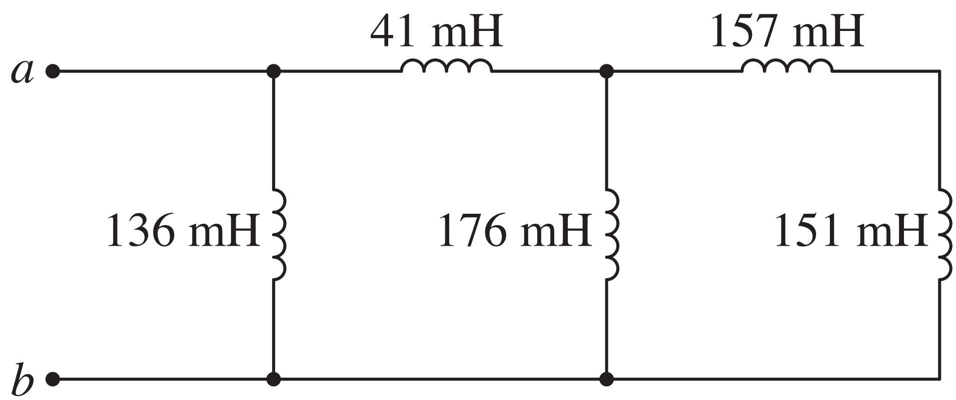
TEST #3 **EE 261** **Spring 2025**

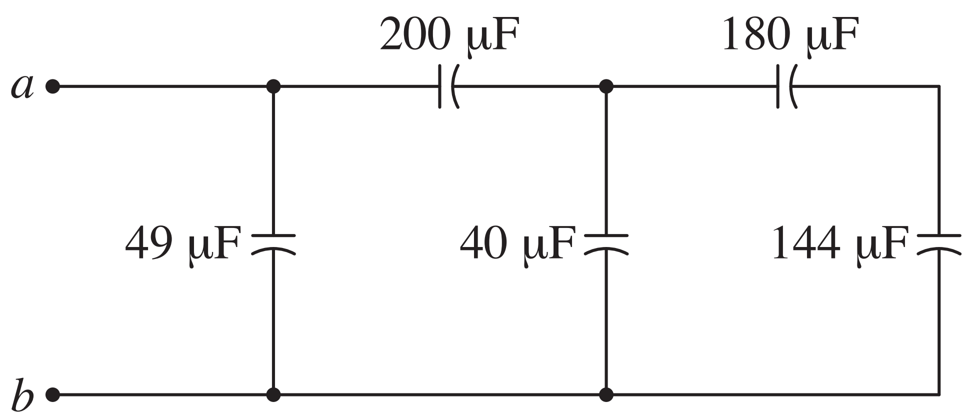
NAME: ______________________________

The rules:

- Relax!
- Closed book.
- Closed notes except you are allowed three sheets (front and back) 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 50 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.
- **Note**: The answers to all the questions can be obtained without significant work. If you find yourself doing a lot of work, you may want to pause and rethink what you're doing.
- The last page provides Table 8.2 from Nilsson and Riedel concerning the natural response of parallel RLC circuits.


41 mH
157 mH
a
136 mH
176 mH
151 mH
b

(a)

