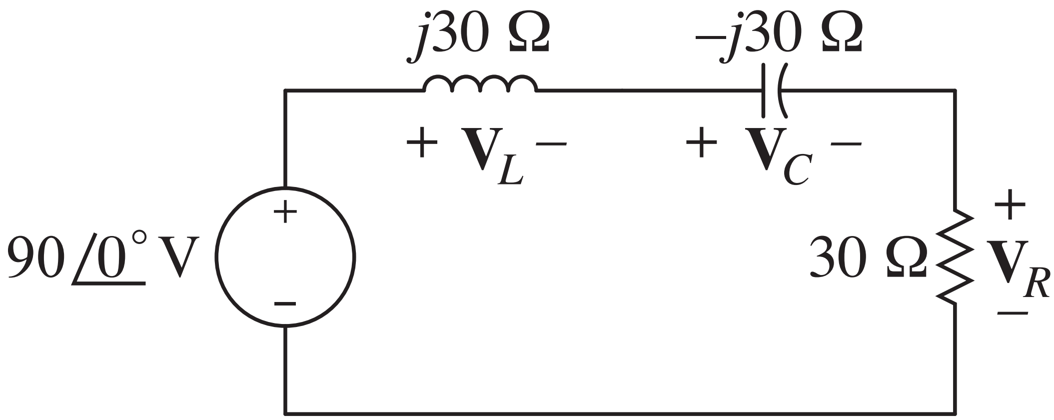
Due Sunday, Apr. 27, 2025 by 11:59 p.m.

NOTE: This is only the "handwritten" portion of Homework 13. There are also problems you must do online via the Mastering site. For this handwritten portion, you must submit a PDF scan of your work at Canvas. Please ensure your work is contained in a single file and is legible.

You must complete the problems on the following pages which made up the final exam in this course from a previous semester. The hardcopy of the exam is printed double-sided.

Shown below are the rules that pertained to this exam, but you are free to treat this assignment like any other homework assignment. These rules are provided merely so that you can become familiar with them as the rules for your exam on Apr. 30 will be similar or the same.

- Relax!
- Closed book.
- Closed notes except you are allowed four sheets (front and back, i.e., the equivalent of 8 pages) of notes (whether handwritten or typeset or some combination thereof).
- All work must be your own. Merely *looking* at the work of others is cheating and may carry all the consequences associated with cheating. Focus on doing your best while completely ignoring your classmates.
- **No work, no credit.** Show your work.
- **Neatness counts.** If I can't easily read it, you won't get credit.
- You may use the "standard" scientific functions of a calculator. Programmed calculations are not permitted. (A programmable calculator is allowed, but you are not allowed to program it or use pre-installed programs.)
- No cell phones or other electronic devices (other than a calculator).
- If you submit your test before 70 minutes from the start of the exam, the number of incorrect points will be multiplied by three. Take your time and check your work!
- The value of each question is indicated within brackets, e.g., [10]. (Questions with equal value are not necessarily of equal difficulty.)
- Unless told otherwise, you are free to use any suitable approach to obtain the answer. Just be sure to properly document your work so it is clear how you arrived at the answer.
- Unless told otherwise, when asked for a complex value, you may express that value in polar or rectangular form. If you use polar form, the angle may be in radians or degrees (but clearly indicate whether the result is radians or degrees). If you use rectangular form, you must provide the real and imaginary part as numbers, not an expression (e.g., $1/(3+j4)$ is not an acceptable answer while the equivalent of $0.12 - j0.16$ is).
- Use appropriate phasor notation, i.e., phasors are labeled with an uppercase letter. A tilde can also be used to emphasis that a value is a phasor, e.g., $\mathbf{I}_1$ or $\tilde{\mathbf{I}}_1$ or simply $\tilde{I}_1$ (since you can't easily write in bold font). This is merely a suggestion, but neatness and proper notation are your friends.
- The last page provides Table 8.3 from Nilsson and Riedel which governs the behaviour of a forced parallel RLC circuit.

