Signature: Key

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FINAL EXAM
ELEE 2335
DECEMBER 13, 1985

INSTRUCTIONS:

1. Fill in the information required on the upper left of this page.

2. All work is to be done in the spaces provided in this booklet. Use the backs if necessary, but indicate clearly where your work and answers may be found. Enclose your final answers in a box. No credit will be given unless necessary work is shown.

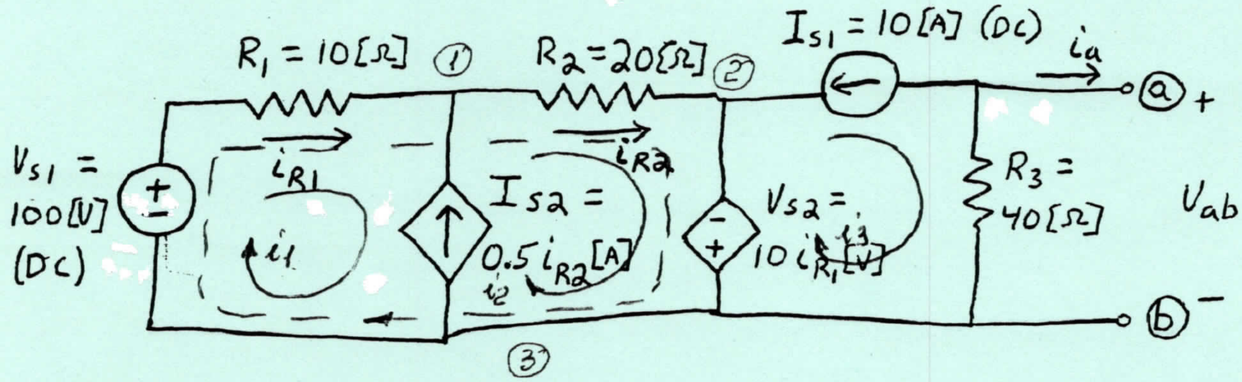
3. Make sure that some kind of clear distinction is obvious between complex quantities (phasors and impedances) and time domain functions. Show all of your units explicitly, both in your final answer and in your intermediate steps. Units in exam questions are placed within square brackets.

4. If your answers and work are not in ink, there will be no provision for changing your grade once the exam is returned to you. Do not use red ink.

1. 25
2. 25
3. 35
4. 25
5. 20
6. 40

170

1. (25 Points) The following circuit is to be used for all parts of this problem. The values of i_{R1} and i_{R2} in the expressions for the dependent sources are to be given in amperes.



a) Determine the values of the currents i_{R1} and i_{R2}. The current i_a is equal to zero for this part of the problem.

General comments about the method to be used:

Could be used to solve the circuit the node-voltage or mesh-current method.

Circuit characteristics:

*) n_e (essential nodes) = 3 (with $i_a = 0$) ⇒ node-voltage equations $= n_e - 1 = 2$

b_e (essential branches) = 5 (—"—) ⇒ mesh-current —"— $= b_e - (n_e - 1) = 3$

*) one dependent voltage source, one —"— current source } imply the same difficulty on each method.

*) in one essential branch the current is known → the mesh current method will have 2 equations.

so: both are equally difficult.

Using the mesh-current method:

mesh 1+2 (supermesh)

$R_1 i_1 + R_2 i_2 - V_{s2} - V_{s1} = 0$

$i_2 - i_1 = I_{s2} = 0.5\, i_{R2} = 0.5\, i_2$

$V_{s2} = 10\, i_{R1} = 10\, i_1$

mesh 3

$i_3 = -I_{s1} = -10[A]$

$\Rightarrow \begin{cases} R_1 i_1 + R_2 i_2 = V_{s1} + 10 i_1 \\ i_2 - i_1 = 0.5 i_2 \quad \rightarrow i_1 = 0.5\, i_2 \end{cases}$

$10 i_1 + 20 i_2 = 100 + 10 i_1 \rightarrow i_2 = \frac{100}{20} = 5[A]$

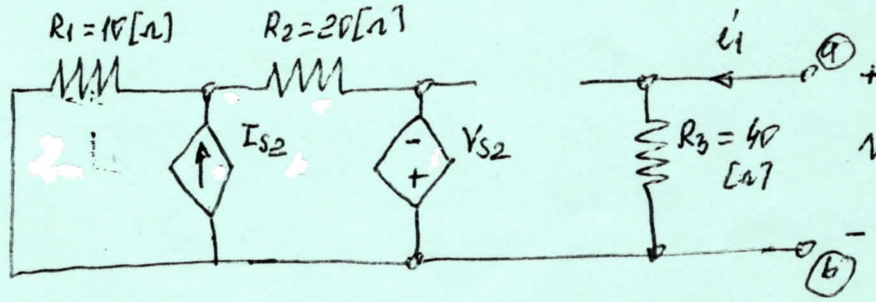
$i_1 = 0.5\, i_2 = 2.5[A]$

$\boxed{i_{R1} = i_1 = 2.5[A]}$; $\boxed{i_{R2} = i_2 = 5[A]}$

1. b) Determine the Thevenin equivalent of the circuit between terminals ⓐ and ⓑ

$$\boxed{v_{Th} = v_{ab_{(ia=0)}} = -I_{S1} R_3 = -10 * 40 = -400[V]}$$

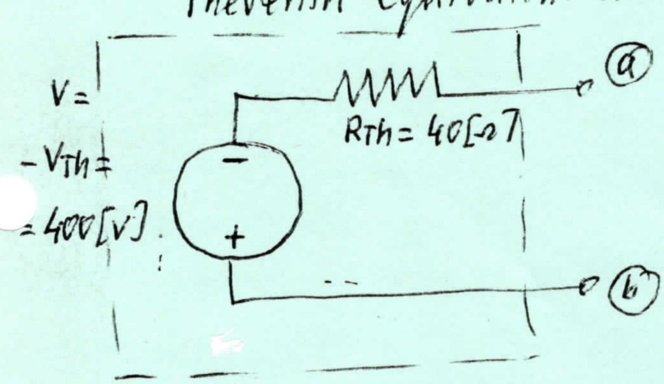
For R_{Th}, deactivate independent sources:



