Name: ______________________________ (please print)

Signature: ___________________________

ECE 2202 – Final Exam

December 3, 2024

Keep this exam closed 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 that is not given in a reasonable order will lose credit. Clearly indicate your answer (for example by enclosing it in a box).
3. Show all units in solutions, intermediate results, and figures. Units in the exam 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 100 minutes to work on this exam.

1. _______________/35

2. _______________/30

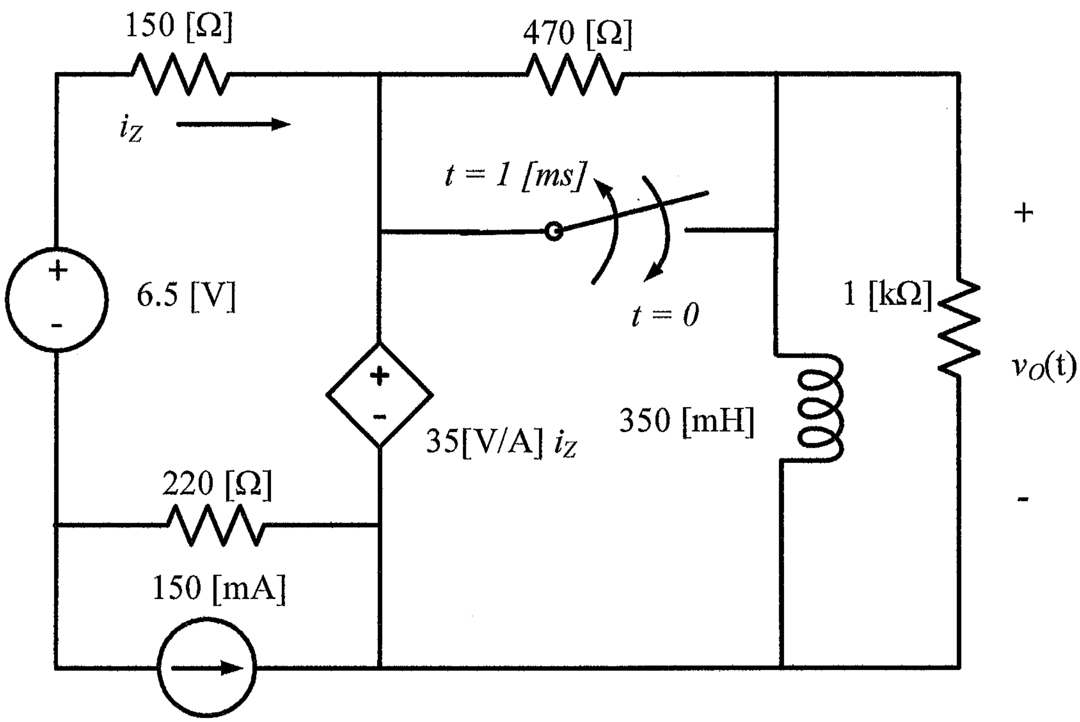
3. _______________/35

Total = 100

Room for extra work

1. {35 Points} In the circuit shown below, the switch was open for a long time. It closed at t = 0 and then opened again at t = 1 [ms].

   Find $v_O(t)$ as a function of time for all time periods $t > 0$.