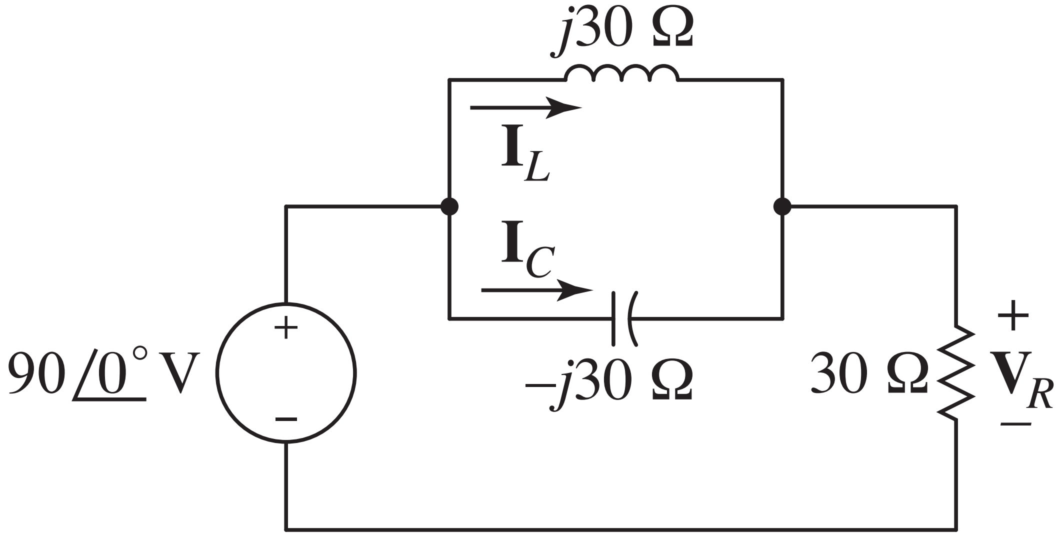

j30 Ω
−j30 Ω
+ V_L −
+ V_C −
90 /0° V
+
−
30 Ω
+
V_R
−

1. The following questions pertain to the circuit shown on the previous page (which is in sinusoidal steady state).

   (a) **[3]** What is the voltage $\mathbf{V}_L$?

   (b) **[3]** What is the voltage $\mathbf{V}_C$?

   (c) **[3]** What is the voltage $\mathbf{V}_R$?


$j30\ \Omega$
$\mathbf{I}_L$
$\mathbf{I}_C$
$90\angle 0^\circ$ V
+
−
$-j30\ \Omega$
$30\ \Omega$
+
$\mathbf{V}_R$
−

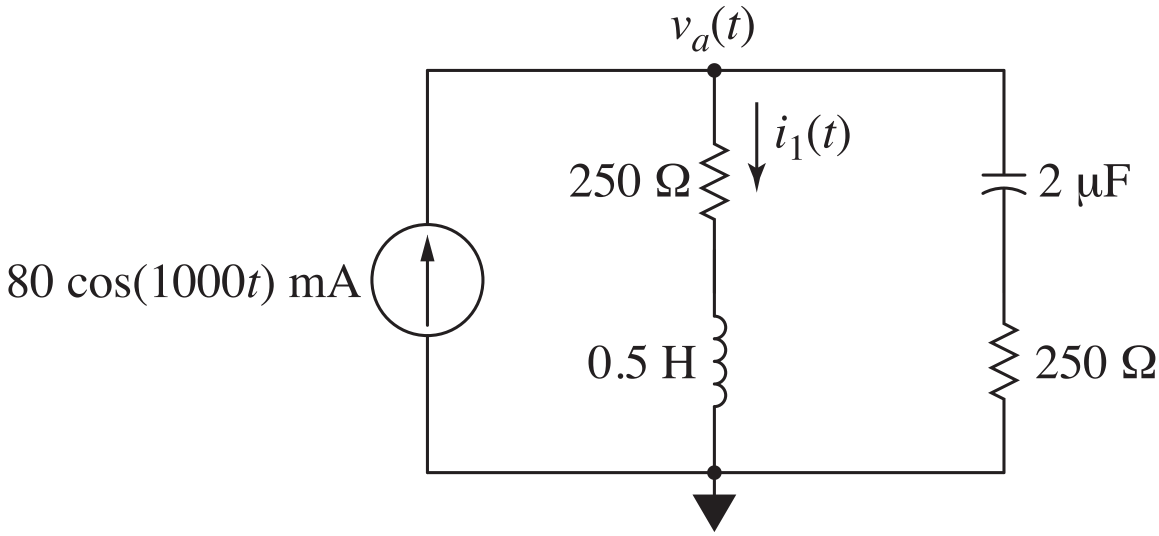
2. The following questions pertain to the circuit shown on the previous page (which is in sinusoidal steady state).