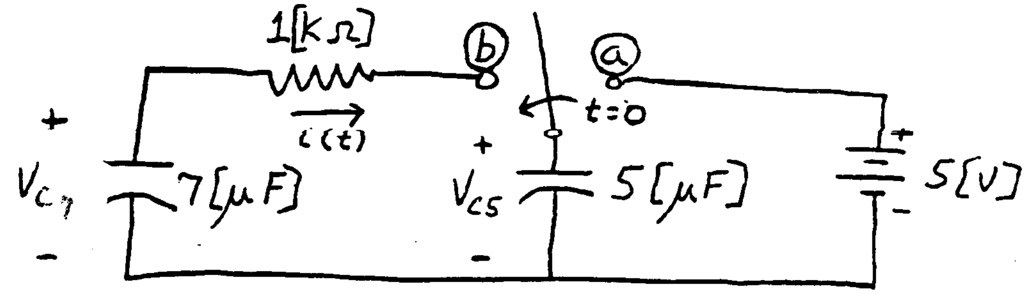
$$v_1 = R_3 i_1$$

$$\boxed{R_{Th} = \frac{v_1}{i_1} = R_3 = 40[\Omega]}$$

Thevenin equivalent circuit:



2. (25 Points) At time t = 0, the switch in the circuit below is moved from position ⓐ to position ⓑ. Assume that the switch was in position ⓐ for a long time before t = 0. Assume that $v_{C7}(0) = 0$.



a) What is the energy stored in the 5[μF] and the 7[μF] capacitors at t = 0⁻?

Energy stored in a capacitor $= \frac{1}{2} C V^2$

in 5[μF] capacitor, $V_{C5}(0) = 5[V]$

$W_5 = \frac{1}{2}(5 \times 10^{-6}) 5^2$ [joules]

$\boxed{W_5 = 62.5 \times 10^{-6} \text{ [joules]}}$

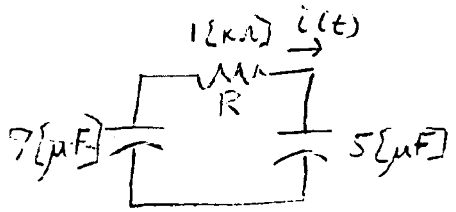
in 7[μF] capacitor, $V_{C7}(0) = 0$

$\boxed{W_7 = 0}$

4 pts total this part.
-2 pts for showing units as watts.
-1 pt for math error

b) Find i(t) for t>0.

The circuit for t > 0 is



The time constant is

$\tau = R C_{eq}$

where C_{eq} is the capacitance seen by R. The capacitors are in series, so

$$C_{eq} = \left(\frac{1}{7[\mu F]} + \frac{1}{5[\mu F]} \right)^{-1} = 2.92 [\mu F]$$

$$\tau = 10^3 [\Omega] \; 2.92 \times 10^{-6} [F] = 2.92 \times 10^{-3} [sec]$$

(Soln. continues on page 6.)

Room for Extra Work.

The response of this circuit is of the form:

$$i(t) = A e^{-t/\tau} + B.$$

at $t=0$,

$$i(t) = \frac{-5[V]}{1[K\Omega]} = -5[mA]$$

as $t \to \infty$, $i(t) \to 0$; since all the charge will have moved.

so $-5[mA] = A + B$

$$0 = B$$

$$i(t) = -5[mA]\, e^{-t/2.92\times10^{-3}}$$

or $\boxed{i(t) = -5\, e^{-343t}\ [mA]}$ for t expressed in seconds.

---

8 pts for this section.

- -1 pt for sign error
- -1 pt for missing units
- -1 pt for math error
- -1 pt to -2 pt for error in initial + final conditions.

2. c) Find $v_{C7}(t)$ and $v_{C5}(t)$ for t>0.

$$V_{C7}(t) = \frac{1}{C_7}\int_{-\infty}^{t} -i(x)\,dx \;;$$

or since $i(x) = -5\,e^{-343x}$ [mA], then

$$V_{C7}(t) = V_{C7}(0) + \frac{1}{7\times10^{-6}}\int_0^t (5\times10^{-3})e^{-343x}\,dx$$

Now since $V_{C7}(0) = 0$, then

$$V_{C7}(t) = \left(\frac{5\times10^{-3}}{7\times10^{-6}}\right)\left.\frac{e^{-343x}}{-343}\right|_0^t \text{ [V]}$$

$$\boxed{V_{C7}(t) = -2.08\left(e^{-343t}-1\right) \text{ [V]}}$$

$$\boxed{V_{C5}(t) = V_{C7}(t) - i(t)R = \left(2.08 + 2.92\,e^{-343t}\right) \text{ [V]}}$$

9 pts this part - grading as in part b.)