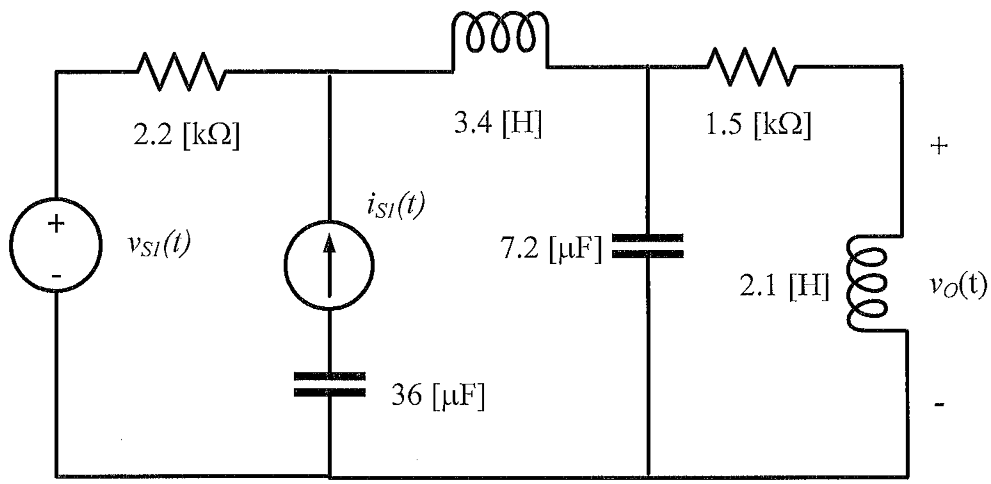
Room for extra work

Room for extra work

2. {30 Points} The sources $v_S(t)$ and $i_S(t)$ in the circuit below are given as follows.

$$v_{S1}(\mathrm{t}) = 20.5\cos\left(377\left[\frac{\mathrm{rad}}{\mathrm{s}}\right]\mathrm{t} - 20°\right)\ [V]$$
$$i_{S1}(t) = 1.25\sin\left(354\left[\frac{rad}{s}\right]t + 32°\right)\ [A]$$

Find the voltage $v_O(t)$.



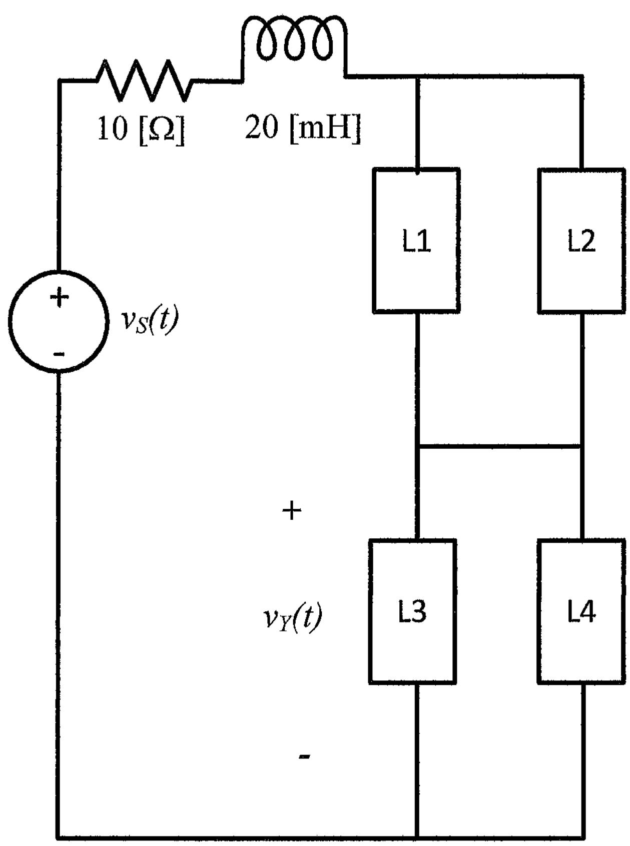
Room for extra work

{35 Points} In the circuit below, the loads are characterized as follows.

Load L1 absorbs $1250\angle 41° \; [VA]$.
Load L2 absorbs 750 [W] at 0.84 power factor leading.
Load L3 absorbs $1520 - j470 \; [VA]$.
Load L4 absorbs 1400 [W] and delivers 460 [VAR].

The voltage $v_Y(t) = 339.41 \cos\left(377 \left[\frac{rad}{s}\right] t\right) \; [V]$.

a. Find $v_S(t)$.
b. Find the total complex power delivered by the source $v_S(t)$.
c. Find the equivalent impedance of L1 in the time domain (that is, find the impedance in terms of R, L, and C).



