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

EGR 224 Spring 2023 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."

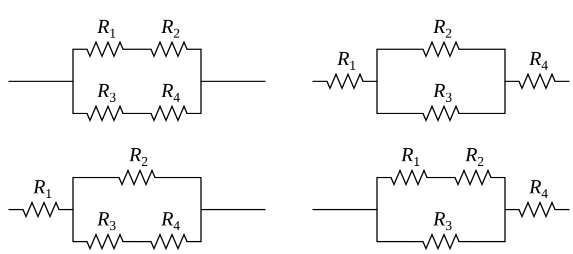
You will *not* be stapling your test but instead will be turning in your test in its original folder to the box at the front of the room. Carefully stack the test pages in order (with any additional pages properly labeled and **after all the original test pages**), put them in the folder you received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

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

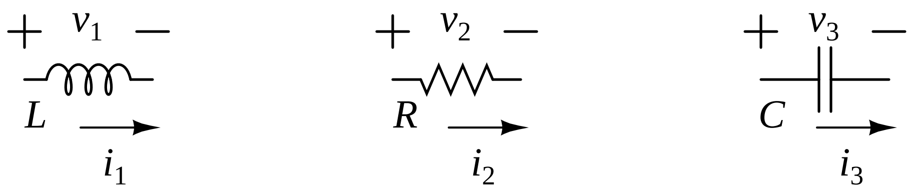
is too vague since it could refer to any of the four combinations below:



Community Standard (please print NetID): Name:

Problem I: [12 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:

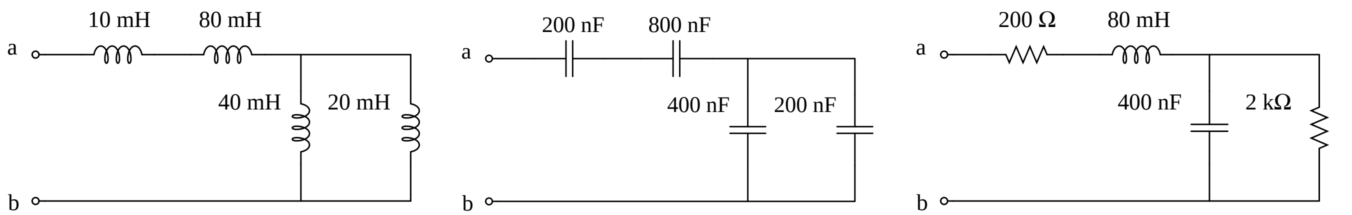
(3) For all the elements above, write the equation for the impedance $\mathbb{Z}$ of each element:

(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.
```

Community Standard (please print NetID): Name:

Problem II: [16 pts.] Equivalent Impedances and Energy



(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 (or mH).

(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 (or nF).

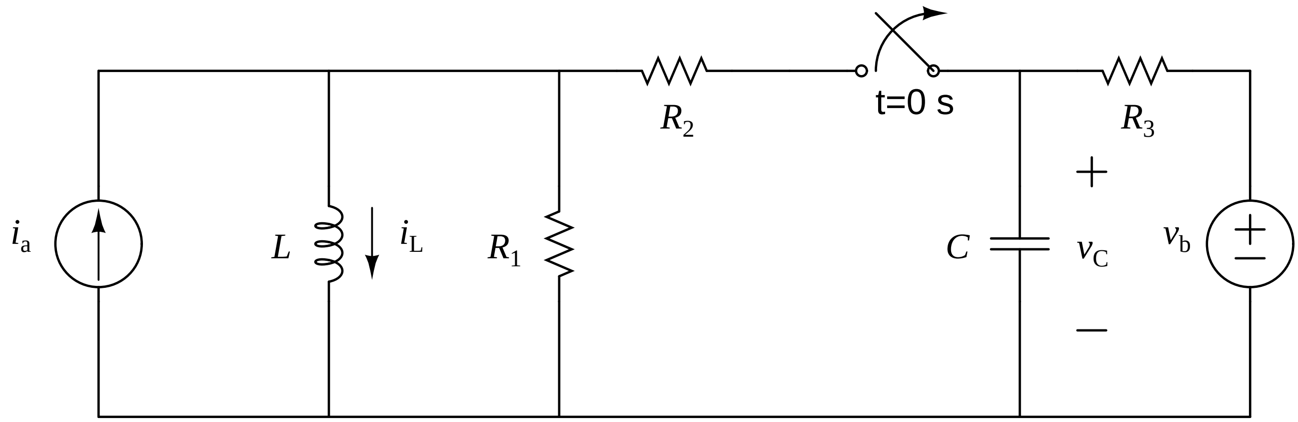
(3) Assuming all sources potentially connected to network (c) are single-frequency sinusoids oscillating at 5000 rad/s, find the equivalent impedance $\mathbb{Z}_{\text{eq}}$ of network (c) from the perspective of terminals a and b. Your answer should be a single complex number, given in Ω. You may report this number in either rectangular or polar form.

(4) Assuming you connect a constant 100 V source to network (c), find the energy stored in the inductor and the energy stored in the capacitor after a long time has passed.

Community Standard (please print NetID): Name:

Problem III: [16 pts.] DCSS Values

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.



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) $i_L(\infty)$

Community Standard (please print NetID): Name:

Problem IV: [12 pts.] Transient Response

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

$$7\frac{di_{\mathrm{o}}(t)}{dt} + 2i_{\mathrm{o}}(t) = -10 \text{ mA}$$

for $t \geq 0$ and that $i_{\mathrm{o}}(0) = 4$ mA, determine the output current $i_{\mathrm{o}}(t)$ for $t > 0$ s. Clearly indicate the time constant for this circuit and then make an **accurate** graph of $i_{\mathrm{o}}(t)$ for $t > 0$ for at least three time constants.

Community Standard (please print NetID): Name:

Problem V: [14 pts.] DE/ACSS[1]

Assuming a system has a transfer function:

$$\mathbb{H}(j\omega) = \frac{\mathbb{X}_{\text{out}}}{\mathbb{X}_{\text{in}}} = \frac{10}{j\omega + 5}$$

(1) Find the differential equation that relates $x_{\text{in}}(t)$ and its derivatives to $x_{\text{out}}(t)$ and its derivatives, and

(2) Find the **AC steady-state** response $x_{\text{out}}(t)$ if the input to the system is

$$x_{\text{in}}(t) = 1 + 3\cos(5t) + 7\sin(9t + 110^\circ)$$

[1]Note that this problem has little to do with Wake Forest University

Community Standard (please print NetID): Name:

Problem VI: [14 pts.] Filters and Transfer Functions

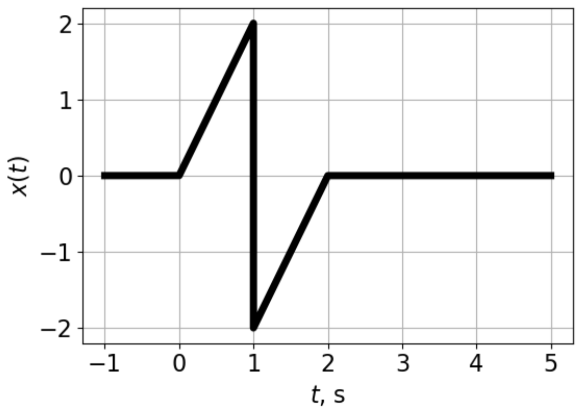
(1) Design a passive low-pass voltage-to-voltage filter with a maximum gain of 1 and a cutoff frequency of 2,000 rad/s using a 1 kΩ resistor and a capacitor. Draw the circuit, specify where the source is and where the output voltage is measured, and specify the value of the capacitor. Also report the transfer function $\mathbb{H}_1(j\omega)$ for this filter - you may use symbols from the circuit or numbers.

(2) Design a passive high-pass voltage-to-voltage filter with a maximum gain of 1 and a cutoff frequency of 5,000 rad/s using a 2 kΩ resistor and an inductor. Draw the circuit, specify where the source is and where the output voltage is measured, and specify the value of the inductor. Also report the transfer function $\mathbb{H}_2(j\omega)$ for this filter - you may use symbols from the circuit or numbers.

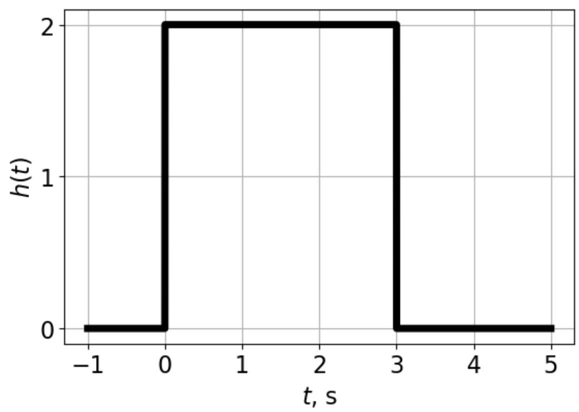
Community Standard (please print NetID): Name:

Problem VII: [16 pts.] Singularity Functions and Convolution

For this problem, you may use the definitions of the singularity functions $\delta(t)$, $u(t)$, $r(t)$, and $q(t)$ that we have used during lectures. Given the signals $x(t)$ and $h(t)$ shown below (where both are equal to 0 for any times not shown):



$x(t)$



$h(t)$

(1) Write a function for $x(t)$ in term of scaled, shifted singularity functions.

(2) Write a function for $h(t)$ in term of scaled, shifted singularity functions.

(3) If $x(t)$ is the input to a system and $h(t)$ is the impulse response of the system, what is the response $y(t)$ of the system? Write this in terms of scaled, shifted singularity functions.

(4) Based on your scaled, shifted singularity functions above, re-write $y(t)$ as a piecewise function. Fill out the figure below by writing in the different functions and the conditions on t that make the different functions active. *Hint 1:* The number of different functions, the time before which the system starts responding, and the time after which the system stops responding are all given. *Hint 2:* use the process we went over in lab to get answers in the format that Connect expected.

$$
y(t) = \begin{cases}
0 & t < 0 \\
\rule{8cm}{0.4pt} & 0 \leq t < \rule{0.7cm}{0.4pt} \\
\rule{8cm}{0.4pt} & \rule{0.7cm}{0.4pt} \leq t < \rule{0.7cm}{0.4pt} \\
\rule{8cm}{0.4pt} & \rule{0.7cm}{0.4pt} \leq t < \rule{0.7cm}{0.4pt} \\
\rule{8cm}{0.4pt} & \rule{0.7cm}{0.4pt} \leq t < \rule{0.7cm}{0.4pt} \\
\rule{8cm}{0.4pt} & \rule{0.7cm}{0.4pt} \leq t < 5 \\
0 & t \geq 5
\end{cases}
$$