d) Find the energy stored in the 5[µF] and the 7[µF] capacitors at t >> 0. In other words, find the final values of the energies stored in the capacitors.

at $t >> 0$

We can see from the solution above, the charge has distributed itself between the capacitors so that $V_{C7} = V_{C5} = 2.08$ [V]

so $$\boxed{W_5 = \frac{1}{2}C_5(V_{C5})^2 = 10.8\times10^{-6} \text{ [joules]}}$$

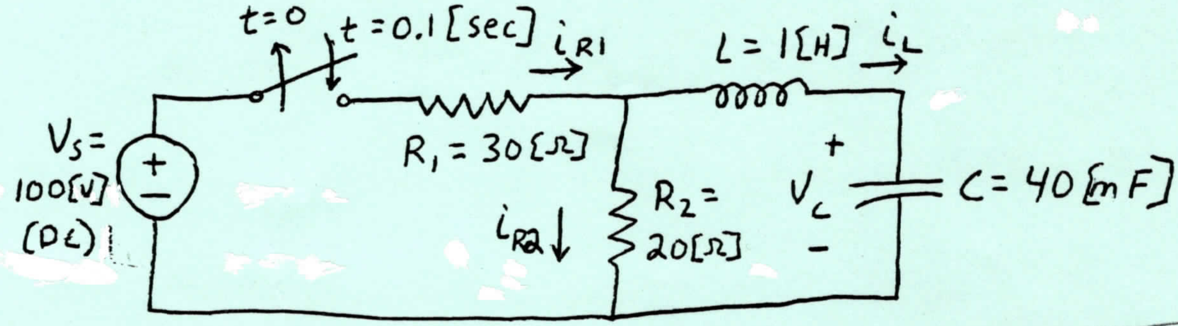
And

$$\boxed{W_7 = \frac{1}{2}C_7(V_{C7})^2 = 15.1\times10^{-6} \text{ [joules]}}$$

Note that the final energy is less than the initial energy. Thus, the system has moved to a lower energy state, as expected.

4 pts this problem. Full credit may be given if answer agrees with c) soln. and is presented logically + clearly.

3. (35 Points) In the following circuit, the switch was closed for a long time. At t = 0, the switch is opened and then is reclosed at t = 0.1[sec].



a) For t < 0, determine the values of i_{R1}, i_{R2}, i_L, and v_C.

5 pts

2, 2, 1 /per relation

V_s, being a DC source: $\boxed{i_L = 0[A]}$;

$$\boxed{i_{R1} = i_{R2} = \frac{V_s}{R_1+R_2} = \frac{100}{30+20} = 2\,[A]}$$

$$\boxed{v_C = i_{R2} R_2 = 2*20 = 40[V]}$$

Common criteria for Problem # 3 & 6

−1, for each distinct math error

−1, for missing units (per part of problem)

−2, for circuit variable sign error (per distinct occurrence)

−0.5, for analytical relation unfinished with numerical value

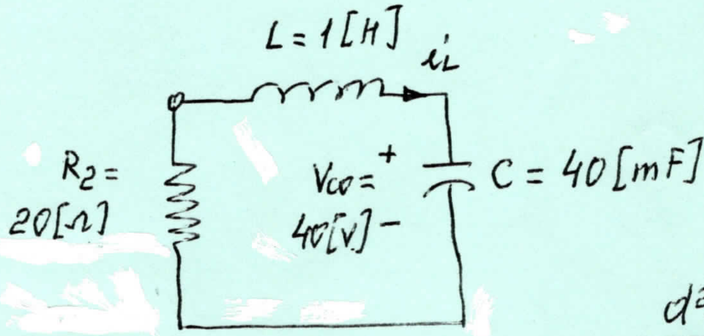
−1, for u(t)

[24 pts]

3. b) Determine the expression for $i_L(t)$ for $0 \le t < 0.1$[sec].

12 pts

For $0 \le t \le 0.1$, the circuit is:



$$R_2 i_L + L\frac{di_L}{dt} + \frac{1}{C}\int_0^t i_L dt + V_{co} = 0$$

$$L\frac{d^2 i_L}{dt^2} + R_2\frac{di_L}{dt} + \frac{1}{C} i_L = 0$$ 5

$$\frac{d^2 i_L}{dt^2} + \frac{R_2}{L}\frac{di_L}{dt} + \frac{1}{LC} i_L = 0$$

the characteristic equation:

$$s^2 + \frac{R_2}{L}s + \frac{1}{LC} = 0; \qquad \alpha = \frac{R_2}{2L} = \frac{20}{2*1} = 10\,[\text{rad/s}].$$ 4

$$\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{1*40*10^{-3}}} = 5\,[\text{rad/s}]$$

$$s_{1,2} = -10 \pm \sqrt{10^2 - 5^2} = -10 \pm 8.660254\,[\text{rad/s}]; \quad \begin{cases} s_1 = -1.339746\,[\text{rad/s}] \\ s_2 = -18.660254\,[\text{rad/s}] \end{cases}$$

It is an overdamped response:

$$i_L(t) = I_{final} + A_1 e^{s_1 t} + A_2 e^{s_2 t}; \quad \boxed{I_{final} = 0\,[A]}$$ 3

To determine the constants:

12 pts

$\underline{t=0^+}$: $i_L(0^+) = i_L(0^-) = 0\,[A] = A_1 + A_2 \Rightarrow i_L(t) = A_1(e^{s_1 t} - e^{s_2 t})$

$$R_2 i_L(0^+) = 0; \quad v_C(0^+) = v_C(0^-) = 40\,[V] \Rightarrow L\frac{di_L}{dt}\Big|_{t=0^+} + V_{co} = 0$$

$$-LA_1(s_1 e^{s_1 t} - s_2 e^{s_2 t})\Big|_{t=0^+} = 40\,[V] \Rightarrow -LA_1(s_1 - s_2) = 40$$

$$A_1 = \frac{V_{co}}{L(s_2 - s_1)} = \frac{40}{1(-18.660254 + 1.339746)} = -2.3094011\,[A].$$

$$\boxed{i_L(t) = -2.3094011\left(e^{-1.339746t} - e^{-18.660254t}\right)u(t)\;[A]}$$

6 pts

3. c) Determine the values of i_{R1}, i_{R2}, and i_L at t = 0.1⁺[sec], after the switch is reclosed.

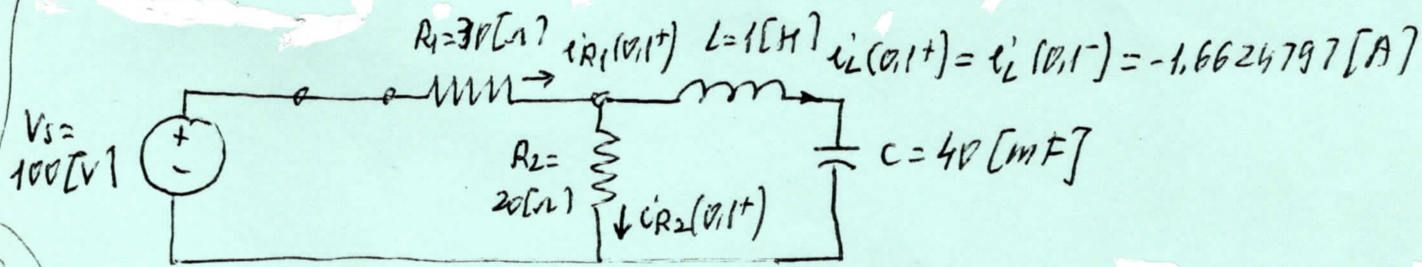
2.5 pts

$\underline{t=0.1^- [s]}$: $i_L(0.1^-) = -2.3094011\left(e^{-0.1339746} - e^{-1.8660254}\right) =$

$= -1.6624797\ [A]$

3.5 pts

$\underline{t=0.1^+ [s]}$, the circuit is:



$$\boxed{i_L(0.1^+) = i_L(0.1^-) = -1.6624797[A]}$$

$i_{R_1}(0.1^+) = i_L(0.1^+) + i_{R_2}(0.1^+)$

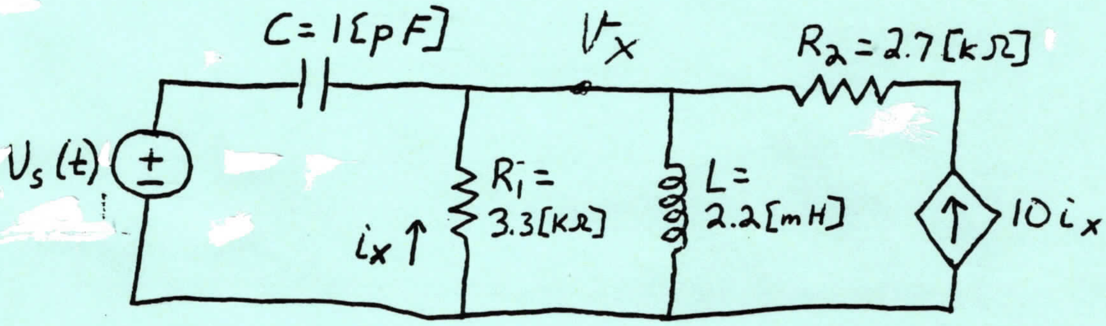
$V_s = R_1 i_{R_1}(0.1^+) + R_2 i_{R_2}(0.1^+) = R_1\left[i_L(0.1^+) + i_{R_2}(0.1^+)\right] + R_2 i_{R_2}(0.1^+)$

$V_s - R_1 i_L(0.1^+) = i_{R_2}(0.1^+)\left(R_1 + R_2\right);$

$$\boxed{i_{R_2}(0.1^+) = \frac{V_s - R_1 i_L(0.1^+)}{R_1 + R_2} = \frac{100 - 30(-1.6624797)}{30+20} = 2.9974878\ [A]}$$

$$\boxed{i_{R_1}(0.1^+) = i_{R_2}(0.1^+) + i_L(0.1^+) = 1.3350088\ [A].}$$

4. (25 Points) In the circuit below, the value of the voltage source is given as:
$v_s(t) = [5.7 \sin(360{,}000t) + 6.3 \cos(370{,}000t)][V]$.
Find $i_x(t)$. Assume that the circuit has been in this configuration for a long time.



We can solve this problem in the phasor domain, or using Laplace transforms. Since it is a sinusoidal problem, phasors are easier to use.

We must apply superposition, since we have the equivalent of two series voltage sources at different frequencies.

Since there are only 2 essential nodes, nodal voltages will be used, calling the top node V_x.

In the phasor domain:

$$\frac{\underline{V_x} - \underline{V_s}}{\frac{1}{j\omega C}} + \frac{\underline{V_x}}{R_1} + \frac{\underline{V_x}}{j\omega L} - 10\,\underline{I_x} = 0$$

note, $\underline{I_x} = -\dfrac{\underline{V_x}}{R_1}$

$$\frac{\underline{V_x}}{\frac{1}{j\omega C}} + \frac{11\,\underline{V_x}}{R_1} + \frac{\underline{V_x}}{j\omega L} = \frac{\underline{V_s}}{\frac{1}{j\omega C}}$$

Grading –
- −10pts for mixing phasor + time domain
- −1,2 pts for math error
- −5 pts for KVL or KCL error
- −2 pts for no units
- +15 pts for correct setup

ROOM FOR EXTRA WORK

Solve for $\underline{V_x}$

$$\underline{V_x} = \frac{\underline{V_S}\, j w C}{j w C + \frac{1}{R_1} + \frac{1}{j w L}}$$

Solve first for source with $w = 360{,}000, \Rightarrow \underline{V_S} = 5.7\angle -90^\circ$

$$\underline{V_{x_1}} = \frac{(5.7\angle -90^\circ)(3.6\times10^{5})(10^{-12})\angle 90^\circ}{(3.6\times10^{5})(10^{-12})j + 3.33\times10^{-3} - j(3.6\times10^{5})^{-1}(2.2\times10^{-3})^{-1}}$$

$$\underline{V_{x_1}} = \frac{2.05\times10^{-6}}{3.33\times10^{-3} - j\,1.26\times10^{-3}} = \frac{2.05\times10^{-6}}{3.56\angle -20.8^\circ}$$

$$\underline{V_{x_1}} = 5.76\times10^{-4}\angle +20.8^\circ \quad [V]$$

And for source with $w = 370{,}000 \Rightarrow V_s = 6.3\angle 0^\circ$

$$\underline{V_{x_2}} = \frac{6.3\,(3.7\times10^{5})(10^{-12})\angle 90^\circ}{(3.7\times10^{5})(10^{-12})j + 3.33\times10^{-3} - j(3.7\times10^{5})^{-1}(2.2\times10^{-3})^{-1}}$$

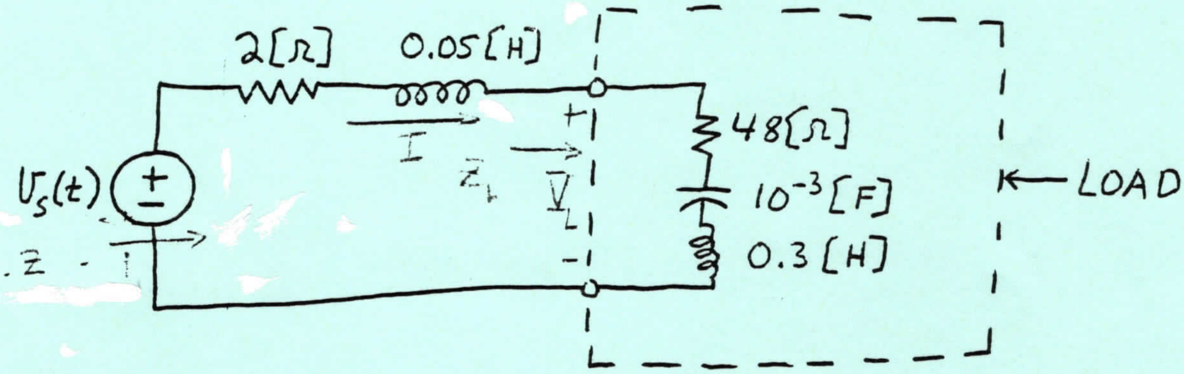
$$\underline{V_{x_2}} = \frac{2.33\times10^{-6}\angle 90^\circ}{3.33\times10^{-3} - 1.23\times10^{-3}j}$$

$$\underline{V_{x_2}} = \frac{2.33\times10^{-6}\angle 90^\circ}{3.55\times10^{-3}\angle -20.3^\circ} = 6.56\times10^{-4}\angle 110^\circ \,[V]$$

So $v_x(t) = 5.76\times10^{-4}(\cos 360{,}000t + 20.8^\circ) + 6.56\times10^{-4}(\cos 370{,}000t + 110^\circ)$ in [Volts]

$$\boxed{\text{so } i_x(t) = \frac{-v_x(t)}{3300} = -.175\,[\mu A]\sin(360000t + 111^\circ) - .199\,[\mu A]\cos(370000t + 110^\circ)}$$

5. (20 Points) In the circuit below, the value of the voltage source is given as:
$v_s(t) = [353.5\cos(100t)][V]$.



a) Calculate the average and reactive power delivered to the load. Express your answer in terms of P, Q, and S.

$\bar{V}_s = 353.5\angle 0^\circ$

$\bar{V}_s = \frac{353.5}{\sqrt{2}}\angle 0^\circ = 250\angle 0^\circ$ V (RMS)

$Z = 2 + j5 + 48 - j10 + j30 = 50 + j25\ \Omega = 55.9\angle 26.56^\circ\ \Omega$

$\bar{I} = \frac{\bar{V}_s}{Z} = \frac{250\angle 0^\circ}{55.9\angle 26.56^\circ} = 4.47\angle -26.56^\circ$ A (RMS)

$P_{LOAD} = |\bar{I}|^2 R_L = (4.47)^2 \times 48 = \underline{959 \text{ WATTS}}$

$Q_{LOAD} = |\bar{I}|^2 X_L = (4.47)^2 \times 20 = \underline{399.6 \text{ VAR}}$