Room for extra work

Room for extra work

Name: SOLUTIONS! (please print)

Signature: ______________________________

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1. ________________/35

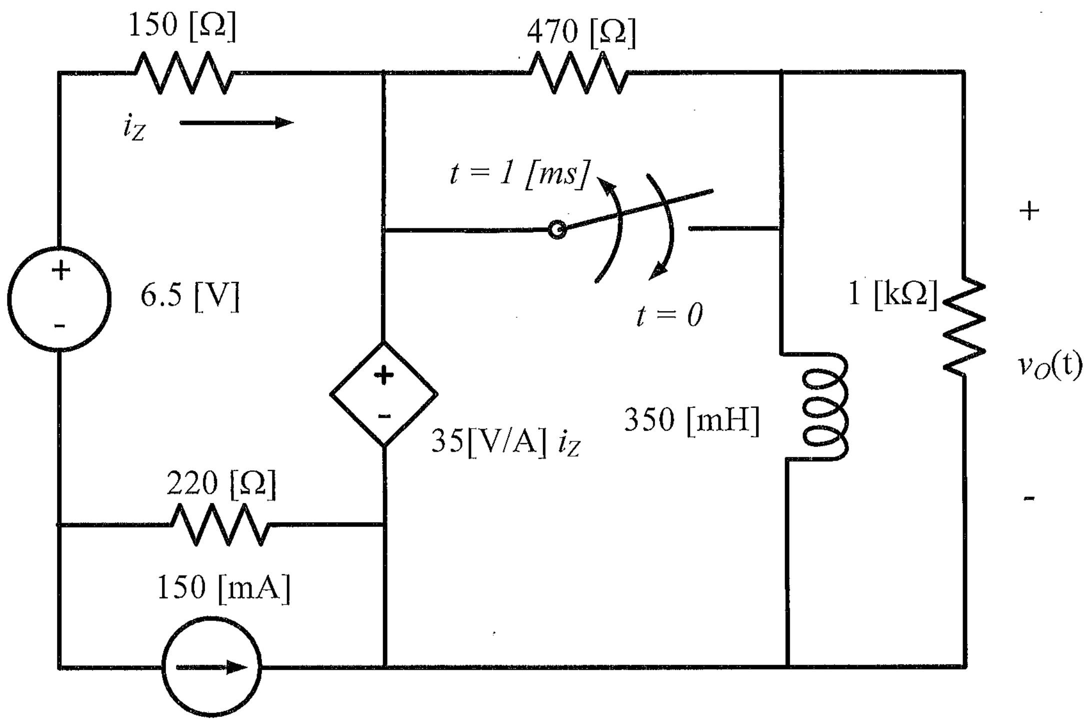
2. ________________/30

3. ________________/35

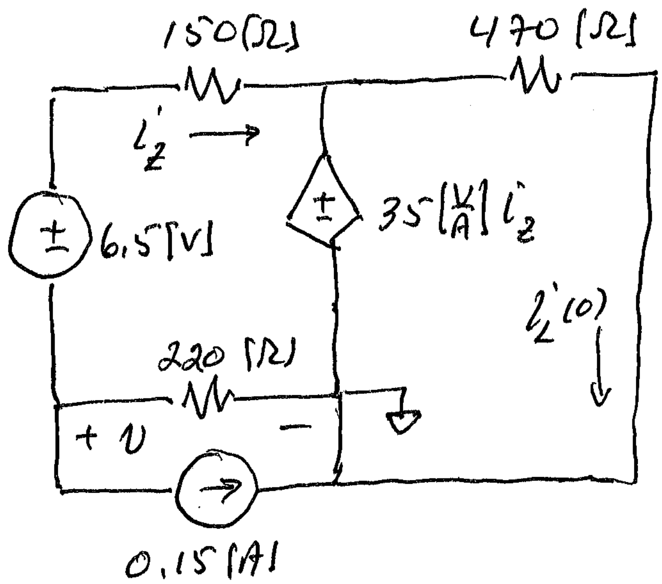
Total = 100

1. {35 Points} In the circuit shown below, the switch was open for a long time. It closed at t = 0 and then opened again at t = 1 [ms].

   Find $v_O(t)$ as a function of time for all time periods $t > 0$.



