

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

EGR 224 Spring 2022 Test II

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 communicate with 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 communicate with 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.

Only write on one side of any given page and please be sure that your name and NetID are clearly written at the top of every page. If an answer box is provided, **please be sure to put each answer in the correct box.** If you absolutely need more space for a particular problem, or want to show work, put that work **on one side** of 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 preprinted pages of the test. Also, in the box for the problem, write a note that says "see extra page."

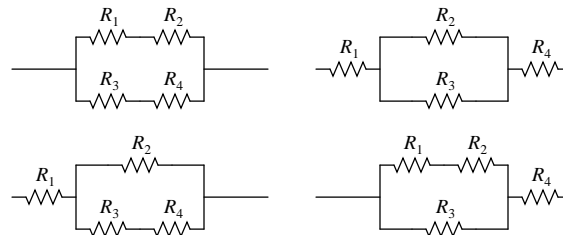
You will *not* be stapling your test but instead will be turning in your test in its original folder to the box at the front of the room. Carefully stack the test pages in order (with any additional pages properly labeled and **after all the original test pages**), put them in the folder you received with the test, and bring the folder to the front of the room.

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.

You may use the || symbol for resistances in parallel and do not need to expand that construction unless you are required to determine a numerical answer. Be clear with your use of parentheses, however; simply writing something like

$$R_{eq} = R_1 + R_2 \parallel R_3 + R_4$$

is too vague since it could refer to any of the four combinations below:

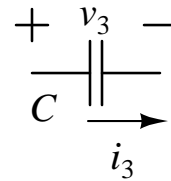
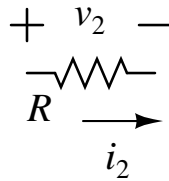
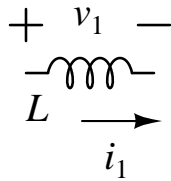


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Problem I: [10 pts.] The Basics

The following problems all relate to the elements shown below:



- (1) Write the equations in the time domain that relate the current to the voltage for each of three elements:

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

- (3) For all the elements above, write the equation for the impedance \mathbb{Z} of each element:

- (4) 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.

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Problem II: [12 pts.] Phasors and Impedance

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

$$v_a(t) = -2 \sin(22t) + 5 \cos(22t) \text{ V}$$

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

$$i_b(t) = 5 \cos(7t + 30^\circ) + 6 \cos(7t + 60^\circ) \text{ mA}$$

- (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 an experiment by applying a sinusoidal voltage across the terminals and then measuring the steady state current going into the box. The voltage you set and the current you measured are:

$$v(t) = 5 \cos(3t) \text{ V}$$

$$i(t) = 553.3 \cos(3t + 51.71^\circ) \mu\text{A}$$

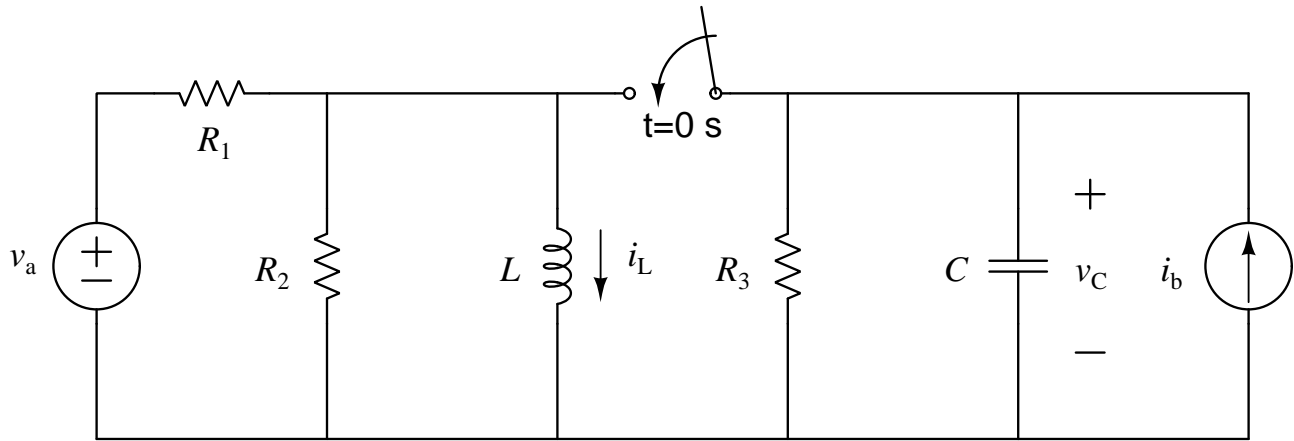
- (a) What is the impedance \mathbb{Z} of this circuit?
- (b) Draw a circuit consisting of a single resistor *in series* with a single reactive element that has this impedance at that frequency. Be sure to label the values of the resistor (in Ω) and the reactive element (in either F or H).
- (c) Draw a circuit consisting of a single resistor *in parallel* with a single reactive element that has this impedance at that frequency. Be sure to label the values of the resistor (in Ω) and the reactive element (in either F or H).

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Problem III: [16 pts.] DCSS Values

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



Assuming that i_a and v_b are constant for all times before (and after) $t = 0$, determine the following in terms of the *symbolic* element and source values (based on the passive sign convention). 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^+ and ∞ without further substitution.

(a) $v_C(0^-)$

(e) $v_C(0^+)$

(i) $v_C(\infty)$

(b) $i_C(0^-)$

(f) $i_C(0^+)$

(j) $i_C(\infty)$

(c) $v_L(0^-)$

(g) $v_L(0^+)$

(k) $v_L(\infty)$

(d) $i_L(0^-)$

(h) $i_L(0^+)$

(l) $i_L(\infty)$

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Problem IV: [12 pts.] Transient Response

Assuming the circuit has been found to have a model equation of:

$$4\frac{dv_o(t)}{dt} + 3v_o(t) = 6$$

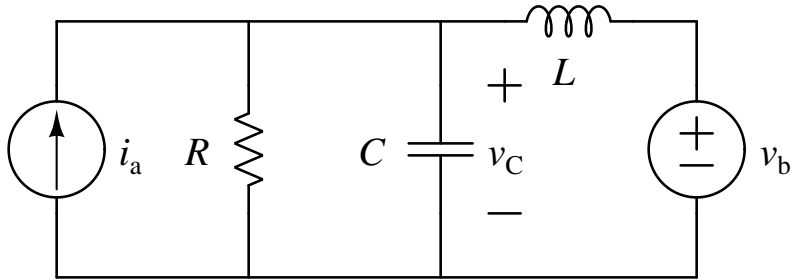
for $t \geq 0$ and that $v_o(0) = -8$ V, determine the output voltage $v_o(t)$ for $t > 0$ s. Clearly indicate the time constant of the response and then make an accurate graph of $v_o(t)$ for $t > 0$ for at least three time constants.

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Problem V: [20 pts.] ACSS

Given the following circuit:



- (1) Determine a transfer function $\mathbb{H}_a(j\omega)$ between source $i_a(t)$ and output $v_C(t)$. Assume $v_b(t)$ is 0 V for this.
- (2) Determine a transfer function $\mathbb{H}_b(j\omega)$ between source $v_b(t)$ and output $v_C(t)$. Assume $i_a(t)$ is 0 A for this.
- (3) Assuming

$$i_a(t) = 3 + 7 \cos(20000t + 20^\circ) \text{ mA} \quad v_b(t) = 4 + 8 \cos(8000t - 40^\circ) \text{ V}$$

$$L = 100 \text{ mH}$$

$$R = 2 \text{ k}\Omega$$

$$C = 40 \text{ nF}$$

(where $1 \text{ nF} = 10^{-9} \text{ F}$) and further assuming the circuit has been place for a very long time prior to $t = 0$ sec, determine an expression in the time domain for the voltage $v_C(t)$ for $t > 0$ sec.

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Problem VI: [15 pts.] Bode Plots 1

Given the transfer function:

$$\mathbb{H}(j\omega) = \frac{\mathbb{V}_{\text{out}}}{\mathbb{V}_{\text{in}}} = \frac{200000(j\omega)^2}{(j\omega + 10)(j\omega + 10000)}$$

- (1) Sketch the straight-line approximation for the Bode magnitude plot. Be sure to properly label the axes, slopes, and magnitudes.
- (2) Sketch the straight-line approximation for the Bode phase plot. Be sure to properly label the axes, slopes, and angles.
- (3) State what kind of filter the transfer function represents and why you believe that. Also indicate the maximum gain and the approximate cutoff frequency or frequencies for the filter.
- (4) Based on the transfer function, determine the expression in the time domain that relates $v_{\text{out}}(t)$ and its derivatives to $v_{\text{in}}(t)$ and its derivatives.

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Problem VII: [15 pts.] Bode Plots 2

Given the straight line approximation to the Bode magnitude plot for some transfer function $\mathbb{H}(j\omega)$, and assuming no underdamped roots, find an expression for $\mathbb{H}(j\omega)$. **Then** determine the maximum gain for this transfer function. To do that, you basically need to figure out the value of the straight-line approximation along the top plateau. The magnitude approximation comes in from the left flat at 60 dB. Note: the first corner in the denominator is not at $\omega=1000$ rad/s.

