Name:

LAB SECTION:



Rutgers

School of Engineering Department of Electrical and Computer Engineering

332:221 Principles of Electrical Engineering I Quiz 3 (THE END!)

Fall 2012

No calculators, no books, no class notes, no nuttin'! Just a pencil/pen, your THREE SIDES of 8.5×11 cheat sheet and you. Final answers must appear in the appropriate box. Show your work outside the box.

- 1. (10 pts) Basic Circuits:
 - All parts refer to FIGURE 1.



Figure 1: Figure for problem 1

- (a) (2 *pts*) What is the *minimum number* of nodes (other than V_m and ground) necessary to uniquely determine all currents and voltages in the circuit using the node voltage method.
- (b) (2 pts) What is minimum number of current meshes in the circuit that will allow you to

determine all currents and voltages in the circuit.

- (c) (2 pts) If $R_m = 2$, what is the impedance seen by source V_1 ?
- (d) (2 pts) If $R_m = 2$, what is the impedance seen by source V_2 ?

(e) (2 pts) Assume $V_1 = V_2 = V$. What is V_m for arbitrary R_m ?

2. (10 pts) Basic Thevenin/Norton:

All questions refer to FIGURE 2.



Figure 2: Figure for problem 2

(a) (5 *pts*) Given $V_1 = 8$ and $I_2 = 2$, please provide a theorem equivalent for the circuit shown.



(b) (5 *pts*) Given $V_1 = 9$ and $I_2 = 3$, please provide a norton equivalent for the circuit shown.



3. (10 pts) Basic Op-Amps:

(a) (5 pts) Please provide a labeled diagram for an amplifier with gain G = -10 and input impedance $30k\Omega$ when the op-amp operates in its linear range. You may use only a single op-amp. For full credit, you must explain how your circuit meets the input impedance specification.

(b) (5 *pts*) Please provide a labeled diagram for a circuit which produces $V_{out} = 6V_2 - 11V_1$. You may use only a single op-amp. If your circuit is operating linearly, what impedance is seen by input V_2 ? (Explain your impedance answer.)

4. (10 pts) Basic RLC/Impedance/Power:

All parts refer to FIGURE 3.



Figure 3: Figure for problem 4

(a) (5 *pts*)

Element A is an inductor with value L. Element B is a resistor with value R. Element C is a capacitor with value C_1 . Element D is a capacitor with with value C_2 . What is the impedance of this circuit as seen from the terminals?

(b) (5 *pts*)

If phasor current $Ie^{j\phi}$ is applied at the terminals, what is the average power dissipated in the resistor?

5. (10 pts) Basic Phasors and Transfer Functions

(a) (1 pts) Y/N:
$$e^{j\pi} = -1$$
:

(b) (1 pts) Y/N:
$$\frac{1}{\sqrt{2}}(e^{j\frac{\pi}{2}}-1) = e^{-j\frac{\pi}{2}}$$
:

(c) (1 pts) Y/N:
$$\cos(\omega t + \phi) = e^{j\omega t + j\phi}$$
:

(d) (3 pts)

$$H(j\omega) = \frac{dj\omega}{a(j\omega)^2 + bj\omega + c}$$

where $a, b, c\&d$ are real. If $\omega = \sqrt{\frac{c}{a}}$ what is $\Re\{H(j\omega)\}$?

(e) (2 pts) If at some frequency ω , $H(j\omega) = 1 + j$ and the input to the system is $\sin \omega t$, what is the output in time domain?

(f) (2 pts) If at some frequency ω , $H(j\omega) = \frac{1}{\sqrt{2}}(1-j)$ and the input to the system is $\cos \omega t$, what is the output in phasor notation?

- 6. (15 pts) Gyrations: You have been asked to design a circuit which has a 1mH inductor and 1k resistor in series with the output of an op-amp (whose $\pm V_{cc} = \pm 10$). The circuit works just fine if you slowly turn on the supply voltage. However, if you flip the on-switch, invariably a whisp of smoke curls up from the op-amp and the circuit no longer works. You decide to measure the currents in your circuit and find that when the power is suddenly switched on, the current through the inductor goes from 0 to 1 amp within $1\mu s$ whereas when the power is ramped up slowly, the current in the inductor rises a factor of 100 more slowly.
 - (a) (2 *pts*))

Why is the op-amp destroyed when the power is flipped on suddenly and not when power is slowly ramped up?

(b) (8 *pts*))

Consider the circuit shown in FIGURE 4. Please derive the sinusoidal steady state



Figure 4: Gyrator circuit

impedance as seen from input V for this circuit. Owing to negative feedback, you may assume the circuit is stable and operating in its linear range.