   (a) **[3]** What is the total impedance seen by the voltage source?

   (b) **[3]** What is the voltage $\mathbf{V}_R$?

   (c) **[3]** What is the current $\mathbf{I}_L$?

   (d) **[3]** What is the current $\mathbf{I}_C$?



(a) The space below is provided to redraw the circuit above in the frequency domain.

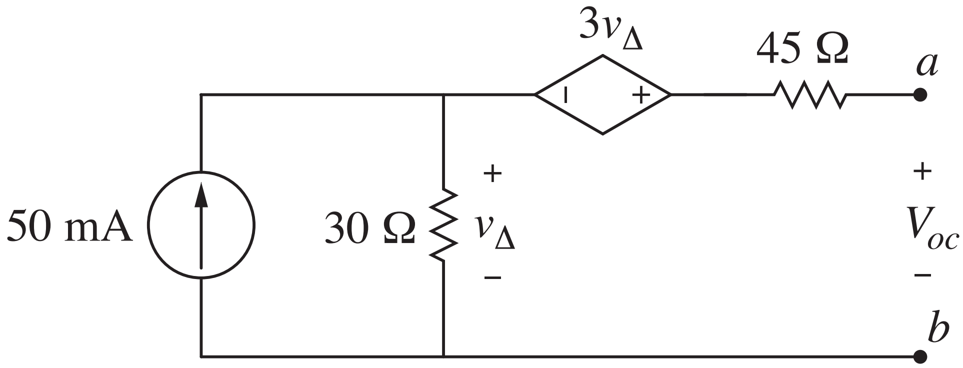
3. The following questions pertain to the circuit shown on the previous page which is *in sinusoidal steady-state*. We wish to obtain frequency-domain values associated with this circuits (i.e., phasors and impedances).

   (a) **[5]** In the space below the circuit on the previous page, redraw the circuit in the frequency domain (i.e., represent the source in phasor form, provide the impedance for each element, and currents and voltages should be labeled with appropriate phasor notation).

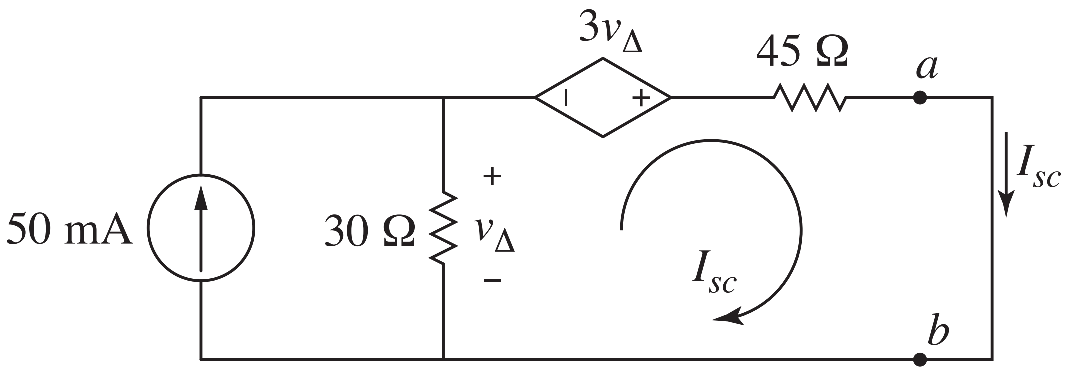
   (b) **[5]** What is the equivalent impedance seen by the current source?