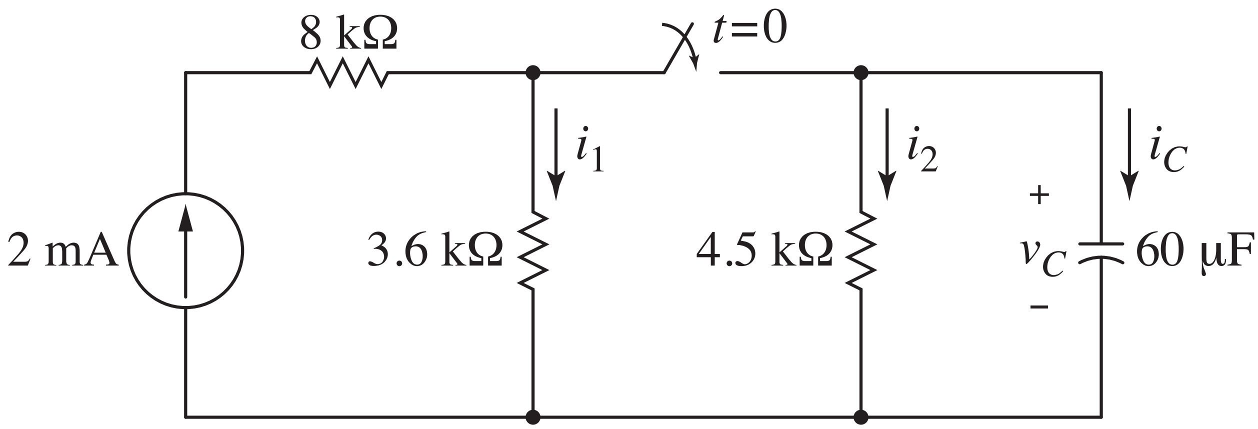

200 μF
180 μF
a
49 μF
40 μF
144 μF
b

(b)

1. The following questions pertain to the circuits shown on the previous page.

   (a) **[7]** What is the equivalent inductance of the inductors shown in (a)?

   (b) **[7]** What is the equivalent capacitance of the capacitors shown in (b)?


8 kΩ
t=0
2 mA
i1
3.6 kΩ
i2
4.5 kΩ
iC
+
vC
−
60 μF

2. The circuit shown on the previous page is *not* in steady state at $t = 0^-$. The capacitor voltage at $t = 0^-$ is 18 V (i.e., $v_C(0^-) = 18$ V).

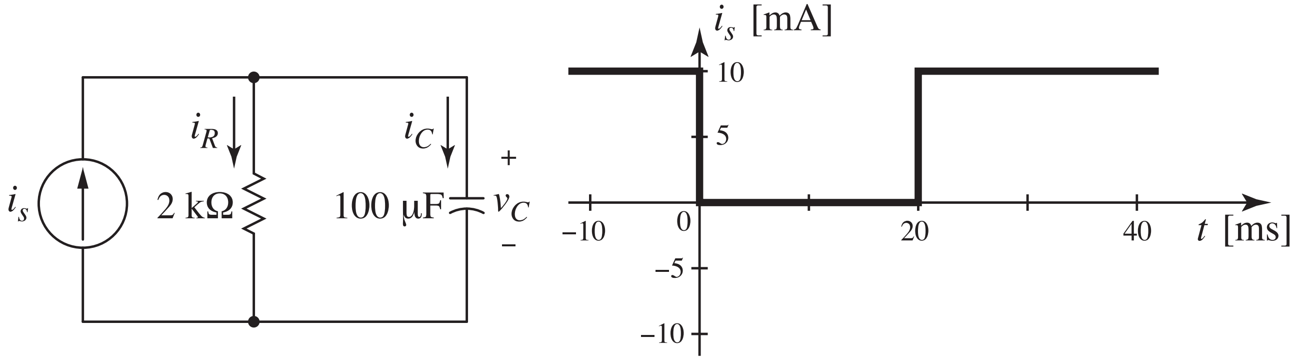
   (a) **[6]** What is $i_1(0^+)$?

   (b) **[6]** What is $i_2(0^+)$?

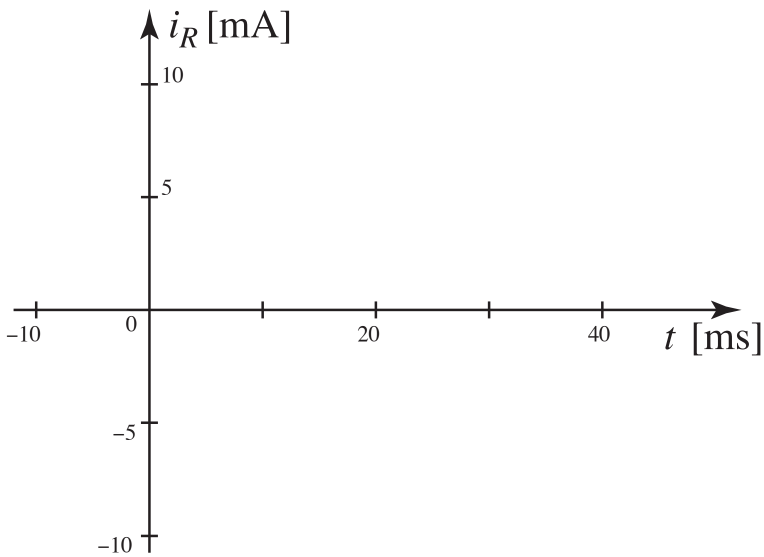
   (c) **[6]** What is $i_C(0^+)$?

