# Midterm

Exam Location: In Person

PRINT your student ID: ______________________________

PRINT AND SIGN your name: ______________, ______________ ______________

(last) (first) (sign)

PRINT your discussion sections and (u)GSIs (the ones you attend): ______________

Row Number: ______________ Seat Number: ______________

Name and SID of the person to your left: ______________________________

Name and SID of the person to your right: ______________________________

Name and SID of the person in front of you: ______________________________

Name and SID of the person behind you: ______________________________

**1. Honor Code (0 pts.)**

We treat all our students with utmost trust and respect, and expect students to return the same trust and respect. In EECS16B we will have ***zero-tolerance*** for academic dishonesty. There will be ***dire consequences*** for students that violate that trust and the Berkeley code of conduct. Both professors are committed to enforcing academic honesty, and ***dishonesty cases will be punished in their fullest -- no excuses or special circumstances will be considered***. Always seek help, never cheat.

I acknowledge: ______________________ (signature)

**2. What is your favorite topic of the course so far? (0 pts.)**

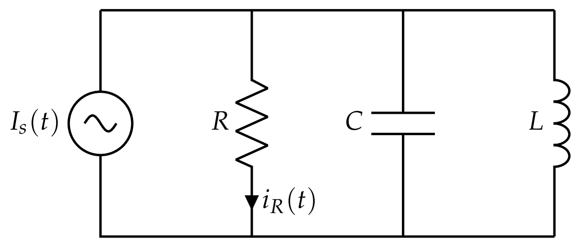
Do not turn this page until the proctor tells you to do so.
You can work on the above problems before time starts.

**3. Circuit Potpourri (12 pts.)**

(a) (3 pts.) Suppose we have voltage $v(t) = V_0 \sin(\omega t)$. Let $\widetilde{V}$ be its phasor representation. **Mark all that are true.**

- ☐ $\widetilde{V}$ is a real number.
- ☐ $\widetilde{V}$ is a purely imaginary number.
- ☐ $\mathrm{j}\widetilde{V}\mathrm{e}^{-3}$ would be a valid phasor.

(b) (3 pts.) Suppose we have the following circuit.




Let $I_s(t) = \cos(\omega_0 t)$ where $\omega_0 = \frac{1}{\sqrt{LC}}$. **What is the value of $\tilde{I}_R$ (the phasor associated with $i_R(t)$)?**

| | | | |
|---|---|---|---|
| ○ | $0$ | ○ | $\tilde{I}_s$ |
| ○ | $\frac{R}{R+(Z_C \| Z_L)}\tilde{I}_s$ | ○ | $\frac{Z_C+Z_L}{R+Z_C+Z_L}\tilde{I}_s$ |

(c) (3 pts.) Suppose you have a 3 bit SAR-ADC with input range $[0, 1)$ and $V_{\text{REF}} = 1V$, and that the input analog signal is $v_{\text{in}} = 0.6V$. **Which of the following best describes the relationship between the digitized state of the signal and the analog signal?**

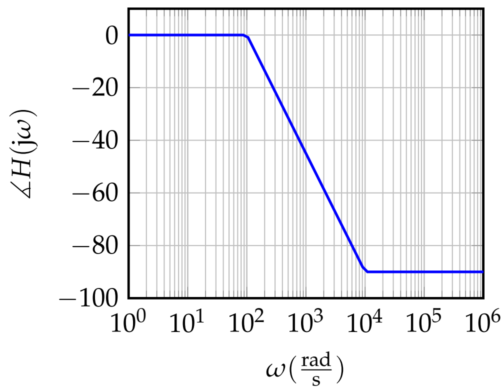
- ○ The digitized state exactly represents the analog signal.
- ○ The digitized state under-estimates the analog signal.
- ○ The digitized state over-estimates the analog signal.
- ○ None of the above

(d) (3 pts.) We are told that the transfer function of some circuit is equal to:

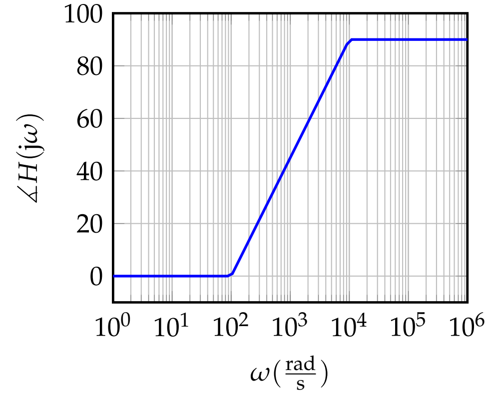
$$H(j\omega) = \frac{1 + j\frac{\omega}{10^2}}{1 + j\frac{\omega}{10^4}} \tag{1}$$

