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

EGR 224 Spring 2021 Test II

Name (please print):

NetID (please print): Start Time: End Time:

Submitting your work for a grade implies agreement with the following: 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.

Instructions

The test is open book, open class notes (yours and mine), open Sakai page for this class, and open Pundit. No other resources are allowed. If you have a question about whether something is allowed, ask the instructor. Be sure that you are in a place where you can work undisturbed for the duration of the test. If a situation arises that disrupts your work, let the instructor know - you will be allowed to pause the clock and resume work later. The Start Time above should be when you first started working on the test (after saving it, printing it out, etc.) and the End Time should be when you stopped doing work on the test and started working on scanning / photographing and uploading it.

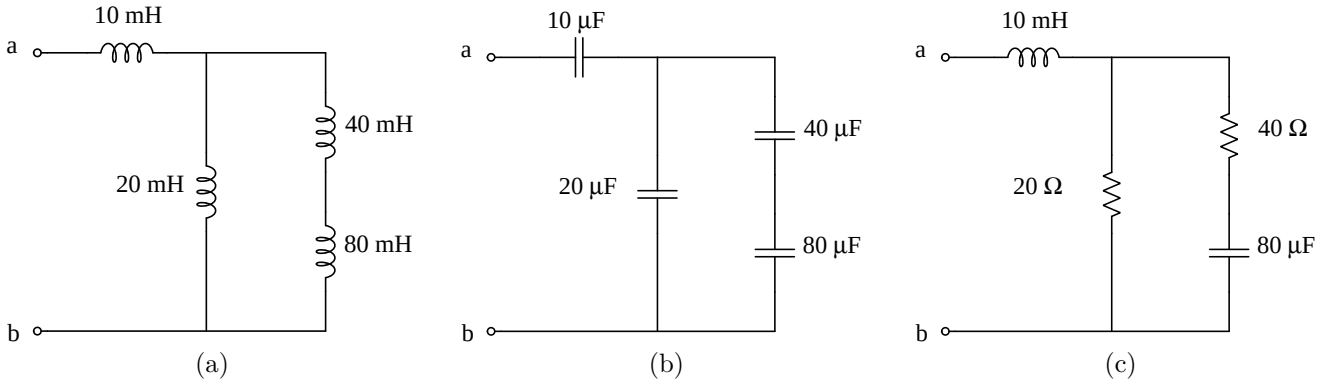
Please be sure that your name *and* **NetID are** *clearly* **written at the top of** *every* **page**. If you need more space for a particular problem or want to show more work, put that work on its own piece of paper, clearly write your name, NetID, and the problem number (in either Arabic or Roman numerals) at the **top center** of that page and submit those extra pages in problem-order.

You will be turning your test into Gradescope. Carefully scan or photograph the test pages in problem-order and make a single PDF of the scans / photographs. When you upload the PDF, you will also need to indicate where the answer for each problem is. **Be sure to indicate all pages with answers to a given problem**.

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.

If we discover that you put all or part of this test on Chegg or some other disallowed site during the test window, or are found to have otherwise engaged in academic dishonesty, you will fail the class and potentially face other sanctions.

Problem I: [25 pts.] Reactive Circuits



(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 2000 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 a constant 9 V source is attached between terminals a and b of network (c) and left in place for a very long time,

(a) How much energy will be stored in the inductor as $t \to \infty$?

(b) How much energy will be stored in the capacitor as $t \to \infty$?

(c) How much total energy will be stored in the resistors as $t \to \infty$?

(5) Assume a network (not one of the ones shown above) has an equivalent impedance of $\mathbb{Z}_{\text{eq2}} = 700 + \text{j}100\ \Omega$ when $\omega = 5000$ rad/s.

(a) 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).