$S = 959 + j399.6 = \underline{1038.8\angle 22.62^\circ \text{ VA}}$

ALTERNATE SOLUTION

$\bar{V}_L = Z_L \bar{I} = (48 + j20)(4.47\angle -26.56^\circ) = 52\angle 22.62^\circ \times 4.47\angle -26.56^\circ$

$= 232.4\angle -3.94^\circ$ VOLTS (RMS)

$S = V_L I_L \angle -3.94^\circ - (-26.56^\circ) = 232.4 \times 4.47\angle 22.62^\circ = \underline{1038.8\angle 22.62^\circ \text{ VA}}$

$P = 1038.8\cos 22.62^\circ = \underline{958.9} \text{ WATTS}$

$Q = 1038.8\sin 22.62^\circ = \underline{399.5} \text{ VAR}$

5. b) What is the power factor of the load?

SINCE $P = V_L I_L \cos\theta$

$PF = \cos\theta = \cos \angle Z_L = \cos 22.62° = \underline{\underline{.923}}$

c) Calculate the average and reactive power supplied by the voltage source. Express your answer in terms of P, Q, and S.

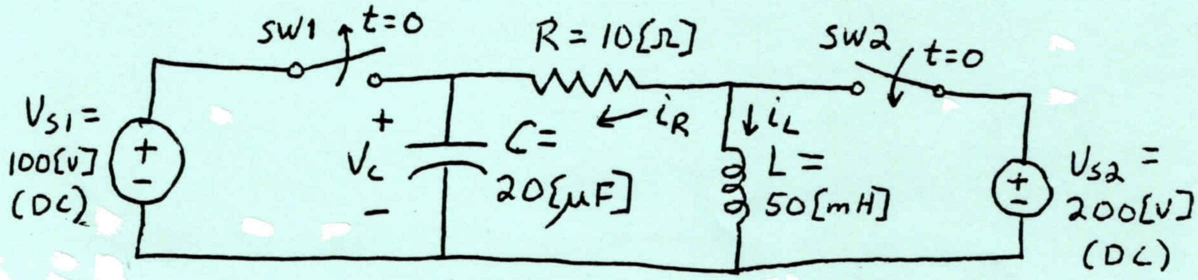
$S = V_s I^* = 250\angle 0° \times 4.47\angle +26.56$

$= \underline{\underline{1117.5 \angle +26.56 \quad VA}}$

$P = 1117.5 \cos 26.56 = \underline{999.6}$ WATTS

$Q = 1117.5 \sin 26.56 = \underline{499.7}$ VAR

6. (40 Points) In the following circuit, the switch SW1 was closed for a long time, and the switch SW2 was open for a long time. At t = 0, the switch SW1 is opened and the switch SW2 is closed.

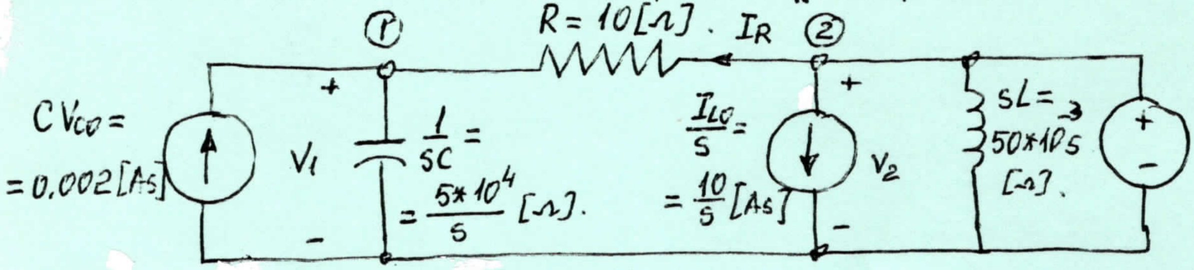


a) For t < 0, determine the values of i_R, i_L, and v_C.

$V_C(0^-) = V_{S1} = 100[V]$; $i_L(0^-) = -i_R(0^-) = \frac{V_{S1}}{R} = \frac{100}{10} = 10[A]$

5 pts

6. b) For $t > 0$, redraw the circuit in the frequency (s) domain. Take care to select for the circuit components the most convenient equivalent circuits, so that it will be easier to solve part for $I_R(s)$ in part c).



$$\frac{V_{S2}}{s} = \frac{200}{s} \text{ [Vs]}.$$

10 pts

c) Determine the expression for i_R in the s domain. In other words, find the value for $I_R(s)$ that is valid for the time domain function $i_R(t)$ for $t \geq 0$.

Applying the Kirchhoff's current law in the node #1:

10 pts

$$-CV_{C0} + \frac{V_1}{\left(\frac{1}{sC}\right)} + \frac{V_1 - \frac{V_{S2}}{s}}{R} = 0; \Rightarrow V_1\left(sC + \frac{1}{R}\right) = \frac{V_{S2}}{sR} + CV_{C0}$$

$$V_1 = \frac{V_{S2} + sRCV_{C0}}{\frac{s\cancel{R}(sCR+1)}{\cancel{R}}} = \frac{RCV_{C0}\left(s + \frac{V_{S2}}{RCV_{C0}}\right)}{sRC\left(s + \frac{1}{RC}\right)} = \frac{V_{C0}\left(s + \frac{V_{S2}}{RCV_{C0}}\right)}{s\left(s + \frac{1}{RC}\right)}$$

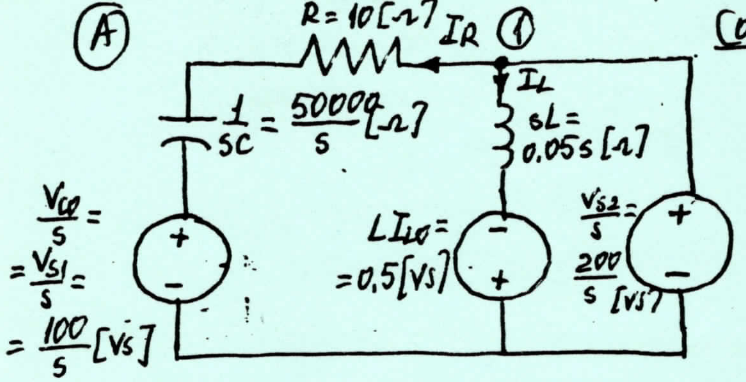
$$I_R = \frac{\frac{V_{S2}}{s} - V_1}{R} = \frac{V_{S2} - sV_1}{sR} = \frac{V_{S2} - \frac{V_{C0}\left(s + \frac{V_{S2}}{RCV_{C0}}\right)}{\left(s + \frac{1}{RC}\right)}}{sR} =$$

$$= \frac{sV_{S2} + \cancel{V_{S2}\frac{1}{RC}} - sV_{C0} - \cancel{V_{S2}\frac{1}{RC}}}{sR\left(s + \frac{1}{RC}\right)} = \frac{s(V_{S2} - V_{C0})}{sR\left(s + \frac{1}{RC}\right)}; \quad V_{C0} = V_{S1}$$

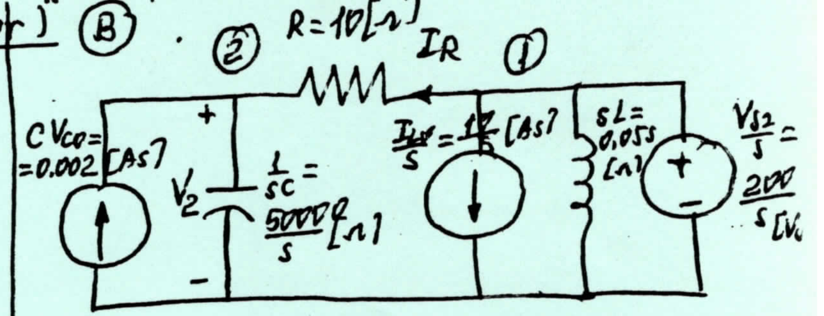
$$\boxed{I_R = \frac{V_{S2} - V_{S1}}{R} * \frac{1}{s + \frac{1}{RC}}}; \quad I_R(s) = \frac{200 - 100}{10} * \frac{1}{s + \frac{1}{10*20*10^{-6}}}$$

$$\boxed{I_R(s) = \frac{10}{s + 5000} \text{ [As]}}$$

6. b) For t > 0, redraw the circuit in the frequency (s) domain. Take care to select for the circuit components the most convenient equivalent circuits, so that it will be easier to solve part for $I_R(s)$ in part c).



(or)



c) Determine the expression for i_R in the s domain. In other words, find the value for $I_R(s)$ that is valid for the time domain function $i_R(t)$ for t ≥ 0.

A

$$I_R = \frac{\frac{V_{s2}}{s} - \frac{V_{s1}}{s}}{R+\frac{1}{sC}} = \frac{V_{s2}-V_{s1}}{s\left(R+\frac{1}{sC}\right)} = \frac{V_{s2}-V_{s1}}{R} * \frac{1}{s+\frac{1}{RC}}$$

$$I_R(s) = \frac{200-100}{10} * \frac{1}{s+\frac{1}{10*20*10^{-6}}}$$

$$= 10 * \frac{1}{s+5000}$$

B

KCL, #2:

$$-CV_{C0} + V_2 sC + \frac{V_2 - \frac{V_{s2}}{s}}{R} = 0$$

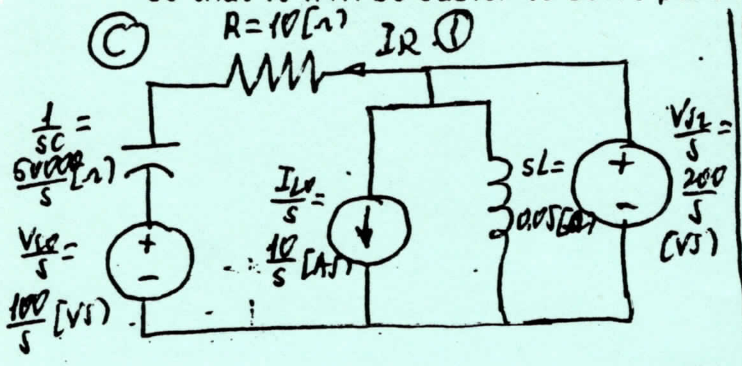
$$V_2\left(sC+\frac{1}{R}\right) = CV_{C0} + \frac{V_{s2}}{sR}$$