Draw for $t<0$. Inductor is a short :



$$\frac{v}{220} + i_z' + 0.15 = 0$$

$$i_z' = \frac{v - 35 i_z' + 6.5}{150}$$

$v = -18.605$ [V]

$i_z' = -65.43$ [mA]

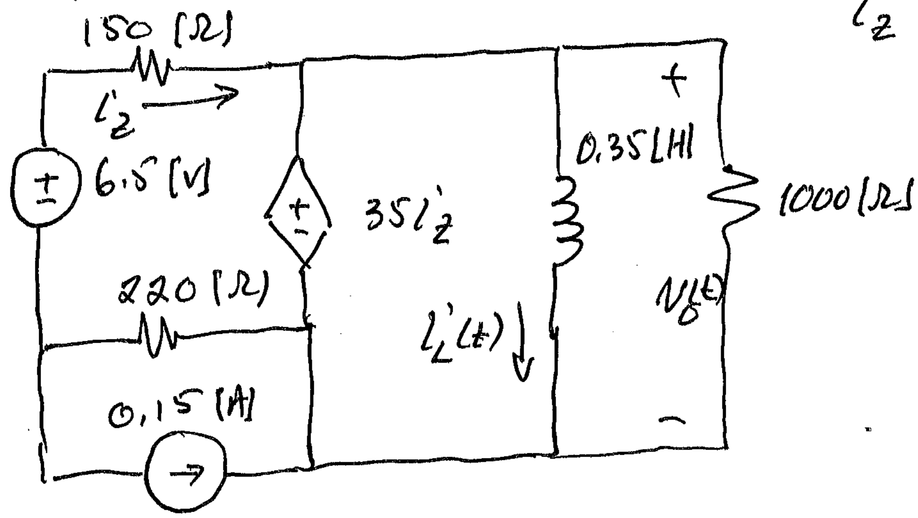
+4

+1 $\quad i_L'(0) = \dfrac{35 i_z'}{470} = -0.00487$ [A]

Room for extra work

Draw for $0 < t < 1$ [ms]

+1



i_Z' is the same as for $t<0$:

$i_Z' = -65.43$ [mA]

+3 $v_o(t) = 35 i_Z' = -2.290$ [V] $\quad 0 < t < 0.1$ [ms]

+1 We also need $i_L'(t = 1\,[\text{ms}])$:

+5 $$i_L'(t) = \frac{1}{0.350}\int_0^t 35 i_Z' \, dt - 0.00487 \quad (i_L'(0))$$

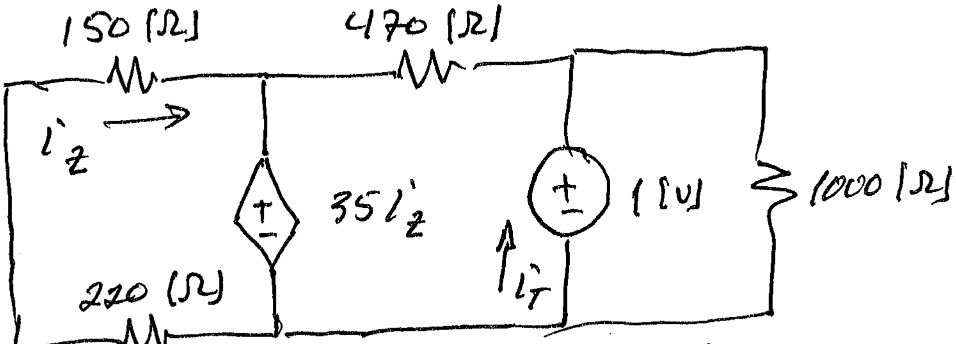
$$= -6.543\left[\frac{V}{s}\right]t - 0.00487 \text{ [A]}$$

+2 $i_L'(1\,[\text{ms}]) = -0.0114$ [A]

M

Room for extra work

Draw for $t > 1$ [ms]. Use test source for R_{TH}:



17

+3 $i_Z = 0 \Rightarrow R_{TH} = \left(\frac{1}{470} + \frac{1}{1000}\right)^{-1} = 319.73\,[\Omega]$

