

12 / 1 / 2003

University ☺ of P☺rtland
Sch☺☺l ☺ of Engineering

EE 261-Electrical Circuits-3 cr. hrs.
Fall 2003

Midterm Exam # 3

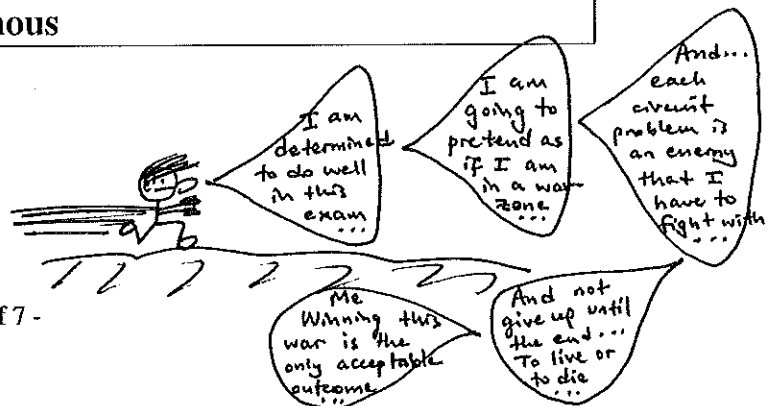
(Monday, November 24, 2003, 1:35p.m.)
(Closed Book Exam, Three Formula Sheets are Allowed)
(Total Time: 55 minutes)

Name: SOLUTIONS! ☺

Signature: [Handwritten Signature] ☺

"An honest mind possesses a kingdom."
Lucius Annaeus Seneca (4B.C.-65A.D.)

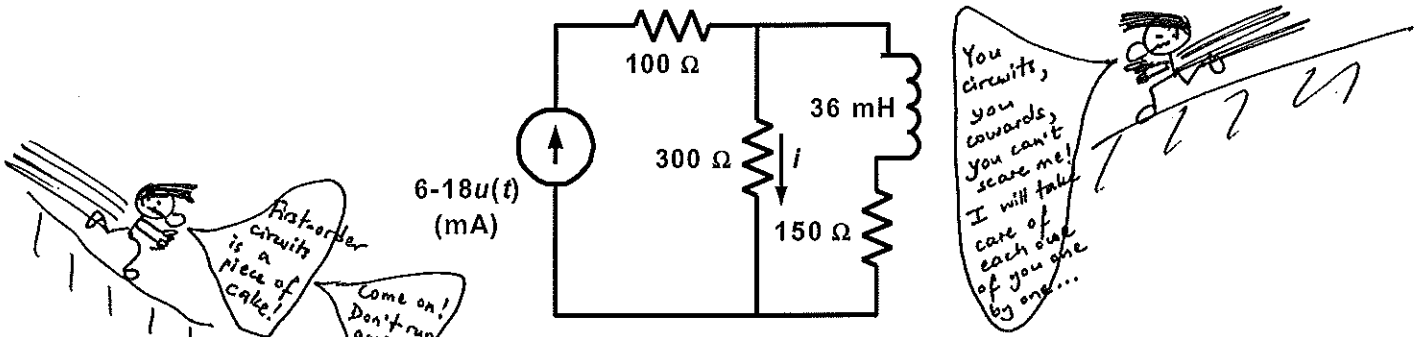
"Honest people are the true winners of the universe."
Anonymous



12/1/2003

NOTE: On all the problems, please show your work clearly, and provide the appropriate units for your answers. Also mark on the schematic to show any current or voltage that you define in your solution.

1. (Total: 30 Points) Consider the circuit shown below.



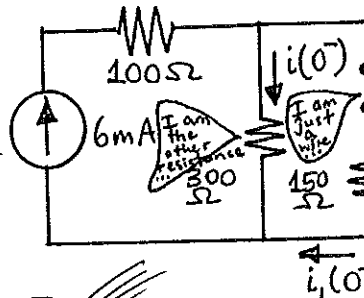
(a) (5 points) Find the value of $i(t=0^-)$.

At $t=0^-$ (steady state):

$$i(0^-) = \frac{150}{450}(6\text{mA}) = 2\text{mA}$$

$$i_L(0^-) = \frac{300}{450}(6\text{mA}) = 4\text{mA}$$

Current divider principle, heeelp!!



(b) (5 points) Find the value of $i(t=0^+)$.

