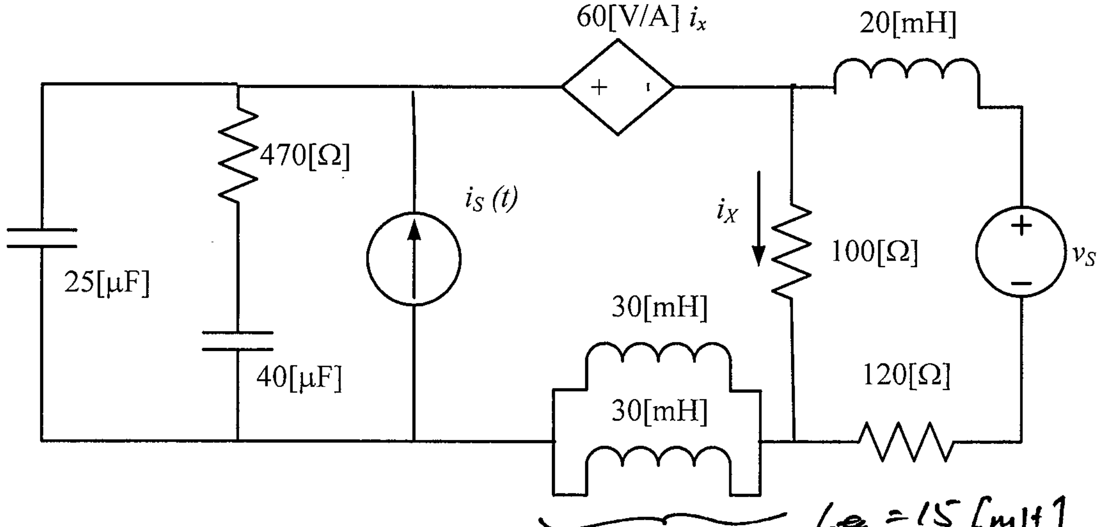
$$\bar{I}_T = \frac{1}{1000} + \frac{(1-4)}{-j666.7} = 6.082 \angle -80.54^\circ \text{ [mA]}$$ +8

$$\therefore \; Z_{Th} = 1/\bar{I}_T = 164.4 \angle 80.54^\circ \text{ [}\Omega\text{]}$$ + 2

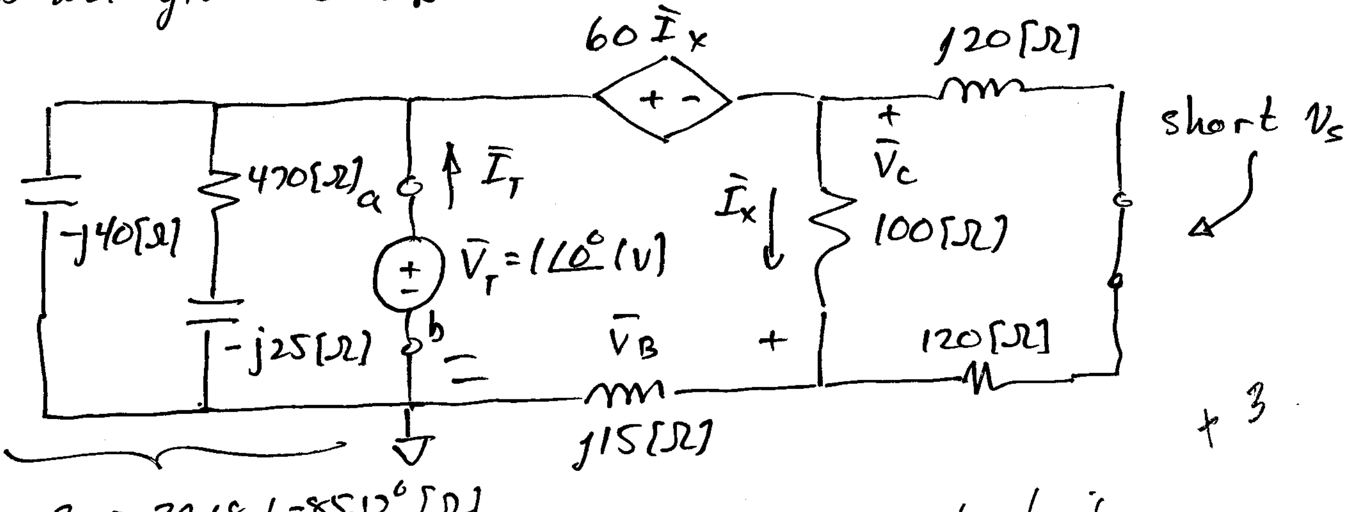
$27.02 + j162.2$ [Ω]

5. (35 points) For the circuit below, find the Norton Equivalent in the time domain seen by the current source i_S. The sources are as follows.

$$i_S(t) = 250\sin(1000[\text{rad/s}]t)\ [\text{mA}]$$
$$v_S(t) = 30\cos(1000[\text{rad/s}]t)\ [\text{V}]$$



We will transform to phasor domain, we will also remove the current source and replace it with a test source because we want the equivalent seen by i_s. This will give us Z_N.