   (c) **[5]** What is the phasor voltage $\mathbf{V}_a$, i.e., the voltage at the top node?

   (d) **[5]** What is the current phasor $\mathbf{I}_1$, i.e., the current through the inductor in series with the resistor?



(a)



(b)

(d) The space below is provided to draw the Thévenin equivalent of the cicuit above (see questions on the following page).

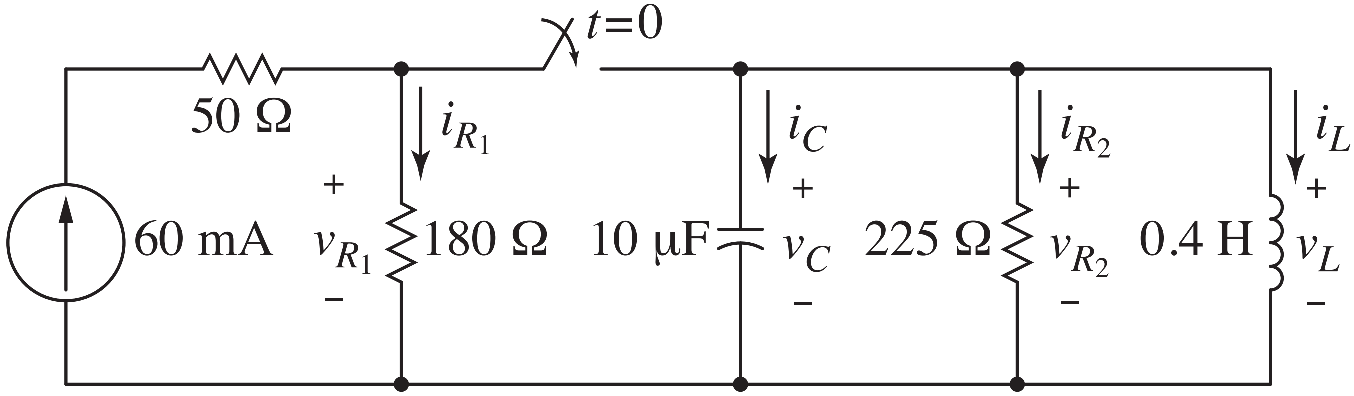
4. The following questions pertain to the circuit shown on the previous page which is depicted with (a) an open circuit and (b) a short circuit load.

   (a) **[4]** With an open circuit between the nodes a and b, what is the open circuit voltage V_{oc} (provide a numeric value)?

   (b) **[4]** With a short present between the nodes a and b we want to use mesh analysis (KVL) to find the one unkown mesh current, i.e., the short-circuit current I_{sc}. What is v_Δ in terms of I_{sc}? (You don't need to solve for anything. You merely need to provide the relationship between v_Δ and I_{sc}.)

   (c) **[4]** Write the mesh equation for I_{sc} then solve for the numeric value of I_{sc}.

   (d) **[4]** Given your answers above, determine the Thévenin equivalent resistance *and* draw the Thévenin equivalent circuit in the space provided on the previous page.


t=0
50 Ω
60 mA
+
v_{R_1}
−
i_{R_1}
180 Ω
10 μF
i_C
+
v_C
−
225 Ω
i_{R_2}
+
v_{R_2}
−
0.4 H
i_L
+
v_L
−

5. For the circuit shown on the previous page, just prior to the switch closing, $v_C(0^-) = 18$ V and $i_L(0^-) = 20$ mA (i.e., the circuit is not in steady state when the switch closes).