(b) 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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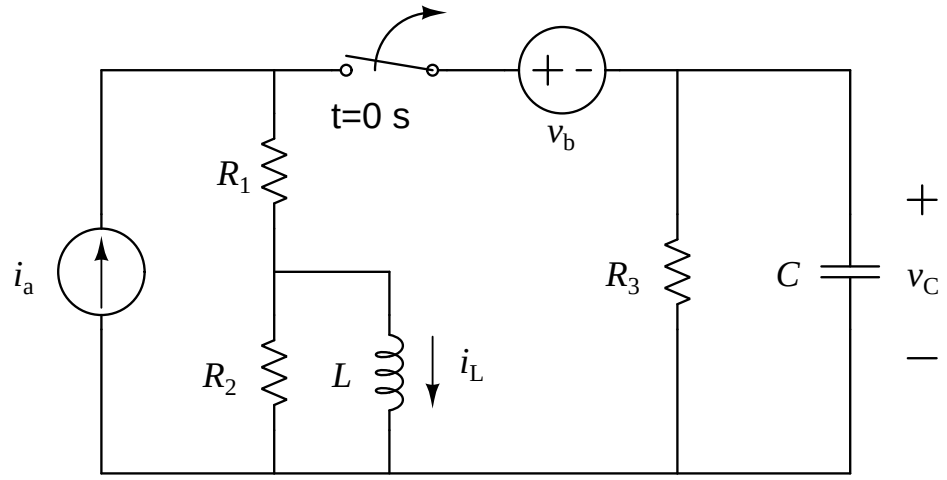
Problem II: [25 pts.] Transient Response

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_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)* $i_L(\infty)$

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

$R_1 = 2$ kΩ $R_2 = 10$ kΩ $R_3 = 4$ kΩ

$L = 50$ mH $C = 20$ μF $i_a(t) = 6$ mA $v_b(t) = -12$ V

determine the current through the inductor, $i_L(t)$, for $t > 0$ s. Also indicate the time constant of the response and then make an accurate graph of $i_L(t)$ for three time constants after the switch opens.

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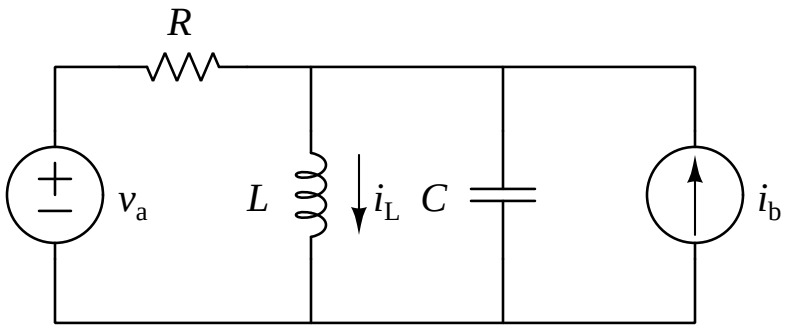
Problem III: [25 pts.] Wait for it...

Given the following circuit:



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

(3) Assuming

$$v_a(t) = 3 + 6\cos(8000t + 19^o) \text{ V} \qquad i_b(t) = 8 + 5\sin(20000t - 27^o) \text{ mA}$$

$$L = 300 \text{ mH} \qquad R = 1 \text{ k}\Omega \qquad C = 50 \text{ nF}$$

(where 1 nF=10^{-9} 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 current $i_L(t)$ $t > 0$ sec.

(4) Given the element values above, what kind of filter does $\mathbb{H}_a(j\omega)$ represent? Why do you think that?

(5) Given the element values above, what kind of filter does $\mathbb{H}_b(j\omega)$ represent? Why do you think that?

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Problem IV: [25 pts.] Bode Plots and Filters

(1) Given the transfer function:

$$\mathbb{H}_1(j\omega) = \frac{\mathbb{V}_{\text{out}}}{\mathbb{V}_{\text{in}}} = \frac{5j\omega}{j\omega + 20}$$

(a) Sketch the straight-line approximation for the Bode magnitude plot. Be sure to properly label the axes, slopes, and magnitudes.

(b) Sketch the straight-line approximation for the Bode phase plot. Be sure to properly label the axes, slopes, and angles.

(c) 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.

(d) 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.

(2) Given the transfer function:

$$\mathbb{H}_2(j\omega) = \frac{(j\omega + 1000)(j\omega + 1000000)}{250000(j\omega + 10)^2} = \frac{(j\omega + 10^3)\,(j\omega + 10^6)}{2.5 \times 10^5\ (j\omega + 10^1)^2}$$

(a) Sketch the straight-line approximation for the Bode magnitude plot. Be sure to properly label the axes, slopes, and magnitudes.

(b) Sketch the straight-line approximation for the Bode phase plot. Be sure to properly label the axes, slopes, and angles.

(c) 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.