We have also identified the terminals, at which we will be finding the Norton equivalent.

Room for extra work

$$\begin{cases} \dfrac{\bar{V}_B}{j15} + \dfrac{\bar{V}_B - \bar{V}_C}{100} + \dfrac{\bar{V}_B - \bar{V}_C}{120 + j20} = 0 \\ \bar{V}_B = 0.1658 \angle 76.22^\circ \text{ [V]} \\ \bar{V}_C = 0.6427 \angle 5.391^\circ \text{ [V]} \end{cases}$$

$$\bar{V}_C = -60\,\bar{I}_x + 1\angle 0^\circ$$

$$\bar{I}_x = \frac{\bar{V}_C - \bar{V}_B}{100}$$

$$\bar{I}_x = 6.087 \angle -9.517^\circ \text{ [mA]}$$

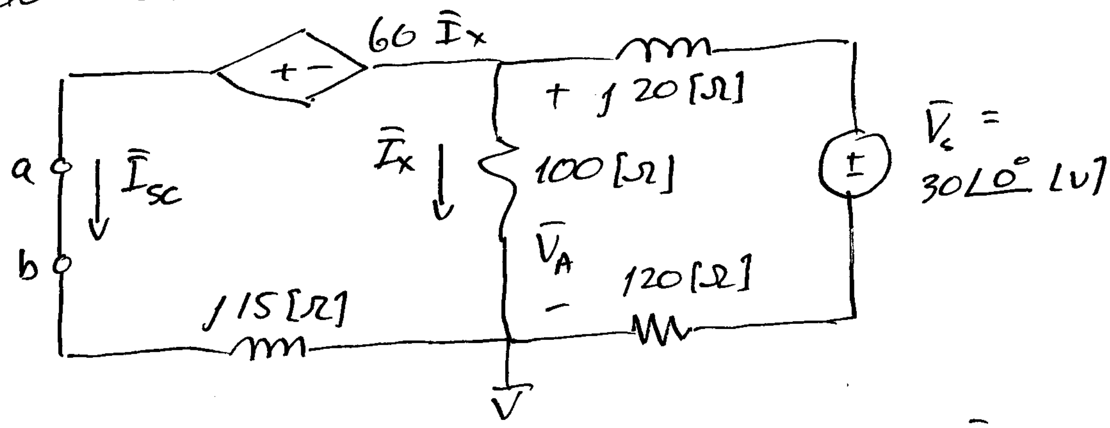
$$\bar{I}_T = \frac{1\angle 0^\circ}{39.68 \angle -85.12^\circ} + \frac{\bar{V}_C - \bar{V}_B}{100} + \frac{\bar{V}_C - \bar{V}_B}{120 + j20} = 25.9 \angle 60.23 \text{ [mA]}$$

$$12.86 + j\,22.48 \text{ [mA]}$$

$$Z_N = 1/\bar{I}_T = 38.62 \angle -60.23^\circ \text{ [}\Omega\text{]} = 19.18 - j\,33.52 \text{ [}\Omega\text{]}$$

+12

Let's do short-circuit current.



$$\frac{\bar{V}_A}{100} + \frac{\bar{V}_A - 30\angle 0^\circ}{120 + j20} + \frac{\bar{V}_A + 60\,\bar{I}_x}{j15} = 0 \qquad \bar{I}_x = \frac{\bar{V}_A}{100}$$

$$\bar{V}_A = 2.252 \angle 71.02 \text{ [V]} \qquad \bar{I}_x = 22.52 \angle 71.02^\circ \text{ [mA]}$$

$$\bar{I}_{sc} = \bar{I}_N = \frac{\bar{V}_A + 60\,\bar{I}_x}{j15} = 240.2 \angle -18.98^\circ \text{ [mA]}$$

$$0.2271 - j\,0.02812 \text{ [A]}$$

+12

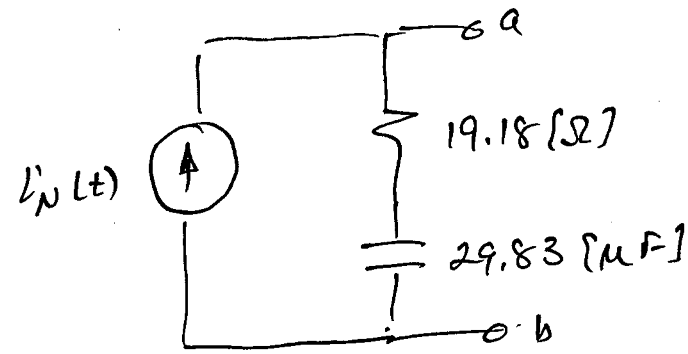
p.2a

Room for extra work

$i_N(t) = 240.2 \cos(1000 [\frac{rad}{s}] t - 18.98^\circ)$ [mA] + 2

$R_N = 19.18$ [Ω] + 4

$-j33.52\ [\Omega] = \frac{-j}{\omega C} \Rightarrow C = \frac{1}{1000(33.52)} = 29.83\ [\mu F]$