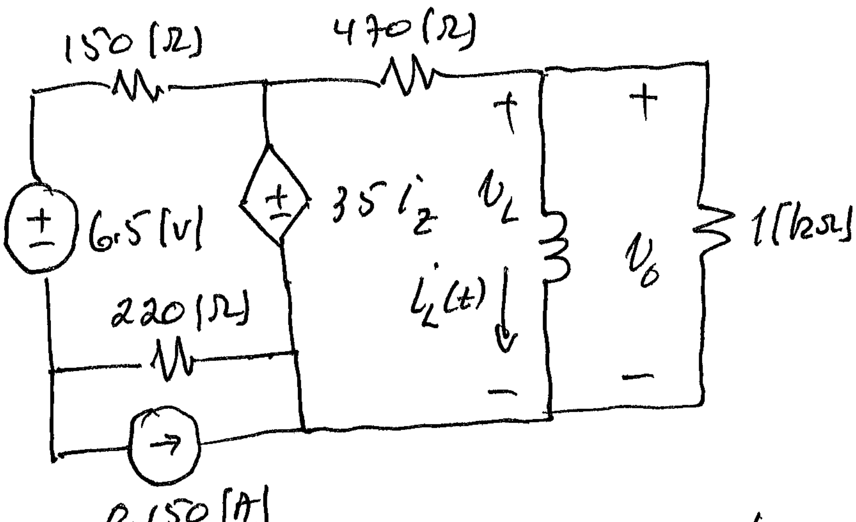
+1 $\tau = L/R_{TH} = 1.09\,[\text{ms}]$

+3 Same circuit as for $t < 0 \Rightarrow i_{L,f} = -0.00487\,[A]$

+3 $\therefore\ i_L(t) = -4.87\,[\text{mA}] + (-11.41 + 4.87)\,[\text{mA}]\, e^{-\frac{(t - 1[\text{ms}])}{1.09\,[\text{ms}]}}$ $t \geq 1\,[\text{ms}]$

+1

+2



$v_o(t) = v_L(t)$

$= L \frac{d i_L(t)}{dt}$

$v_o(t) = 0.35\,(-6.54 \times 10^{-3}) \frac{-1}{1.09 \times 10^{-3}}\, e^{\frac{-(t - 1[\text{ms}])}{1.09\,[\text{ms}]}}$

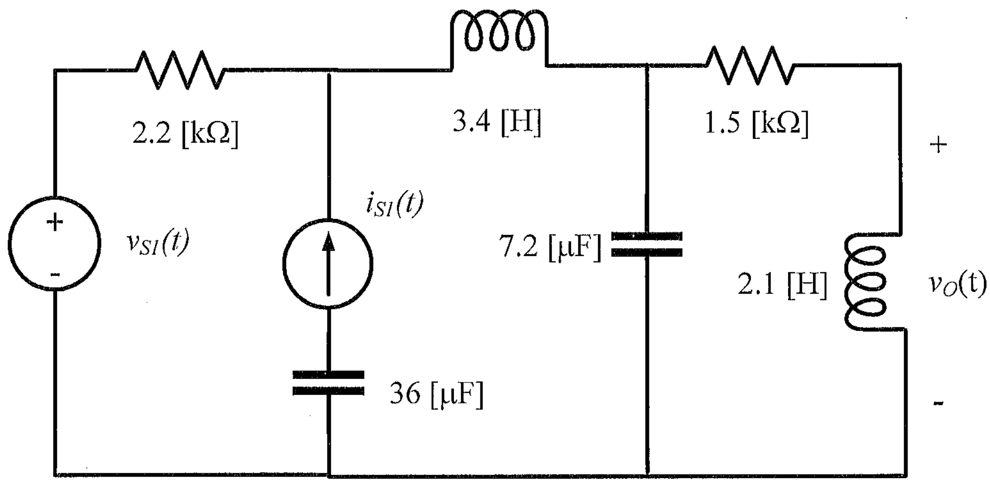
+3 $v_o(t) = 2.1\,[V]\, e^{-\frac{(t - 1[\text{ms}])}{1.09\,[\text{ms}]}}$ $t > 1\,[\text{ms}]$

+1

2. {30 Points} The sources $v_S(t)$ and $i_S(t)$ in the circuit below are given as follows.

