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

ECE 110 Fall 2019

Test II

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Name (please print):

NetID (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 answer in the correct box and **only use one side of the page**. If you absolutely need more space for a particular problem, put that work on its own piece of paper, clearly write your name, NetID, and the problem number (in either Arabic or Roman numerals) at the top center of that page and submit those extra pages in problem-order **after** all the original pages of the test. Also, in the box for the problem, write a note that says "see extra page."

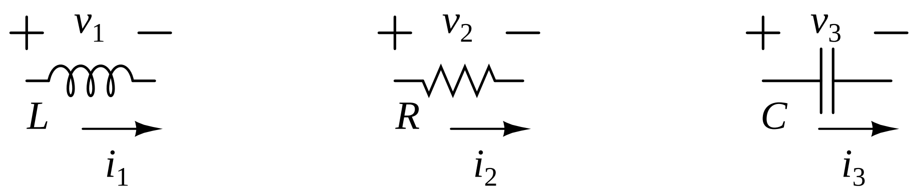
To turn in your test, carefully stack the test pages in order (with any additional pages properly labeled and after all the original test pages), staple them back together if you took them apart, and place the test in the box at the front of the room with the top left corner of the test going in the back left of the box.

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.

Problem I: [16 pts.] The Basics

(1) Write the equations that relate the current to the voltage for the following three elements:



(2) For the reactive elements above, write the equation for the energy stored in each element:

(3) Circle the appropriate entries in the sentence below:

The (current through / voltage drop across) an inductor and the (current through / voltage drop across) a capacitor must be continuous.

(4) Fill in the following table:

Quantity	Symbol	Name of real part	Symbol	Name of imaginary part	Symbol
Impedance					
Admittance					

(5) Calculate the value of $\mathbb{N}$ and report the value using both rectangular ($n_r + jn_i$) and polar ($n\angle\theta$) forms.

$$\mathbb{N} = (2 + j3)\frac{4\angle 45^o}{6 - j2}$$

Problem II: [18 pts.] Phasors and Impedance

(1) Clearly using phasors, simplify the following signal into a single cosine:

$$v_\mathrm{a}(t) = 3\sin(8t) - 5\cos(8t) \text{ V}$$

(2) Clearly using phasors, simplify the following signal into a single cosine:

$$i_\mathrm{b}(t) = 9\cos(1000t + 41^o) + 6\cos(1000t - 18^o) \text{ mA}$$

(3) A resistor is connected to a reactive element inside a box, but you do not know what the element is or if they are connected in series or parallel. Two terminals are sticking out of the box. You conduct two experiments by sending a sinusoidal current through the box and then measuring the steady state voltage drop across the terminals. The inputs and outputs you measured are below:

Source Current (mA)	Source Voltage (V)
$5\cos(20t)$	$13.09\cos(20t - 60.23^o)$
$5\cos(100t)$	$6.886\cos(100t - 19.27^o)$

(Note - there may be some small round-off in the calculations). What is the reactive element? How are the resistor and reactive element connected? What are their values? *Hint:* look at the formulas for and values of the impedance and admittance.

(4) Design a series-connected combination of a resistor and a reactive element that has an impedance of $\mathbb{Z} = 1500 + j2000\ \Omega$ at a frequency of 10,000 rad/s. Draw and label the circuit.

(5) Design a parallel-connected combination of a resistor and a reactive element that has an impedance of $\mathbb{Z} = 1500 + j2000\ \Omega$ at a frequency of 10,000 rad/s. Draw and label the circuit.

Problem III: [20 pts.] Fun With Transfer Functions

A voltage-to-voltage circuit has a transfer function and input voltage, respectively, of:

$$\mathbb{H}(j\omega) = \frac{\mathbb{V}_{\text{out}}}{\mathbb{V}_{\text{in}}} = \frac{j\omega}{j\omega + 100} \qquad\qquad v_{\text{in}}(t) = 10 + 15\cos(50t) + 20\cos(300t)$$

(1) Sketch and properly label the straight-line approximations for the Bode magnitude and phase plots of $\mathbb{H}$.