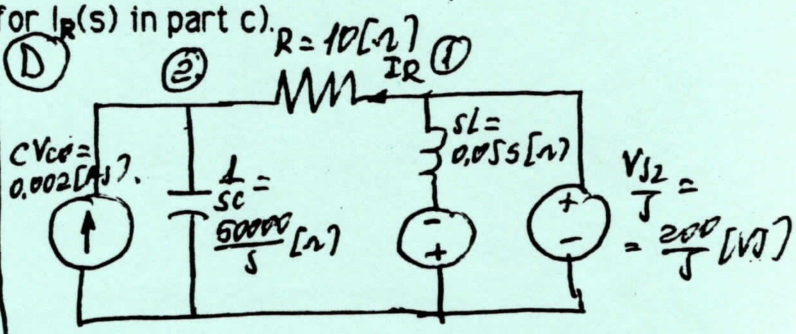
$$V_2 = \frac{V_{s2}+sCRV_{C0}}{s(sCR+1)} = \frac{\cancel{CR}\left(sV_{s1}+\frac{V_{s2}}{CR}\right)}{s\cancel{CR}\left(s+\frac{1}{RC}\right)}$$

$$I_R = \frac{\frac{V_{s2}}{s} - V_2}{R} = \frac{\frac{V_{s2}}{s} - \frac{sV_{s1}+V_{s2}/CR}{s\left(s+\frac{1}{RC}\right)}}{R}$$

$$= \frac{V_{s2}s + \cancel{V_{s2}\frac{1}{RC}} - sV_{s1} - \cancel{V_{s2}\frac{1}{RC}}}{sR\left(s+\frac{1}{RC}\right)} = \frac{V_{s2}-V_{s1}}{R\left(s+\frac{1}{RC}\right)}$$

6. b) For t > 0, redraw the circuit in the frequency (s) domain. Take care to select for the circuit components the most convenient equivalent circuits, so that it will be easier to solve part for $I_R(s)$ in part c).





c) Determine the expression for i_R in the s domain. In other words, find the value for $I_R(s)$ that is valid for the time domain function $i_R(t)$ for $t \geq 0$.

C like on A

D like on B

6. d) If the expression for $I_R(s)$ is

$$I_R(s) = \left(\frac{V_{s2} - V_{s1}}{R}\right) \cdot \left(\frac{1}{\left(s + \frac{1}{RC}\right)}\right) ,$$

then, apply the initial and final value theorems to obtain the initial and final values of $i_R(t)$. That is, find $i_R(0^+)$ and $i_R(+\infty)$.

$$\lim_{t \to 0^+} [i_R(t)] = \lim_{s \to \infty} [s I_R(s)] = \lim_{s \to \infty} \left[\frac{V_{s2} - V_{s1}}{R} * \frac{s}{s + \frac{1}{RC}} \right] = \frac{V_{s2} - V_{s1}}{R} = \frac{200 - 100}{10} = 10[A]$$

$$\lim_{t \to \infty} [i_R(t)] = \lim_{s \to 0} [s I_R(s)] = \lim_{s \to 0} \left[\frac{V_{s2} - V_{s1}}{R} * \frac{s}{s + \frac{1}{RC}} \right] = 0[A]$$

7pts

e) If the expression for $I_R(s)$ is

$$I_R(s) = \left(\frac{V_{s2} - V_{s1}}{R}\right)\left(\frac{1}{s + \frac{1}{RC}}\right)$$,

then, determine the value of $i_R(t)$ for $t \geq 0$.

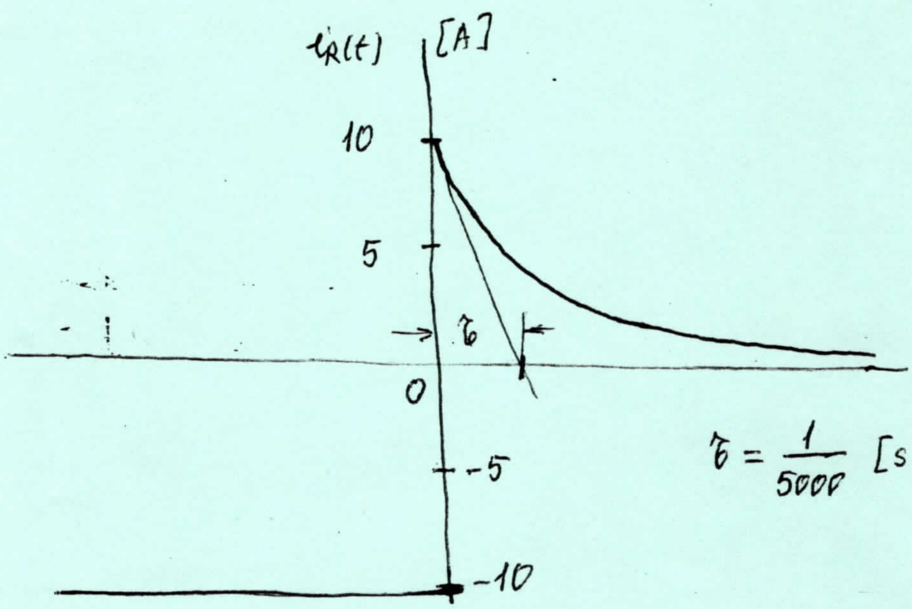
$$i_R(t) = \frac{V_{s2} - V_{s1}}{R} e^{-\frac{t}{RC}} * \mu(t) =$$

$$= \frac{200 - 100}{10} * e^{-\frac{t}{10 * 20 * 10^{-6}}} * \mu(t);$$

$$\boxed{i_R(t) = 10 e^{-5000t} * \mu(t) [A]}$$

6/6

6. f) Sketch the graph for $i_R(t)$, for positive and negative values of t. Label your axes, and show the significant values on the plot.



$$\tau = \frac{1}{5000} [s] = 0{,}2 [ms]$$

2pb