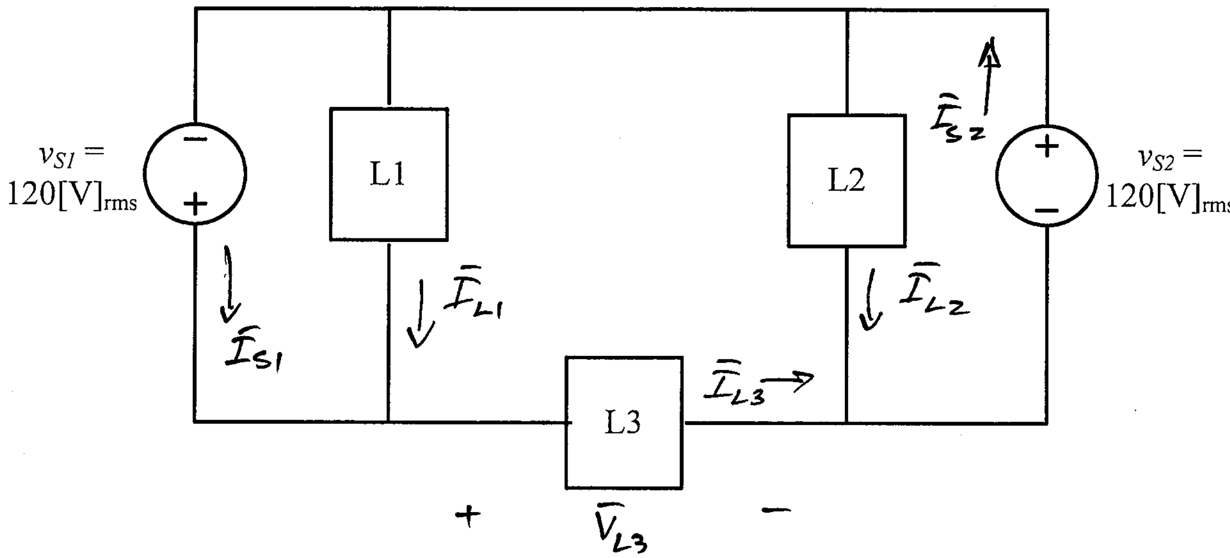


+ 2

$\tilde{V}_{oc} = 9.275 \angle -79.21^\circ$ [V] +12

$(1.736 - j9.111)$ [V]

6. (35 points) In the circuit below, load L1 absorbs 2.5 [kW] and 450 [VAR]. Load 2 absorbs 3.5 [kVA] at 0.96 pf lead. Load 3 is a 15 [Ω] resistor in series with a reactance of $-\mathbf{j}15$ [Ω]. Find the power delivered by each of the sources.



we need the load currents. For L1 and L2, we'll find complex power. We'll use Ohm's Law for L3.

$S_1 = 2500 + j450$ [VA] $2540 \angle 10.2°$ [VA] +5

$\bar{I}_{L1}^* = \frac{-S_1}{\bar{V}_1} = -\frac{2500+j450}{120} = 21.17 \angle -169.8°$ [A]

$\bar{I}_{L1} = 21.17 \angle 169.8°$ [A] $-20.83 + j3.75$ [A] +3

$S_2 = 3500(0.96) - j\,3500(0.28)$ [VA] (3360 − j 980) $3500 \angle -16.26°$ [VA]

$\cos(\theta_v - \theta_i) = 0.96$
$\Rightarrow \sin(\theta_v - \theta_i) = 0.28$
"lead" $\Rightarrow Q < 0$

$\bar{I}_{L2}^* = \frac{S_2}{\bar{V}_2} = 29.17 \angle -16.26°$ [VA] +5

$\bar{I}_{L2} = 29.17 \angle +16.26°$ [A] $28.00 + j8.167$ [A]

+3

Room for Extra Work

$\bar{V}_{L3} = \bar{V}_1 + \bar{V}_2 = 240$ [V] rms

$\bar{I}_{L3} = \dfrac{240}{15-j15} = 11.31 \angle 45^\circ$ [A] $7.997 + j7.997$ [A] +5

$\bar{I}_{s_1} = \bar{I}_{L3} - \bar{I}_{L4} = 29.14 \angle 8.382^\circ$ [A] $28.83 + j4.248$ [A] +3

$\bar{I}_{s2} = \bar{I}_{L2} + \bar{I}_3 = 39.46 \angle 24.18^\circ$ [A] $36.00 + j16.16$ [A] +3

$S_{del\ by\ \bar{V}_{s_1}} = \bar{V}_{s_1} \bar{I}_{s_1}^* = 120(29.14 \angle -8.382^\circ) = 3497 \angle -8.382^\circ$ [VA]

$3459 - j509.7$ [VA] +4

$S_{del\ by\ \bar{V}_{s2}} = \bar{V}_s \bar{I}_{s2}^* = 120(39.46 \angle -24.18^\circ) = 4735 \angle -24.18^\circ$ [VA]

$4320 - j1940$ [VA]

+4

$S_3 = \bar{V}_{L3} \bar{I}_{L3}^* = 2714 \angle -45^\circ$ [VA]

$1919 - j1919$ [VA]