Duke University
Edmund T. Pratt, Jr. School of Engineering

EGR 224 Spring 2013

Test II

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Name (please print)____

In keeping with the Community Standard, I have neither provided nor received any assistance on this test. I understand if it is later determined that I gave or received assistance, I will be brought before the Undergraduate Conduct Board and, if found responsible for academic dishonesty or academic contempt, fail the class. I also understand that I am not allowed to speak to anyone except the instructor about any aspect of this test until the instructor announces it is allowed. I understand if it is later determined that I did speak to another person about the test before the instructor said it was allowed, I will be brought before the Undergraduate Conduct Board and, if found responsible for academic dishonesty or academic contempt, fail the class.

Signature:____

Instructions

First - please turn **off** any cell phones or other annoyance-producing devices. Vibrate mode is not enough - your device needs to be in a mode where it will make no sounds during the course of the test, including the vibrate buzz or those acknowledging receipt of a text or voicemail.

Please be sure to put each problem on its own page or pages - do *not* write answers to more than one problem on any piece of paper and do not use the back of a problem for work on a *different* problem. You will be turning in each of the problems independently. This cover page should be stapled to the front of Problem 1.

Make sure that your name *and* NET ID are *clearly* written at the top of *every* page, just in case problem parts come loose in the shuffle. Make sure that the work you are submitting for an answer is clearly marked as such. Finally, when turning in the test, individually staple all the work for each problem and place each problem's work in the appropriate folder.

Your calculator may only be used as a calculation device, not a memory storage unit. Using a calculator for any purpose other than performing "just-in-time" numerical calculations is a violation of the community standard.

Note that there may be people taking the test after you, so you are not allowed to talk about the test - even to people outside of this class - until I send along the OK. This includes talking about the specific problem types, how long it took you, how hard you thought it was - really anything. Please maintain the integrity of this test.

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Problem I: [30 *pts.*] Basics

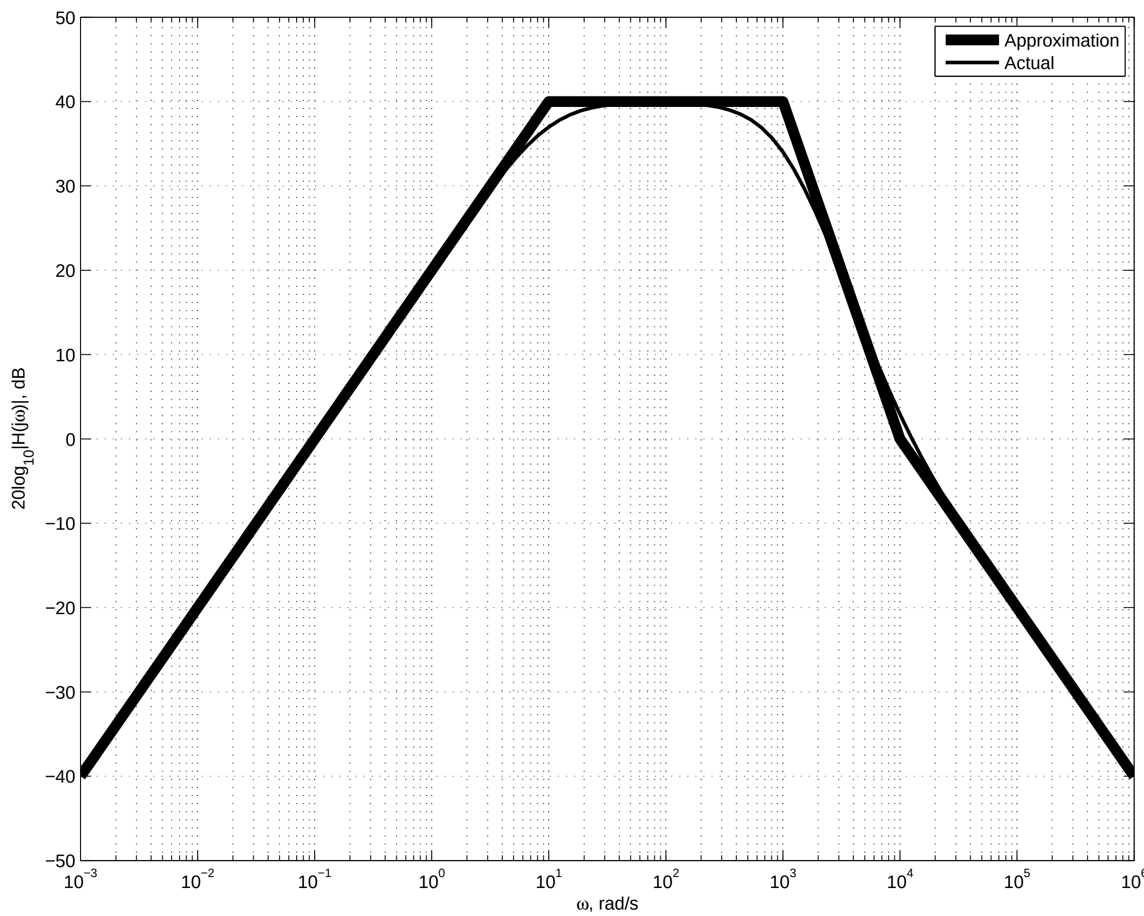
The following items get at the "core" of some of the concepts you have learned in the course. Note however that they are *not* related to each other.