**Which of the following graphs is the phase Bode plot of this transfer function?**

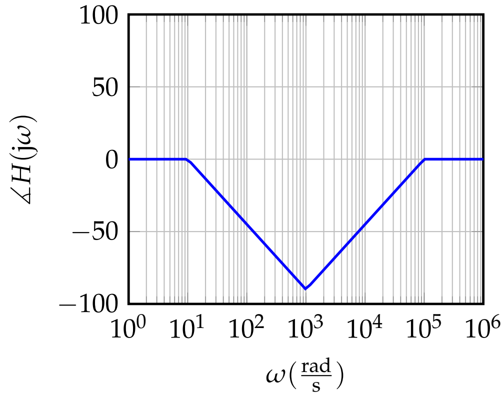
**Option 1**



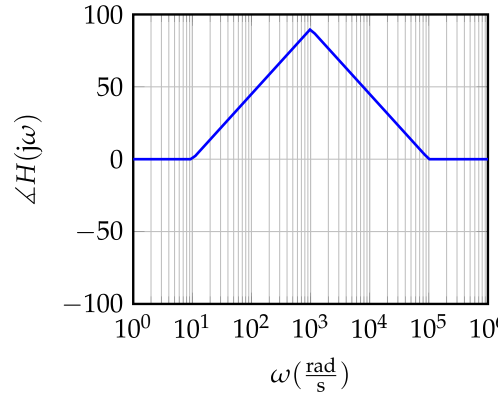

**Option 2**




**Option 3**



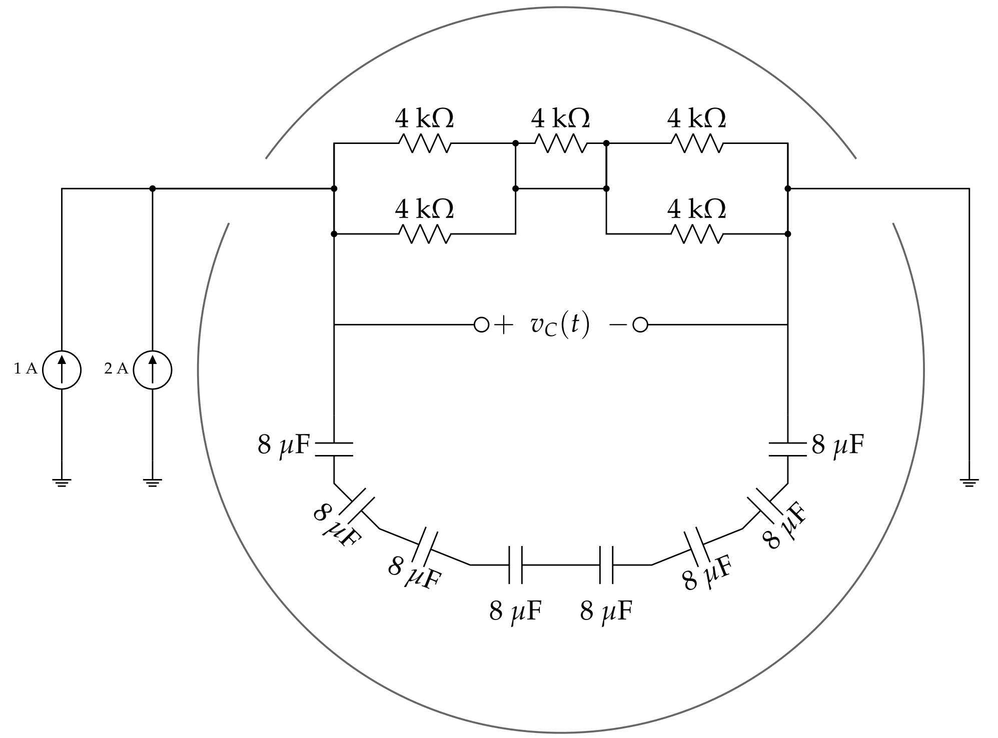

**Option 4**



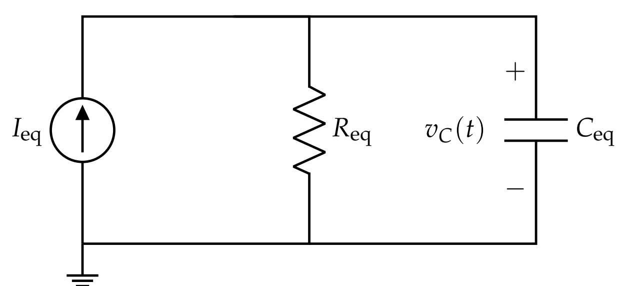

| ◯ Option 1 | ◯ Option 2 | ◯ Option 3 | ◯ Option 4 |

**4. The exam is smiling at you. Be happy! (18 pts.)**

Keep calm and smile on! Recall *Divide et impera* ("divide and conquer").