(c) (5 *pts*))

If we assume that we choose component values so that we always have $R_1Cj\omega \ll 1$, explain how the circuit can be used to save your filter circuit op-amp from power-on transients?

- 7. (15 pts) Emma and Castor Join Forces: You know that Emma the Electrical Engineer and her arch nemesis, the wily Dr. Castor Canadensis don't like each other at all. But rather than drag you through their plans for each other's destruction they have called a truce in order torture you more directly.
 - (a) (5 *pts*)

Castor: the following lovely circuit diagram is modeled after the pattern on my enormous and powerful beaver tail! Impressive, no?! When I apply phasor voltage V = 1





at frequency ω_0 , I measure an input current waveform $i(t) = 10 \sin \omega_0 t$ corresponding to the phasor current I as shown. What is the voltage across the resistor, $v_R(t)$? Why?

(b) (5 *pts*)

Emma: So, you let Castor show you his tail, huh? Do you now understand why I hate that beaver? I hate him so much I removed all his capacitors and replaced them with diodes as shown in FIGURE 6. If V is a positive DC voltage what is the voltage across the resistor? Why? If V is negative, does your answer change? Why/why not?



Figure 6: Beaver Tail Diode

(c) (5 *pts*)

Suppose all the diodes in the previous circuit are replaced by shorts, but the circuit no longer operates only at DC. Draw an equivalent circuit and derive the transfer function from the voltage input to the voltage across the resistor.

8. $(20 \, pts)$

EE's Rule ALL Engineering!:



Figure 7: Figure for problem 8

I have an hour-long commute from NY into Rutgers (though on bad days – which occur too often - it can be 2 hours). Almost needless to say, I listen to a LOT of music - it has a calming effect and keeps me from committing vehiclecide. :)

On a recent trip, I was listening to *Teach Me How to Dougie* by Cali Swag District (the "clean" version, of course! :)) at high volume. If you've heard the song, you know it employs bass drums at different pitches.

[BOOM!] They be like Smoove (what?) Can you teach me how to Dougie? [BOOM!] You know why? [BOOM!] *Cuz all the girls love it* **[BOOM!]**

Now you just do-you And I'ma do me (all-day) [BOOM!]

where the [BOOM!] is a particularly low frequency, heart-stopping, but still pleasant drum thump. I noticed "Dougie" had an odd effect on my rear view mirror when trying to merge in between two semis to get off at Exit 9. During the [BOOM!] the semi behind me began to bounce violently. I thought The Dougie had driven the bridge into resonance and it was collapsing - for a millisecond of so. :) Of course, being a card-carrying gnerd, I realized it was my MIRROR that had been driven into resonance, so I decided to analyze the situation and figure out how much my mirror weighs (without snapping it off the supporting arm, of course!).

First, I drew the diagram of FIGURE 7 which shows a mass m (my mirror), a spring k (the arm which holds my mirror) and a damper/dashpot b (the lossiness of the spring – notice how when you "work" a piece of metal like a paper clip, it gets warm?). Basic physics gave me the following differential equation:

$$m\frac{d^2}{dt^2}x_m(t) + b\frac{d}{dt}\left[x_m(t) - x_{\text{Dougie}}(t)\right] + k\left[x_m(t) - x_{\text{Dougie}}(t)\right] = 0$$

where $x_m(t)$ is the position of the mass (my mirror) and $x_{\text{Dougie}}(t)$ is the sound-induced position of the windshield. I then rewrote the equation as:

 $m\ddot{x}_m + b\dot{x}_m + kx_m = b\dot{x}_{\text{Dougie}} + kx_{\text{Dougie}}$

using the "dot" derivative notation.

(a) (5 pts) Assuming the input is always in sinusoidal steady state at frequency ω , please write down the transfer function from input $x_{\text{Dougie}}(t)$ to output $x_m(t)$.

HINT: Do not mix frequency and time domains or you will incur my UNDYING WRATH!



(b) (10 pts) Assume that $x_m(t)$ is analogous to the voltage across some component in a circuit and $x_{\text{Dougie}}(t)$ is analogous to a voltage source. Please draw a circuit with a voltage input $x_{\text{Dougie}}(t)$, appropriate values of resistance, inductance and capacitance and voltage across some circuit segment $x_m(t)$ which produces the same differential equation as the mass, spring, dashpot combination shown in FIGURE 7.

(c) (5 *pts*)

If the springiness of the arm which holds my mirror is $k = 720\pi^2 N/m$ and the frequency of the [**BOOM!**] is 60π radians, what is the approximate mass of my mirror? NOTE: A correct guess gets exactly one point. Your answer needs to be consistent with your previous work.