However, $i_L(0^+)$ is still the same as $i_L(0^-)$...

$t=0^+$ means $u(t) = 1$! Here, steady state doesn't apply...

The enemy is in a disarray and my tactic is working. Press on!!

I recognize you inductor no matter how hard you try to hide...

Kirchhoff's current law at node A!!

Thanks Kirchhoff! I can't imagine how I would have survived in this battle without your laws...

I am just a current source...

I have to watch out Mr. Coil!

I reversed direction!

Be a man and fight like a man!

No! I am the other resistance...

KCL at node A $\rightarrow 12\text{mA} + i(0^+) + 4\text{mA} = 0$

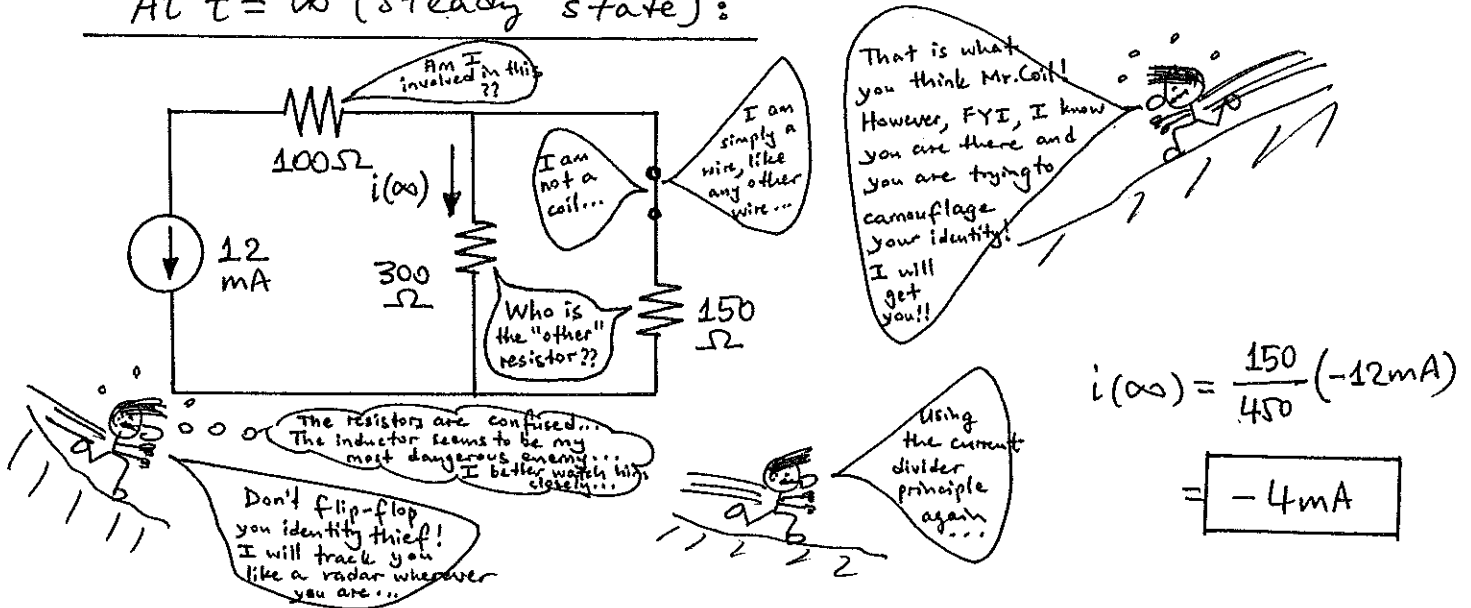
$\therefore i(0^+) = -16\text{mA}$

The fight continues on...