The above circuit can be simplified to the circuit below:




(a) (6 pts.) **Find the numerical values of $I_{eq}$, $R_{eq}$, and $C_{eq}$ for the equivalent model above.**

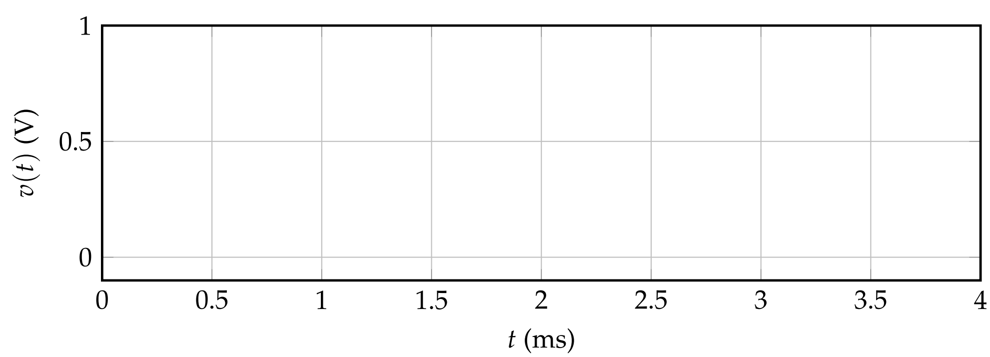
(b) (6 pts.) The differential equation for $v_C(t)$ can be written in the following form:

$$\frac{\mathrm{d}v_C(t)}{\mathrm{d}t} + av_C(t) = u(t)$$

**Find expressions for $a$ and $u(t)$ in terms of $I_{\text{eq}}$, $R_{\text{eq}}$, and $C_{\text{eq}}$.**

(c) (6 pts.) Suppose that $I_{\text{eq}} = 1$ mA, $R_{\text{eq}} = 1$ k$\Omega$, and $C_{\text{eq}} = 1$ $\mu$F, and that the capacitor is initially discharged at $t = 0$ (in other words, $v_C(0) = 0$).

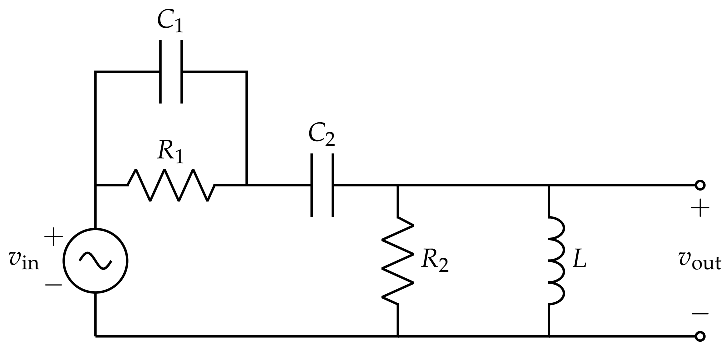
**Qualitatively plot the waveform of $v_C(t)$.** The plot does not need to be exact, but should indicate knowledge of the initial condition, steady state value, and time constant associated with this circuit.



5. **Karaoke (20 pts.)**

Professor Ana Arias is building a microphone for her homemade karaoke system. She wants to create a filter to attenuate noisy frequencies so the mic only picks up her voice. She decides to build the following circuit.

**Circuit 1:**



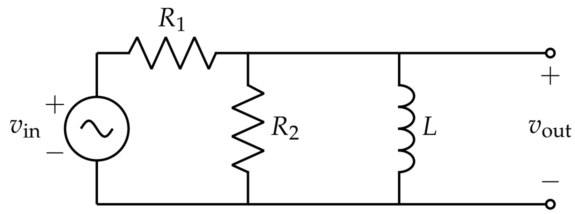

(a) (6 pts.) **For Circuit 1: Find the value of the transfer function** $H_1(j\omega) = \frac{\widetilde{V}_{\text{out}}}{\widetilde{V}_{\text{in}}}$ ***only*** **at** $\underline{\omega = 0}$ ("hint hint").

(b) (6 pts.) **For Circuit 1: Find the value of the transfer function** $H_1(j\omega) = \frac{\widetilde{V}_{\text{out}}}{\widetilde{V}_{\text{in}}}$ ***only*** **at** $\underline{\omega \to \infty}$ ("hint hint").

Professor Arias decides to remove the capacitors and is thus left with the following circuit.