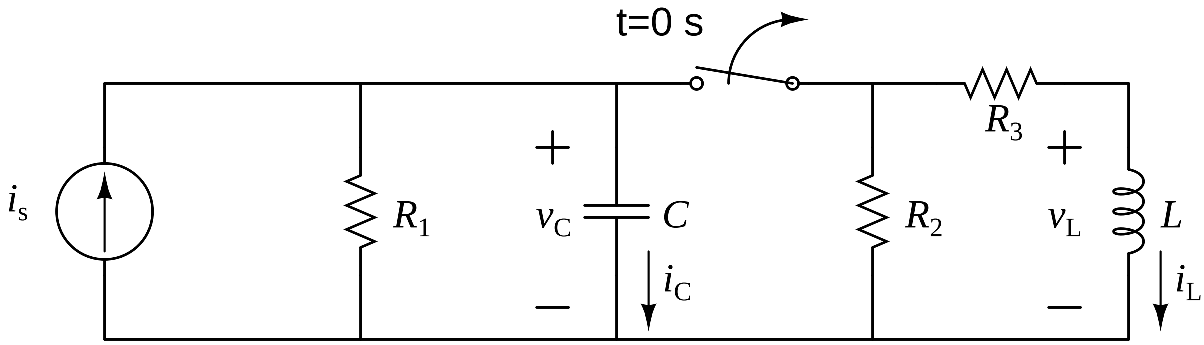
(2) What kind of filter does the transfer function represent? Why do you believe that?

(3) Determine the steady-state function for the output voltage.

(4) Find the differential equation that relates $v_{\text{out}}(t)$ and its derivatives to $v_{\text{in}}(t)$ and its derivatives.

Problem IV: [24 pts.] Transient Response

For the circuit below, assume that the switch has been closed for a very long time before $t = 0$ s. At t=0 s the switch opens.



(1) Assuming that i_s is constant for all times before $t = 0$, determine the following in terms of the symbolic element and source values. Put your answers in the box below. Also, you may use $v_C(0^-)$, $i_C(0^-)$, $v_L(0^-)$, and $i_L(0^-)$ in your solutions for the variables at 0^+ without further substitution.

(a) $v_C(0^-)$

(e) $v_L(0^-)$

(b) $i_C(0^-)$

(f) $i_L(0^-)$

(c) $v_C(0^+)$

(g) $v_L(0^+)$

(d) $i_C(0^+)$

(h) $i_L(0^+)$

(2) Assuming the circuit has the following element and source values:

$R_1 = 5\ \text{k}\Omega$ $\qquad R_2 = 5\ \text{k}\Omega$ $\qquad R_3 = 5\ \text{k}\Omega$ $\qquad C = 140\ \mu\text{F}$ $\qquad L = 200\ \text{mH}$ $\qquad i_s(t) = 24\ \text{mA}$

determine the voltage drop across the capacitor, $v_C(t)$, for $t > 0$ s. Also indicate the time constant of the response and then make an accurate graph of $v_C(t)$ for three time constants.

(3) Assuming the circuit has the same element and source values as above:

$$R_1 = 5\ \text{k}\Omega \qquad R_2 = 5\ \text{k}\Omega \qquad R_3 = 5\ \text{k}\Omega \qquad C = 140\ \mu\text{F} \qquad L = 200\ \text{mH} \qquad i_\text{s}(t) = 24\ \text{mA}$$

determine the current through the inductor, $i_\text{L}(t)$, for $t > 0$ s. Also indicate the time constant of the response and then make an accurate graph of $i_\text{L}(t)$ for three time constants.

Problem V: [22 pts.] Bode Plots

For these first two transfer functions, sketch the straight-line approximation for the Bode plots of both the magnitude and the phase of the transfer functions below. Be sure to properly label the axes, slopes, magnitudes, and angles. Then state what kind of filter the transfer function represents and approximately what the cutoff frequency is (or cutoff frequencies are).

(1) $\mathbb{H}_1(j\omega) = \frac{20}{j\omega+400}$

(2) $\mathbb{H}_2(j\omega) = \frac{100(j\omega+200)}{(j\omega+1)(j\omega+40000)^2}$

(3) Given the straight-line approximation to the Bode magnitude plot below, and also given that any double corners below are represented by critically damped (i.e. repeated) roots, determine a reasonable expression for the transfer function $\mathbb{G}(j\omega)$ from which it was generated. *Carefully* note where the corners are. Also state what kind of filter you believe this is, why you believe that, *approximately* what the cutoff frequency/frequencies is/are, and what the passband gain is/is.