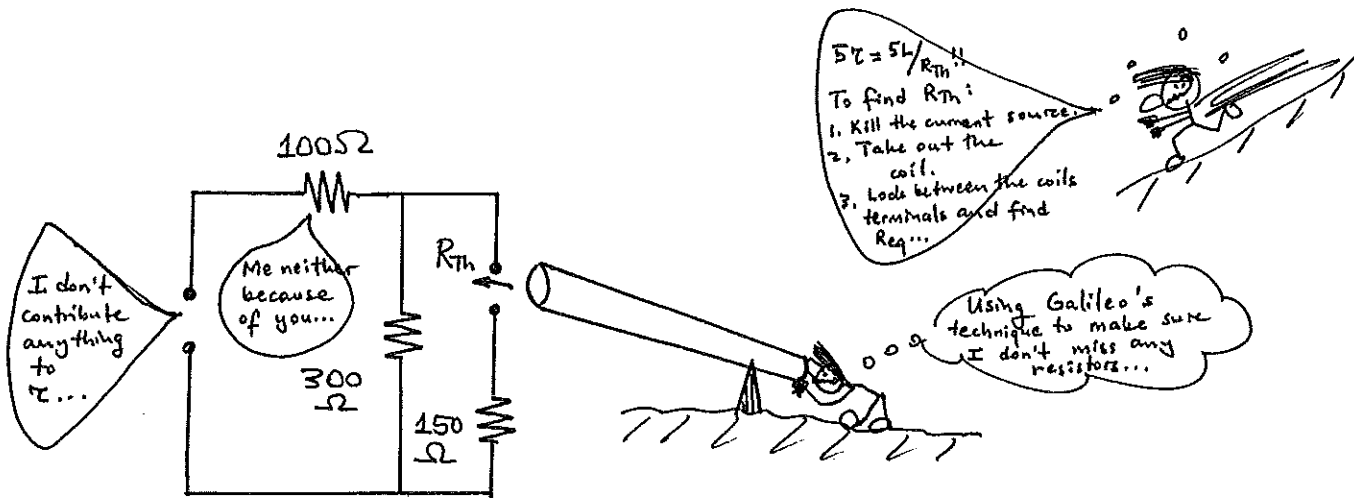
12 / 1 / 2003

(c) (5 points) Find the value of $i(t = \infty)$.

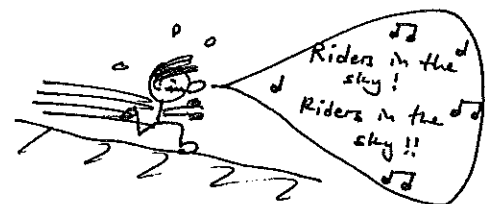
At $t = \infty$ (steady state):



(d) (5 points) Find the approximate time it will take the circuit to reach steady state.