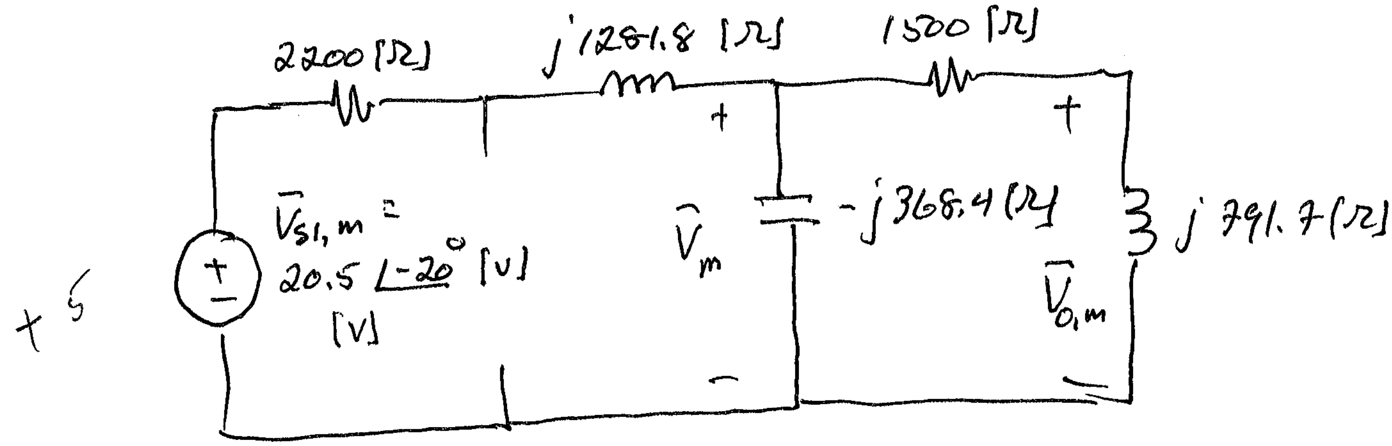
$$v_{S1}(\mathrm{t}) = 20.5\cos\left(377\left[\frac{\mathrm{rad}}{\mathrm{s}}\right]\mathrm{t} - 20°\right)\ [V]$$
$$i_{S1}(t) = 1.25\sin\left(354\left[\frac{rad}{s}\right]t + 32°\right)\ [A]$$

Find the voltage $v_O(t)$.



Since ω is different for each source, we need superposition. Also we need to subtract 90° from the argument of sin to make it cos.

For $v_{S1}(t)$: i_{S1} → open circuit ; $\omega = 377\ [\frac{rad}{s}]$



no 'm' -1

no overbar -3

no 'o' -1

Room for extra work

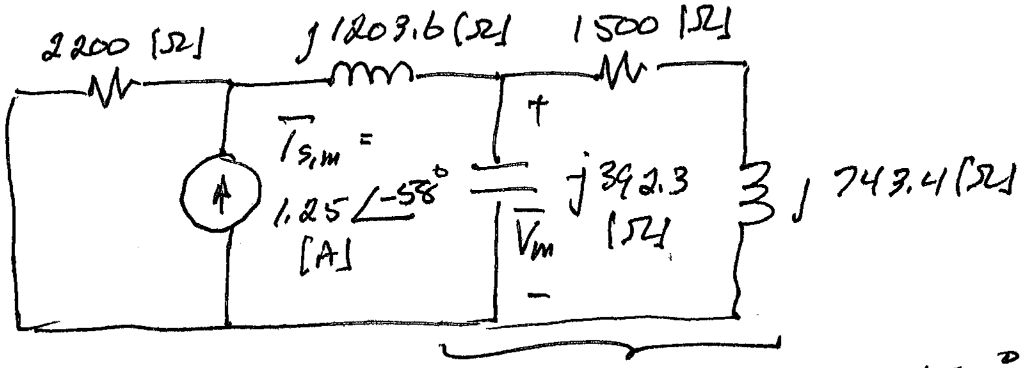
$$\frac{\bar{V}_m}{-j368.4} + \frac{\bar{V}_m - 20.5\angle 20^\circ}{2200 + j1281.8} + \frac{\bar{V}_m}{1560 + j791.7} = 0$$

$$\bar{V}_m = 3.353\,[V]\angle -119.2^\circ$$

+8 $$\bar{V}_{om}' = \bar{V}_m \cdot \frac{j791.7}{1500 + j791.7} = 1.565\,[V]\angle -57.02^\circ$$

For $i_s(t)$, $v_{s_1} \rightarrow$ short circuit and $\omega = 354\,[\frac{rad}{s}]$

+5



$$Z_{eq} = 426.31\angle -76.81^\circ\,[\Omega]$$

$$\bar{V}_m = 1.25\angle -58^\circ \cdot \frac{2200}{2200 + j1203.6 + Z_{eq}} \cdot Z_{eq} = 482.68\angle -153.8^\circ\,[V]$$

+8 $$\bar{V}_{o,m}'' = \bar{V}_m \frac{j743.4}{1500 + j743.4} = 214.34\angle -90.12^\circ\,[V]$$

$$v_o(t) = v_o'(t) + v_o''(t)$$

$$v_o(t) = 1.565\cos(377[\tfrac{rad}{s}]t - 57^\circ)\,[V] + 214.34\cos(354[\tfrac{rad}{s}]t - 90.12^\circ)\,[V]$$

+4

{35 Points} In the circuit below, the loads are characterized as follows.

Load L1 absorbs $1250\angle 41°\ [VA]$.
Load L2 absorbs 750 [W] at 0.84 power factor leading.
Load L3 absorbs $1520 - j470\ [VA]$.
Load L4 absorbs 1400 [W] and delivers 460 [VAR].

The voltage $v_Y(t) = 339.41\cos\left(377\left[\frac{rad}{s}\right]t\right)\ [V]$.

a. Find $v_S(t)$.
b. Find the total complex power delivered by the source $v_S(t)$.
c. Find the equivalent impedance of L1 in the time domain (that is, find the impedance in terms of R, L, and C).

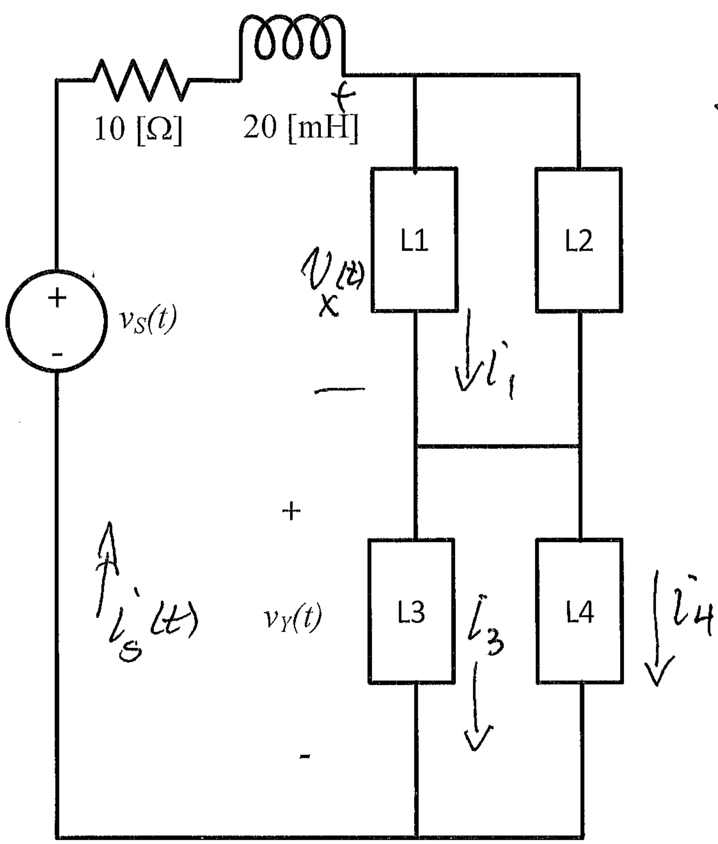
For load 2 :

$|S_{abs2}| = \frac{750}{0.84}$

$= 892.86\ [VA]$

$rf = \sqrt{1-0.84^2}$

$= 0.5426$



$j\omega(20\times10^{-3})$
$= j\,7.54\ [\Omega]$

+1 $S_{abs1} = 1250\angle 41°\ [VA]$

+4 $S_{abs2} = 750 + j892.86\,(0.5426) = 892.86\angle -32.86°\ [VA]$ $= 750 - j484.5$

+2 $S_{abs3} = 1591\angle -17.18°\ [VA]$ $= 1520 - j469$

+2 $S_{abs4} = 1473.6\angle -18.19°\ [VA]$ 8 $= 1400 - j\,460.$

Room for extra work

The rms amplitude of $v_Y(t)$ is $\frac{339.41}{\sqrt{2}} = 240\,[V]_{rms}$.
If we use this value, then calculations of $\bar{V}$ and $\bar{I}$ will be in rms, and $S = \bar{V}\bar{I}^*$.

$$S_{abs3} = \bar{V}_Y \cdot \bar{I}_3^* \Rightarrow \bar{I}_3 = \left(\frac{S_{abs3}}{\bar{V}_Y}\right)^* = \left(\frac{1591\angle{-17.18^\circ}}{240}\right)^*$$

+3 $\bar{I}_3 = 6.629\angle{+17.18^\circ}\,[A]_{rms} = 6.333 + j\,1.958$

9.375   8.956 + j 2.769

$$S_{abs4} = \bar{V}_Y \cdot \bar{I}_4^* \Rightarrow \bar{I}_4 = \left(\frac{S_{abs4}}{\bar{V}_Y}\right)^* = \left(\frac{1473.6\angle{-18.19^\circ}}{240}\right)^*$$

+3 $\bar{I}_4 = 6.140\angle{+18.19^\circ}\,[A]_{rms} = 5.833 + j\,1.917$

8.68   8.249 + j 2.704

+2 $\bar{I}_S = \bar{I}_3 + \bar{I}_4 = 12.769\angle{17.67^\circ}\,[A]_{rms} = 12.167 + j\,3.876$

18.06   17.209 + j 5.481

$$\bar{V}_S = (10 + j\,7.54)\,\bar{I}_S + \bar{V}_X + \bar{V}_Y$$

$$\bar{I}_S^*\bar{V}_X = S_{abs1} + S_{abs2} \Rightarrow \bar{V}_X = \frac{S_{abs1} + S_{abs2}}{\bar{I}_S^*} = \frac{1726.3\angle{11.21^\circ}}{12.769\angle{-17.67^\circ}}$$

+4

a) $\Rightarrow \bar{V}_X = 135.2\angle{28.88^\circ}\,[V]_{rms} = 118.38 + j\,65.3$

191.2   167.41 + j 92.35

$\therefore \bar{V}_S = 491.5\angle{23.48^\circ}\,[V]_{rms} = 450.80 + j\,195.83$

695.1   637.54 + j 276.20

+3

$$\Rightarrow v_S(t) = 491.5\sqrt{2}\cos\left(377\left[\tfrac{rad}{s}\right]t + 23.48^\circ\right)\,[V]$$

+2

$$v_S(t) = 695.1\cos\left(377\left[\tfrac{rad}{s}\right]t + 23.48^\circ\right)\,[V]$$

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pg 2

Room for extra work

Prob 3 b)

$$S_{del\ by\ \bar{V}_s} = \bar{V}_s \bar{I}_s^* = (491.5 \angle 23.48^\circ)(12.769 \angle -17.69^\circ)$$

+3

$$S_{del\ by\ \bar{V}_s} = 6276.0 \angle 5.81^\circ \ [VA]$$

$$= 6243.8 + j634.8 \ [VA]$$

c)

$$S_{abs_1} = \bar{V}_x \bar{I}_1^* = \frac{\bar{V}_x \cdot \bar{V}_x^*}{Z_1^*}$$

$$\therefore Z_1 = \left(\frac{|\bar{V}_x|^2}{S_{abs_1}}\right)^* = \left(\frac{(135.2)^2}{1250 \angle 41^\circ}\right)^* = 14.62 \angle 41^\circ \ [\Omega]$$

+4

$$Z_1 = 11.04 - j9.59 \ [\Omega]$$

+1

$$\therefore R = 11.04 \ [\Omega]$$

+1

$$C = \frac{1}{9.59\omega} = 276.6 \ [\mu F]$$

$S_1 = 1250 \angle 41^\circ$ [VA] $= 943.4 + j820.1$

$S_2 = 892.86 \angle -32.86^\circ$ [VA] $= 750 - j484.5$

$S_3 = 1591 \angle -17.18$ [VA] $= 1520 - j469$

$S_4 = 1473.6 \angle -18.19$ [VA] $= 1400 - j460.$

a) S: +9

$\bar{V}_s$: +15

N_s: +2

b) +3

c) +6