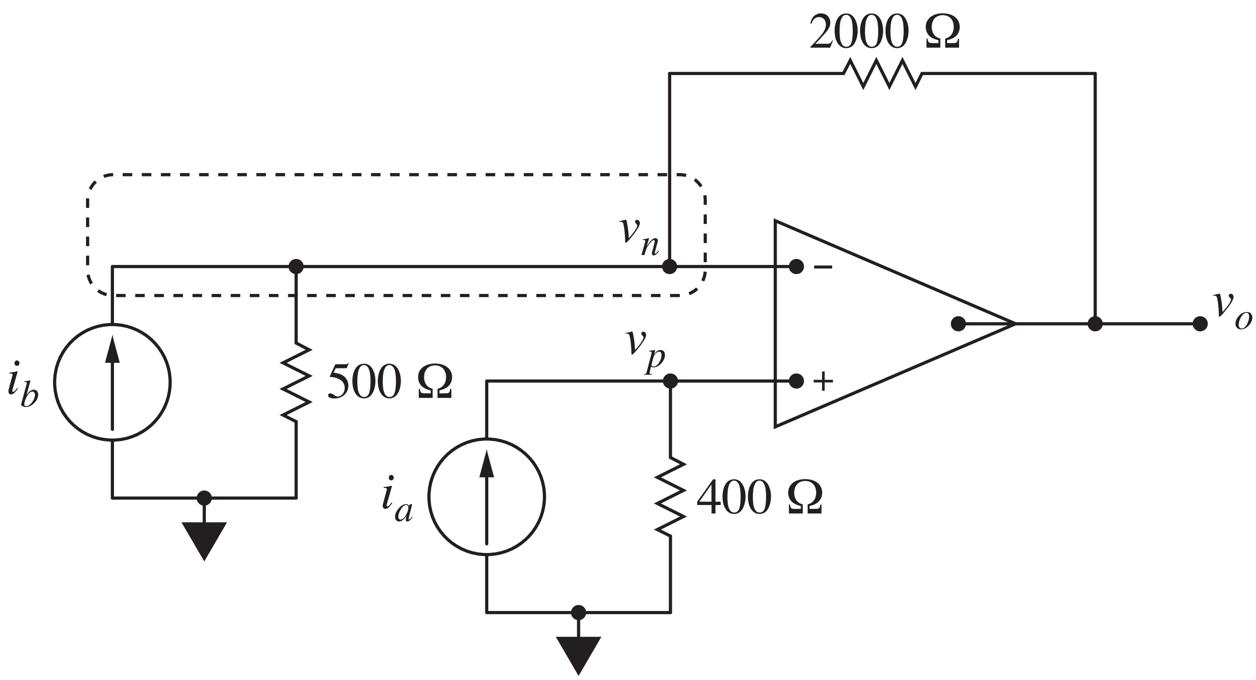
   (a) **[4]** What is the current $i_{R_2}(0^-)$?

   (b) **[4]** What is the current $i_C(0^-)$?

   (c) **[4]** What is the current $i_C(0^+)$?

   (d) **[4]** What is the current $i_L(\infty)$?

   (e) **[4]** For $t > 0$, does the circuit behave in an overdamped, critically damped, or underdamped manner?


2000 Ω
v_n
−
v_o
v_p
+
i_b
500 Ω
i_a
400 Ω

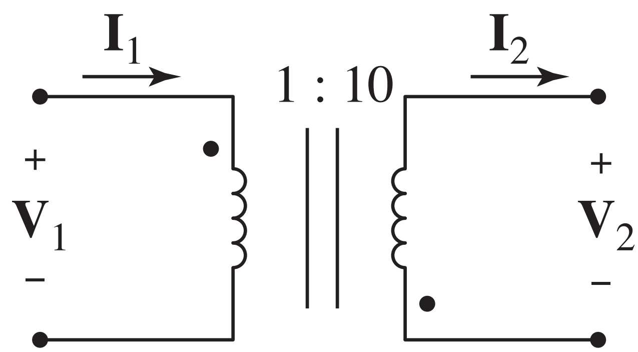
6. The ideal op-amp on the previous page is not saturated and is used to amplify the difference between the two currents i_a and i_b. Your answers to the following questions will contain some combination of i_a, i_b, v_0, and numeric values.