(1) You are given a circuit with a switch that is thrown at $t = 2$ sec. Based on continuity requirements, you have found that the output voltage $v_{\text{x}}(t)$ just after the switch is thrown is $v_{\text{x}}(2^+) = 15$ V. In analyzing the circuit after the switch is thrown, you find the the following equation models the output voltage:

$$12\frac{d}{dt}v_{\text{x}} + 4v_{\text{x}} = -40$$

(a) Determine an expression for the unknown voltage $v_{\text{x}}(t)$ as a function of time for $t > 2$ sec and
(b) Make an accurate sketch of the voltage v_{x} for at least three time constants after the switch is thrown. Be sure to show any "construction lines" used to make the sketch more accurate.

(2) Determine the formula for a transfer function $\mathbb{H}(s)$ or $\mathbb{H}(j\omega)$ which has the following straight-line approximation to the Bode magnitude plot:



(3) Given the Laplace transforms for an input $x(t)$ and output $y(t)$ for some linear, time invariant system:

$$X(s) = \frac{3(s+3)}{s^2 + 11s + 30} \qquad\qquad Y(s) = \frac{6(s+3)}{s^2 + 10s + 41}$$

find:

(a) $x(t)$
(b) $y(t)$
(c) $H(s)$ for the system

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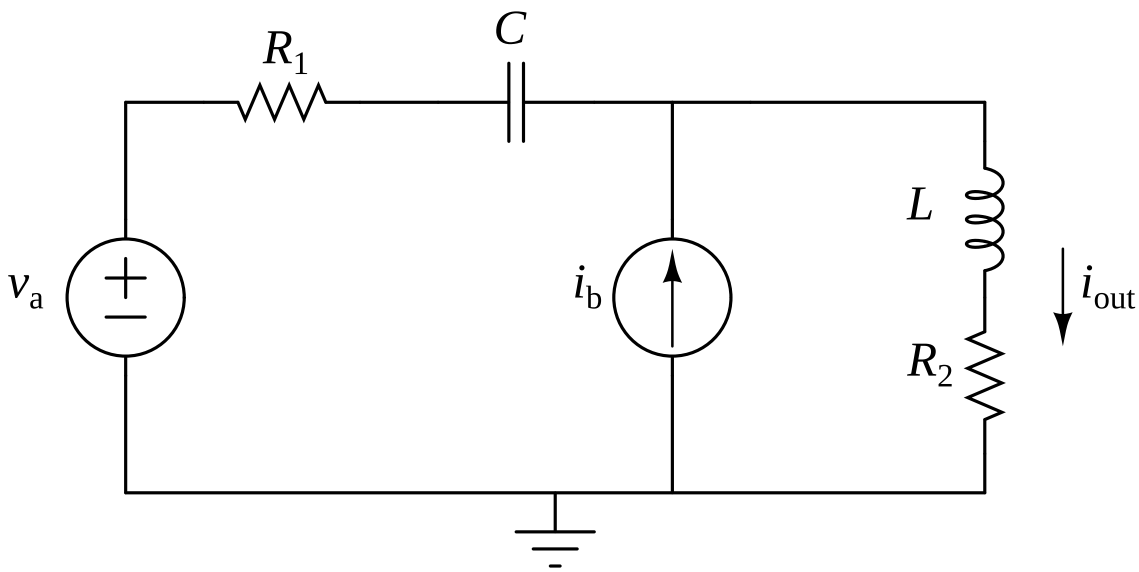
Problem II: [20 *pts.*] Steady-State Analysis

Given the following circuit:



and assuming the circuit has been in place for a very long time, find an expression for the steady-state value of the output current, $i_\mathrm{out}(t)$, if the sources and passive elements have the following values:

$v_\mathrm{a} = 10 + 6\cos(1000t + 15^o)$ V	$i_\mathrm{b} = 8 + 7\sin(2000t - 37^o)$ mA
$R_1 = 3$ kΩ	$R_2 = 4$ kΩ
$C = 2\ \mu$F	$L = 5$ mH

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Problem III: [25 *pts.*] Filter Design

(1) Determine the transfer function for a first-order high-pass filter with a maximum gain of 8 and a cutoff frequency of 5000 Hz. Then, using only 47 nF capacitors, one of the LM 324 chips used in lab (which is to say up to four operational amplifiers), and any reasonably sized resistors you need, design a voltage-to-voltage circuit that has this transfer function *and* which draws no current from the input voltage. Also answer this question: what does "reasonably sized resistors" mean and why?

(2) Determine the transfer function for a second-order band-pass filter with cutoff frequencies of 1000 rad/s and 10000 rad/s and a pass-band gain of 20. For this filter:

(a) Determine the damping ratio, logarithmic center frequency, linear center frequency, bandwidth, and quality for the filter. Be sure to clearly indicate which value is which and include units when appropriate.

(b) Write the transfer function for the band-pass filter using one of the two "standard" forms we discussed in class for band-pass filters.

(c) Sketch a Bode plot of the magnitude using straight-line approximations. Be sure to label the axes, including numerical values, along with all slopes and critical frequencies. Also indicate corner frequencies.

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Problem IV: [25 *pts.*] Operational Amplifiers

(1) Clearly state the ideal operational amplifier assumptions. *Be careful!*

(2) Given three voltage sources (v_a, v_b, and v_c) for which you have access to only their positive terminals, design a practical circuit using operational amplifiers (LM741) and resistors that will not draw any power from any of the sources and will have an output voltage (as measured from ground) given by:

$$v_o = \frac{1}{2}v_a - 5v_b - 3v_c$$

You may use up to six operational amplifiers.

(3) Determine the transfer function for the following circuit, then write a differential equation that relates the input voltage and its derivatives to the output voltage and its derivatives: