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

ECE 110 Fall 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."

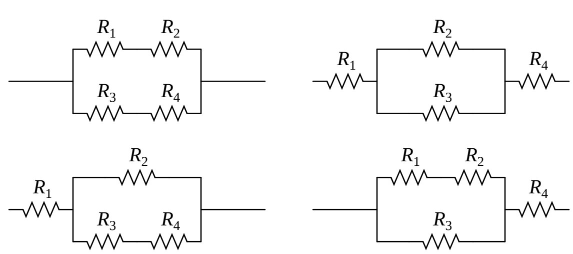
You will *not* be stapling your test but instead will be turning in your test in its original folder to the box at the front of the room. Carefully stack the test pages in order (with any additional pages properly labeled and **after all the original test pages**), put them in the folder you received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

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

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



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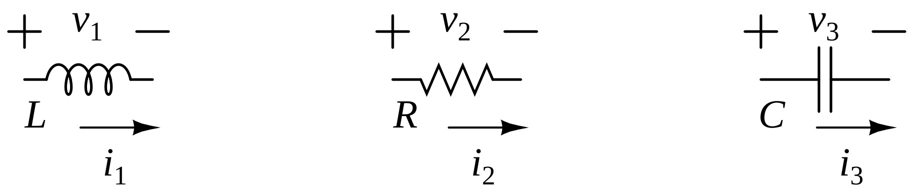
Problem I: [20 pts.] The Basics

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

(5) Fill in the following table:

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

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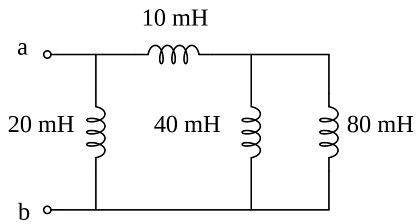
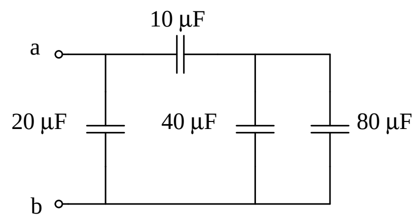
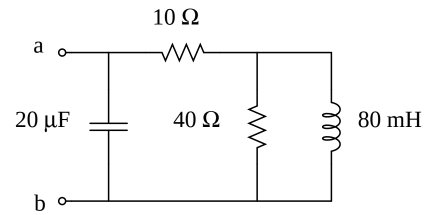
Problem II: [12 pts.] Equivalent Impedances



(a)



(b)



(c)

(1) Find the equivalent inductance L_{eq} of network (a) from the perspective of terminals a and b. Your answer should be a single number given in H.

(2) Find the equivalent capacitance C_{eq} of network (b) from the perspective of terminals a and b. Your answer should be a single number given in F.

(3) Assuming all sources potentially connected to network (c) are single-frequency sinusoids oscillating at 1000 rad/s, find the equivalent impedance $\mathbb{Z}_{\text{eq}}$ of network (c) from the perspective of terminals a and b. Your answer should be a single complex number, given in Ω. You may report this number in either rectangular or polar form.

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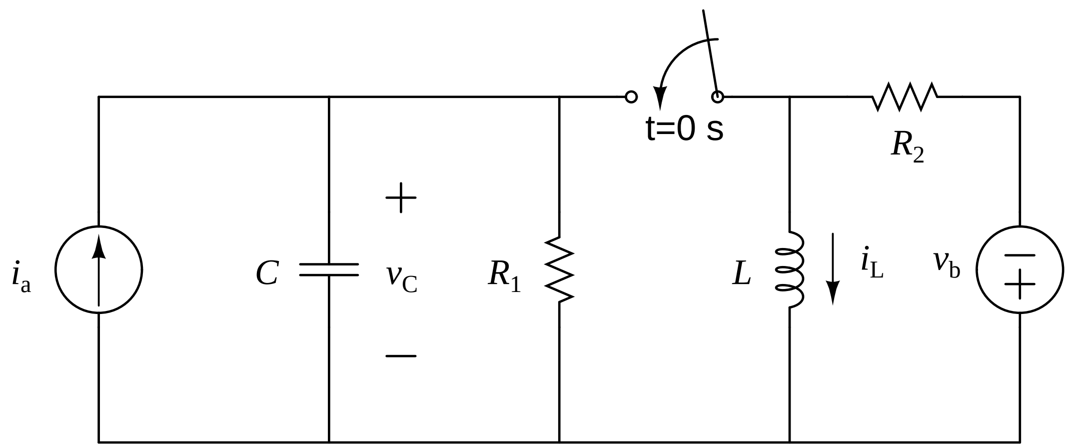
Problem III: [18 pts.] DCSS Values

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:

$$5\frac{di_{\text{o}}(t)}{dt} + 2i_{\text{o}}(t) = -12$$

for $t \geq 0$ and that $i_{\text{o}}(0) = 20$ A, determine the output current $i_{\text{o}}(t)$ for $t > 0$ s. Clearly indicate the time constant of the response and then make an accurate graph of $i_{\text{o}}(t)$ for $t > 0$ for at least three time constants.

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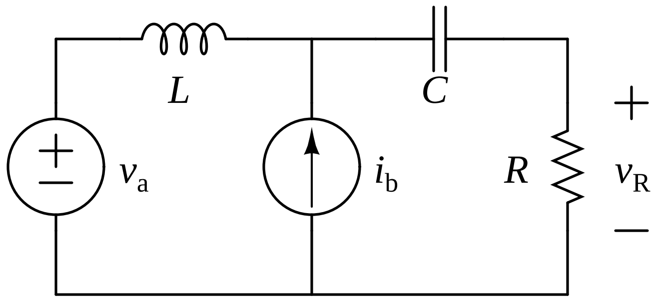
Problem V: [12 pts.] Transfer Functions

Given the following circuit:



(1) Determine a transfer function $\mathbb{H}_a(j\omega)$ between source $v_a(t)$ and output $v_R(t)$. Assume $i_b(t)$ is 0 A for this.

(2) Determine a transfer function $\mathbb{H}_b(j\omega)$ between source $i_b(t)$ and output $v_R(t)$. Assume $v_a(t)$ is 0 V for this.

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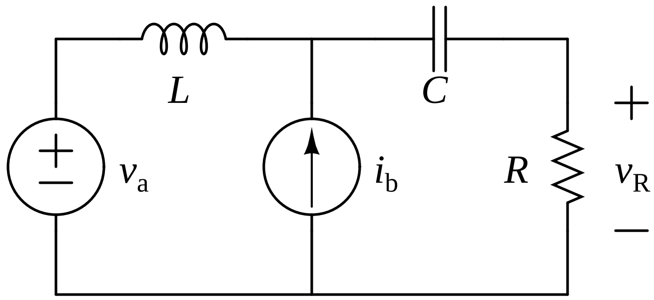
Problem VI: [6 pts.] Resonant Frequency

Given the following circuit:



(1) What is the resonant frequency from the perspective of the voltage source, v_a? To find this, set the current source to 0 A.

(2) Circle your answer to the following:
"Aren't you glad I am not asking, 'What is the resonant frequency from the perspective of the current source, i_b?' "
(yes / no)
(if you said no, for 0+1j points, find the resonant frequency from the perspective of the current source, i_b? Note that your test grade will be the real part of your test score)

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Problem VII: [20 pts.] Filters

Given the transfer function:

$$\mathbb{H}(j\omega) = \frac{\mathbb{V}_{\text{out}}}{\mathbb{V}_{\text{in}}} = \frac{2000}{2000 + j\omega}$$

(1) State what kind of filter the transfer function represents and why you believe that. Also indicate the maximum gain and the half-power frequency for the filter.

(2) Assuming:

$$v_{\text{in}}(t) = 5 + 6\,\cos\left(500t + 12^\circ\right) - 7\,\sin\left(5000t + 84^\circ\right)$$

find the AC steady state expression for $v_{\text{out}}(t)$.

(3) Assuming you have access to a single 1 kΩ resistor and a box filled with any inductors or capacitors you might want, design a voltage-to-voltage electric circuit that has this transfer function. Be sure to clearly indicate where the output voltage measurement is taken and the value of the inductor or capacitor you need.

(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.