$\therefore 5\tau = 400 \mu\text{s}$

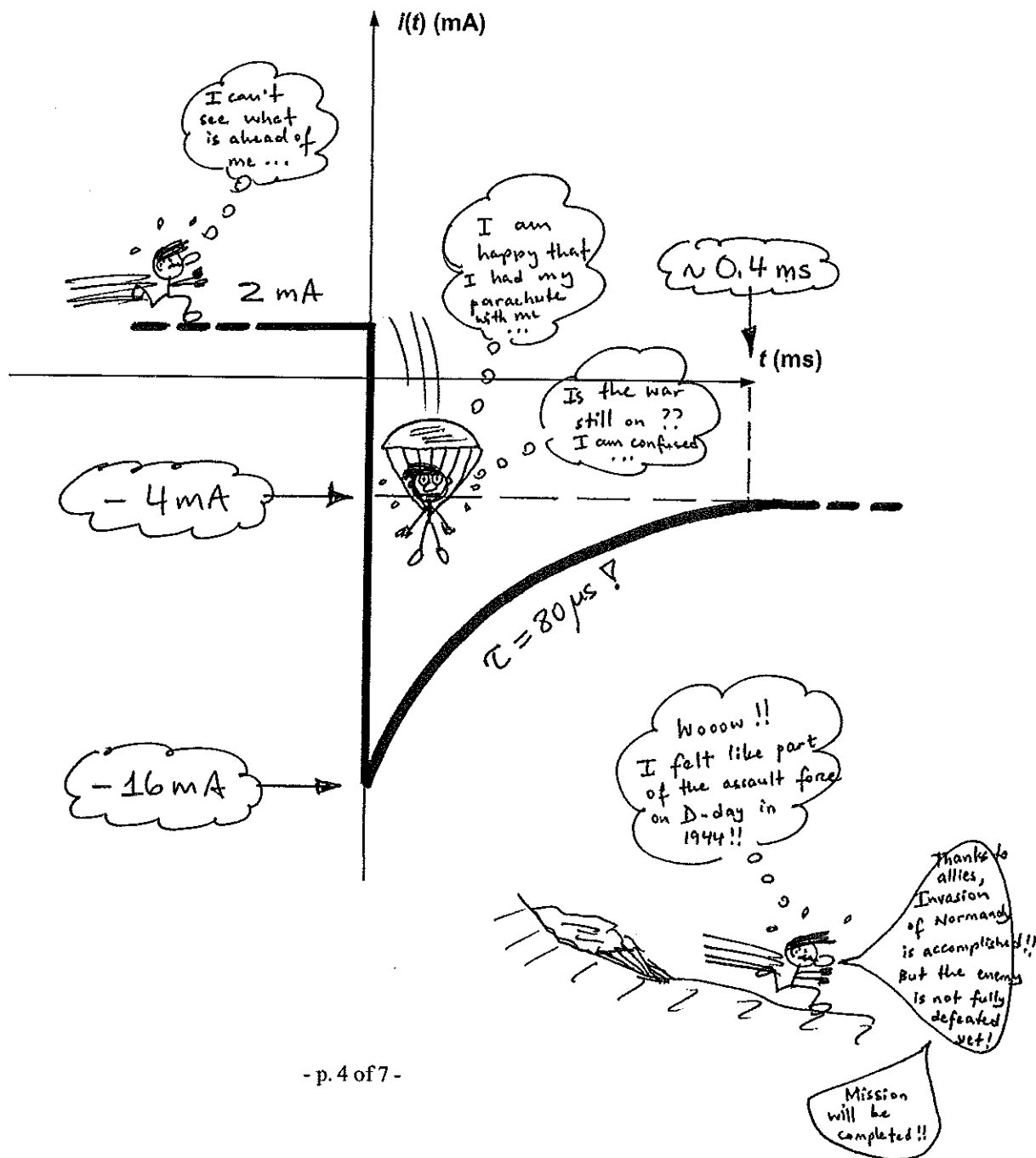


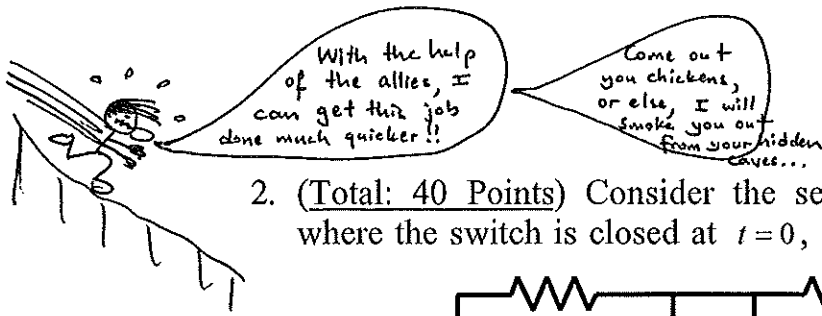
12/1/2003

(e) (10 points) Write the complete mathematical expression for $i(t)$ and sketch $i(t)$ over the time interval $-1\text{ms} \leq t \leq 1\text{ms}$. Provide all the appropriate time and current values on your sketch.

$$i(t) = -16 e^{-12,500t} - 4(1 - e^{-12,500t})$$
$$= -4 - 12e^{-12,500t}, \text{ for } t > 0$$

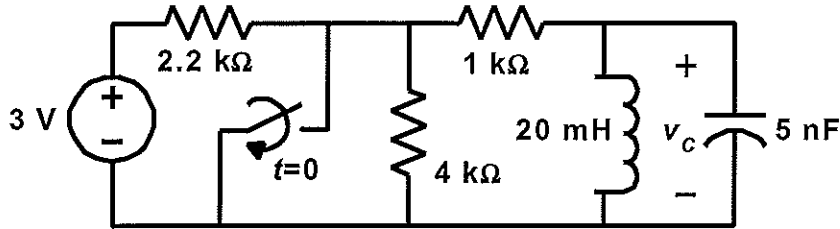
Note that the initial value of i is the value at $t=0^+$ which is different from the value at $t=0^-$...





12/1/2003

2. (Total: 40 Points) Consider the second-order circuit shown below where the switch is closed at $t=0$, after being open for a long time.



(a) (15 points) Find the roots of the characteristic equation of the circuit and determine the type (over-damped, critically-damped, or under-damped?) of the natural response $v_C(t)$ across the 5-nF capacitor for $t \geq 0$.

$R = 1\text{ k}\Omega$

$L = 20\text{ mH}$

$C = 5\text{ nF}$

I am the closed switch! I shorted the 4-kΩ resistor!

Characteristic equation is

After $t=0$, the right hand side circuit becomes a parallel RLC circuit.