   (d) **[6]** What is $v_C(\infty)$?

   (e) **[6]** What is the time constant τ that pertains for $t > 0$?

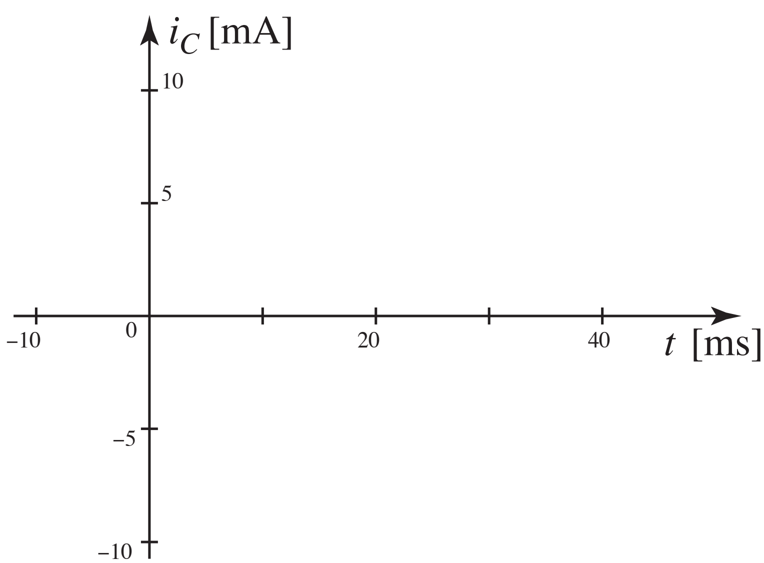


i_s
i_R
2 kΩ
i_C
100 μF
+
v_C
−
i_s [mA]
10
5
0
−10
20
40
−5
−10
t [ms]



i_R [mA]
10
5
−10
0
20
40
t [ms]
−5
−10

(a)



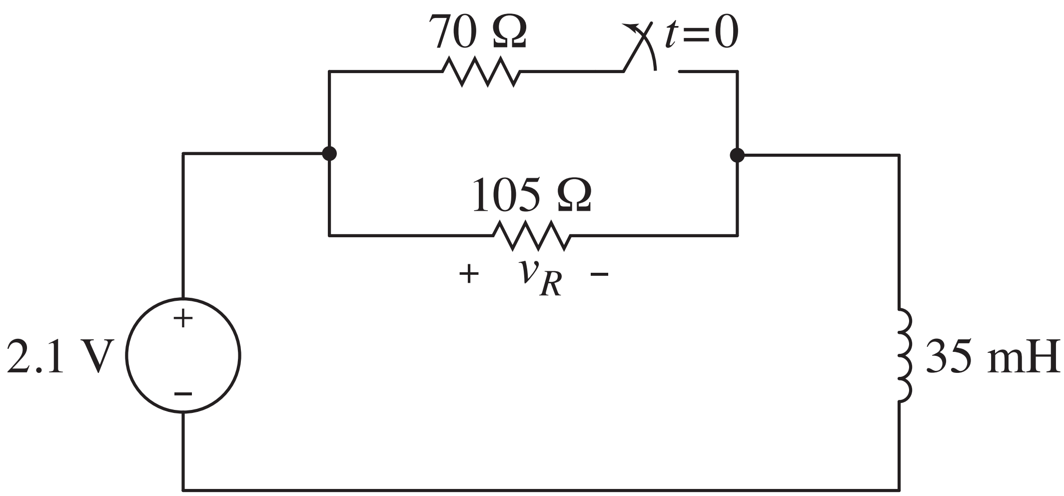
i_C [mA]
10
5
−10
0
20
40
t [ms]
−5
−10

(b)

3. The current source in the circuit shown on the previous page maintains a constant current of 10 mA except for the interval $0 < t < 20$ ms when it is deactivated (as indicated in the plot on the right).

   (a) **[7]** Using the axes provided on the previous page, sketch the current $i_R(t)$ over roughly the interval $-10 < t < 40$ ms. Your sketch does not need to be precise in terms of depicting the rate of decay and the value it has at $t = 20$ ms, but it should be reasonably close to the actual values. (You are not required to provide the mathematical description of the current in the different time intervals, but you are free to obtain those equations and they could aid production of your sketch.) It should be clear when and what types of changes occur and the value to which the current is converging.