   (a) **[4]** What is the non-inverting voltage v_p?

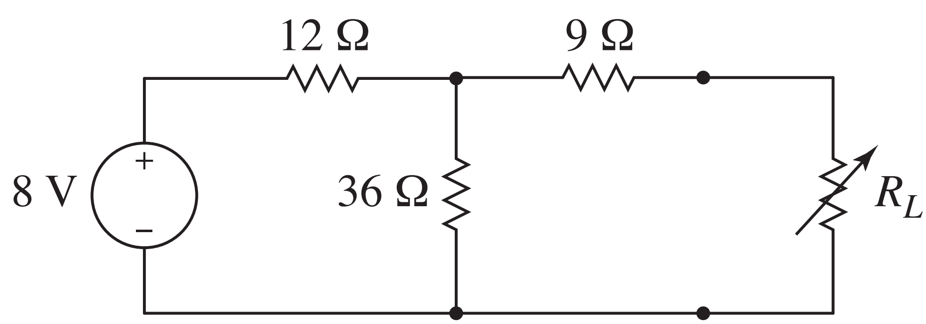
   (b) **[4]** What is the inverting voltage v_n?

   (c) **[4]** Write the KCL equation that pertains to the inverting terminal (i.e., the node enclosed in the dashed box).

   (d) **[4]** Given your answer to the previous question, what is the output voltage v_0 in terms of the currents i_a and i_b?



For Problem 7.



For Problem 8.

7. **[4]** For the ideal transformer shown on the previous page, write (a) the relationship between the voltage phasors and (b) the relations between the current phasors.

8. **[3]** For the circuit shown at the bottom of the previous page, what value of R_L will maximize the power delivered to this load resistor?

Table 8.3 from Nilsson and Riedel concerning the step response of parallel RLC circuits. ($V_0 = v_C(0)$; $I_0 = i_L(0)$)

Table 8.3 Equations for Analyzing the Step Response of Parallel *RLC* Circuits

Characteristic equation	$s^2 + \frac{1}{RC}s + \frac{1}{LC} = 0$
Neper, resonant, and damped frequencies	$\alpha = \frac{1}{2RC} \quad \omega_0 = \sqrt{\frac{1}{LC}} \quad \omega_d = \sqrt{\omega_0^2 - \alpha^2}$
Roots of the characteristic equation	$s_1 = -\alpha + \sqrt{\alpha^2 - \omega_0^2}, \quad s_2 = -\alpha - \sqrt{\alpha^2 - \omega_0^2}$
$\alpha^2 > \omega_0^2$: overdamped	$i_L(t) = I_f + A_1' e^{s_1 t} + A_2' e^{s_2 t}, \quad t \geq 0$ $i_L(0^+) = I_f + A_1' + A_2' = I_0$ $\frac{di_L(0^+)}{dt} = s_1 A_1' + s_2 A_2' = \frac{V_0}{L}$
$\alpha^2 < \omega_0^2$: underdamped	$i_L(t) = I_f + B_1' e^{-\alpha t}\cos\omega_d t + B_2' e^{-\alpha t}\sin\omega_d t, \quad t \geq 0$ $i_L(0^+) = I_f + B_1' = I_0$ $\frac{di_L(0^+)}{dt} = -\alpha B_1' + \omega_d B_2' = \frac{V_0}{L}$
$\alpha^2 = \omega_0^2$: critically damped	$i_L(t) = I_f + D_1' t e^{-\alpha t} + D_2' e^{-\alpha t}, \quad t \geq 0$ $i_L(0^+) = I_f + D_2' = I_0$ $\frac{di_L(0^+)}{dt} = D_1' - \alpha D_2' = \frac{V_0}{L}$