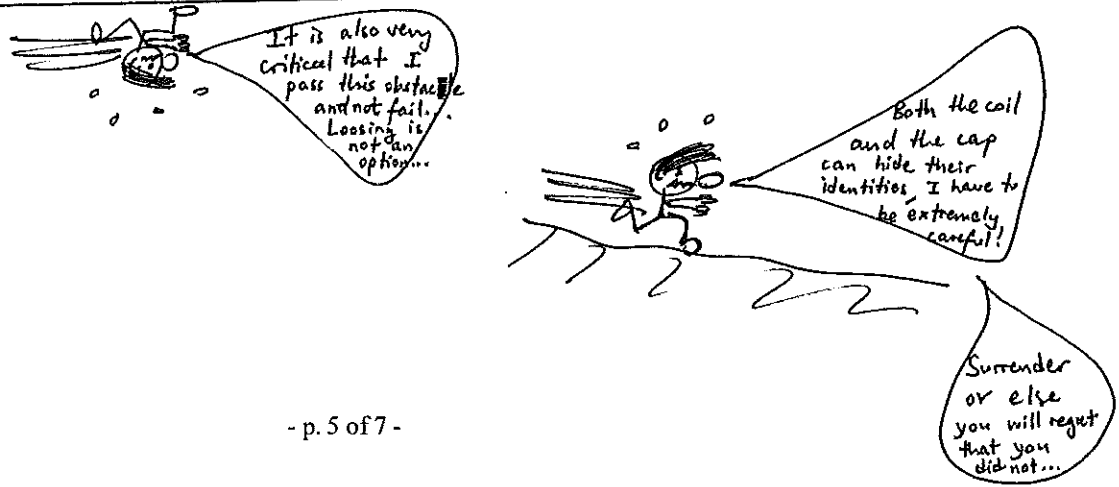
$$s^2 + \frac{1}{RC}s + \frac{1}{LC} = 0 \rightarrow s^2 + 2 \times 10^5 s + 10^{10} = 0$$

$$\rightarrow (s + 10^5)^2 = 0 \rightarrow \therefore s_1, s_2 = -10^5$$

\therefore Critically-damped response.

(b) (5 points) Based on part (a) results, write the general mathematical expression for the voltage $v_C(t)$ valid for $t \geq 0$.

$$v_C(t) = (K_1 + K_2 t) e^{-10^5 t} \quad \text{valid for } t \geq 0.$$



12 / 1 / 2003

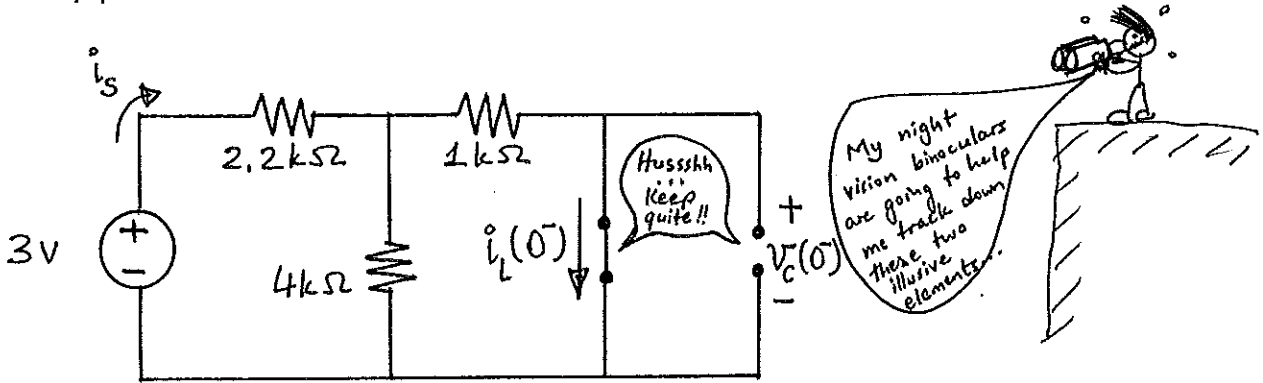
Aha!! The coil and the cap disappeared! I knew they were going to disguise...

I better think about how to deal with them...

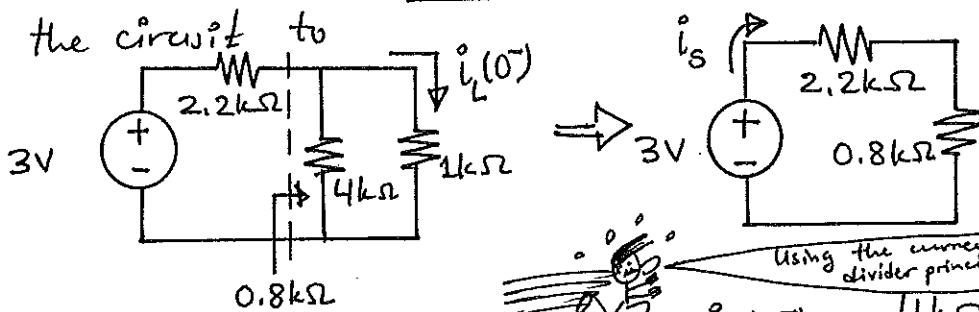
How to locate them...

(c) (20 points) Solve for the values of the unknown coefficients using the appropriate initial conditions and provide the complete mathematical expression for $v_c(t)$ for $t \geq 0$.

To find the initial condition, we go back in time to the $t = 0^-$ circuit (steady state applies):



Obviously, $v_c(0^-) = 0$. To obtain $i_L(0^-)$, we simplify



Using the current divider principle...

$$i_s(0^-) = 3V / 3k\Omega = 1mA \rightarrow i_L(0^-) = \frac{4k\Omega}{5k\Omega} (1mA) = \underline{\underline{0.8mA}}$$

At $t = 0^+$:

$$v_c(0^+) = v_c(0^-) = 0.$$

$$i_L(0^+) = i_L(0^-) = 0.8mA.$$

$$\therefore v_c(0) = K_1 = 0$$

$$\text{Also, } i_c(t) \Big|_{0^+} = C \frac{dv_c(t)}{dt} \Big|_{0^+} = (5n) [-10^5 K_1 + K_2] = -0.8mA$$

$$\therefore K_2 = \frac{-0.8m}{5n} = \underline{\underline{-160,000}}$$

$$\therefore v_c(t) = -160,000 e^{-10^5 t} \text{ valid for } t \geq 0.$$

All the coil current flows into the cap!

$0 = iR$ since cap forces its voltage to zero.

I have no other choice since you force the resistor current to zero.

They are here, I can feel their existence!

I will track you down no matter what!

Yessss!! The second mission is also complete!!



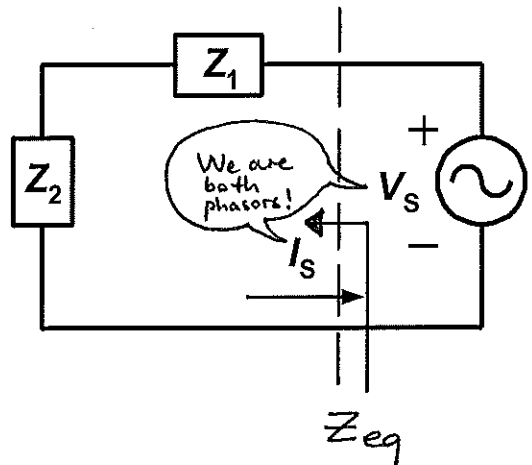
I feel as if I ~~can~~ break the sound barrier...
 I can jolt like lightning...
 Sweep like a tsunami...
 Impact like an asteroid...

12/1/2003

3. (30 Points) For the sinusoidal steady-state circuit shown, given the source voltage and current in phasor form as $V_s = 4.5e^{j0} V$, $I_s = 0.03e^{-j53.13^\circ} A$, and given the impedance $Z_1 = (50 - j50)\Omega$, find the value of the impedance Z_2 .



A phasor domain circuit! Piece of cake!!
 Complex numbers, heeeeey!!



Using Ohm's law, we have

Salute to you Mr. Ohm! Like I am, your law is undefeatable!!
 I am impressed that Ohm's law is still applicable in phasor domain...

$$\frac{V_s}{I_s} = Z_{eq} = Z_1 + Z_2$$



Substituting the known values,

$$\frac{4.5 e^{j0}}{0.03 e^{-j53.13^\circ}} = \frac{150 e^{j53.13^\circ}}{90 + j120} = 90 + j120 = 50 - j50 + Z_2$$

∴ Solving for Z_2 , we find

$$Z_2 = 40 + j170 \Omega$$