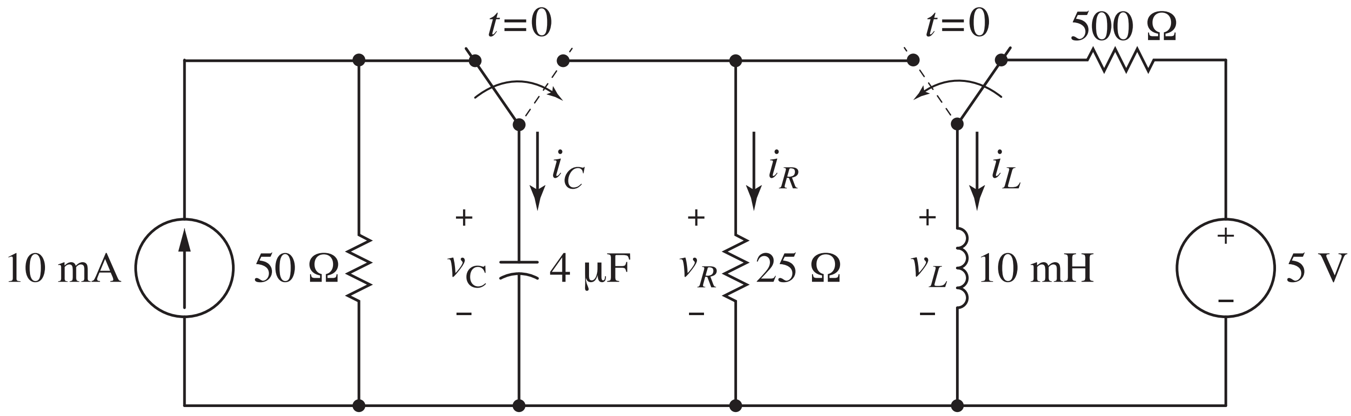
   (b) **[7]** Using the axes provided on the previous page, sketch the current $i_C(t)$ over roughly the interval $-10 < t < 40$ ms. The same comments concerning the precision of the sketch mentioned above still pertain.


70 Ω
t=0
105 Ω
+ vR −
2.1 V
+
−
35 mH

4. The following questions pertain to the circuit shown on the previous page which is in steady state prior to the switch opening at $t = 0$.

   (a) **[6]** What is $v_R(0^-)$?

   (b) **[6]** What is $v_R(0^+)$?



t=0
t=0
500 Ω
i_C
i_R
i_L
10 mA
50 Ω
v_C
4 μF
v_R
25 Ω
v_L
10 mH
5 V

5. The following questions pertain to the circuit on the previous page which is in steady state prior to $t = 0$ when both switches simultaneously change position.

(a) **[6]** What is the value of $i_L(0^+)$?

(b) **[6]** What is the value of $v_R(0^+)$?

(c) **[6]** What is the value of $i_R(0^+)$?

(d) **[6]** What is the value of $i_C(0^+)$?

(e) **[6]** For $t > 0$, will $v_R(t)$ behave in an overdamped, critically damped, or underdamped manner? (Justify your answer.)

Table 8.2 from Nilsson and Riedel concerning the natural response of parallel RLC circuits. ($V_0 = v_C(0)$; $I_0 = i_L(0)$)

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	$v(t) = A_1 e^{s_1 t} + A_2 e^{s_2 t}, \text{t} \geq 0$
	$v(0^+) = A_1 + A_2 = V_0$
	$\frac{dv(0^+)}{dt} = s_1 A_1 + s_2 A_2 = \frac{1}{C}\left(\frac{-V_0}{R} - I_0\right)$
$\alpha^2 < \omega_0^2$: underdamped	$v(t) = B_1 e^{-\alpha t}\cos\omega_d t + B_2 e^{-\alpha t}\sin\omega_d t, \text{t} \geq 0$
	$v(0^+) = B_1 = V_0$
	$\frac{dv(0^+)}{dt} = -\alpha B_1 + \omega_d B_2 = \frac{1}{C}\left(\frac{-V_0}{R} - I_0\right)$
$\alpha^2 = \omega_0^2$: critically damped	$v(t) = D_1 t e^{-\alpha t} + D_2 e^{-\alpha t}, \text{t} \geq 0$
	$v(0^+) = D_2 = V_0$
	$\frac{dv(0^+)}{dt} = D_1 - \alpha D_2 = \frac{1}{C}\left(\frac{-V_0}{R} - I_0\right)$