**Circuit 2:**




(c) (8 pts.) Given that the transfer function for Circuit 2 is of the form

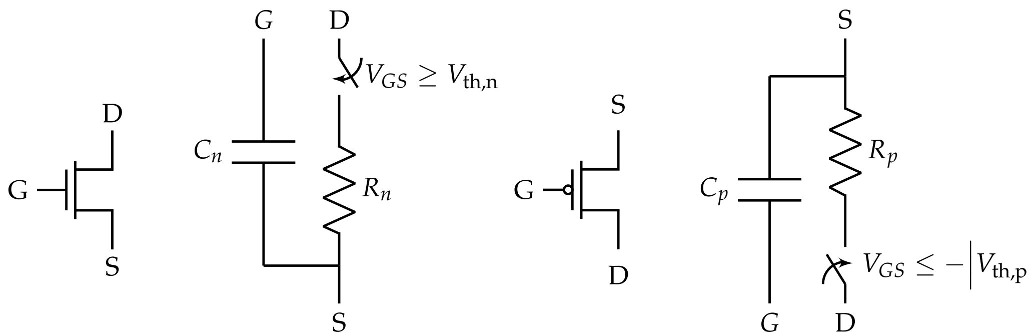
$$H_2(j\omega) = \frac{\widetilde{V}_{out}}{\widetilde{V}_{in}} = K\frac{j\omega}{1 + j\frac{\omega}{\omega_c}} \tag{2}$$

where $K \in \mathbb{R}$, **find the values of $K$ and $\omega_c$ in terms of the circuit quantities $R_1$, $R_2$, and $L$.**

**6. Transistor Time (10 pts.)**

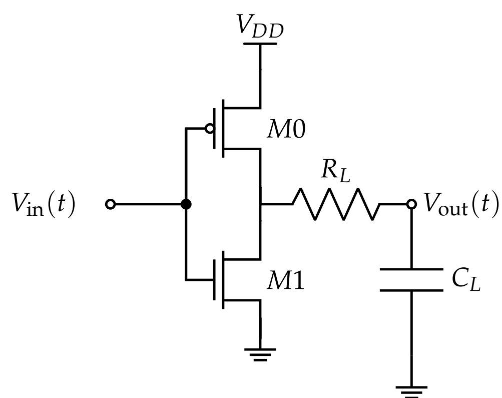
For this problem, assume that $V_{DD}$ is greater than the NMOS threshold $V_{\text{th,n}}$ and the PMOS threshold $|V_{\text{th,p}}|$.

Also assume that we model transistors with the RC models below.




**(a)** NMOS Resistor-Capacitor Model **(b)** PMOS Resistor-Capacitor Model

Consider the following circuit:

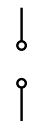



Suppose we have the following input:

$$V_{\text{in}}(t) = \begin{cases} 0 & t < 0 \\ V_{DD} & t \geq 0 \end{cases}$$

See the next page for questions.

(a) (5 pts.) **Draw the equivalent RC circuit model for $t \geq 0$** with all resistors and capacitors included (specify which switches are open and closed in your equivalent diagram, as shown below):



**(a)** Open Switch

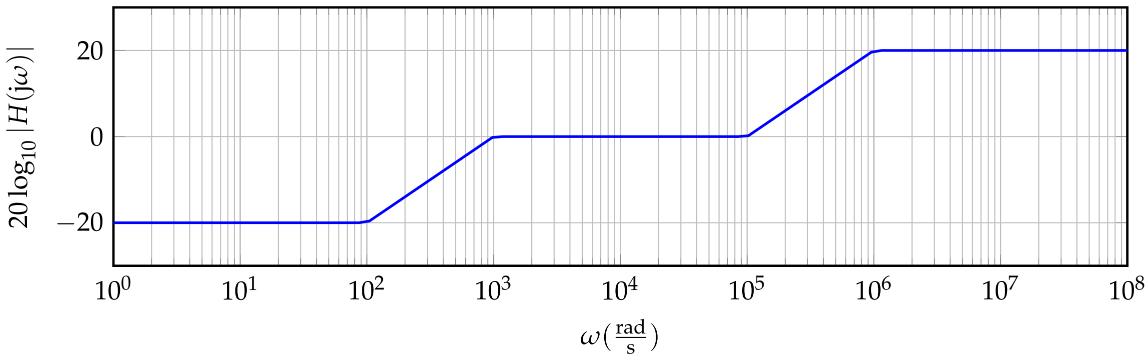
**(b)** Closed Switch

(b) (5 pts.) Let $C_p = C_n = 5\,\mu\text{F}$, $R_p = 20\,\Omega$, $R_n = 10\,\Omega$, $R_L = 40\,\Omega$, and $C_L = 100\,\mu\text{F}$.

With these values, and for the same input $V_{\text{in}}(t)$, **calculate the RC time constant $\tau$ of the circuit for $t \geq 0$.**

**7. Bode Plots (20 pts.)**

For this question, we will analyze the provided magnitude Bode plot.




(a) (5 pts.) **What are the pole and zero frequencies of this Bode plot?** Make sure to specify which frequencies are pole frequencies and which frequencies are zero frequencies.

(b) (5 pts.) **Write a possible transfer function** $H(j\omega)$ **that would produce this Bode plot** (there is more than one possible answer, you only need to write down one possible answer).

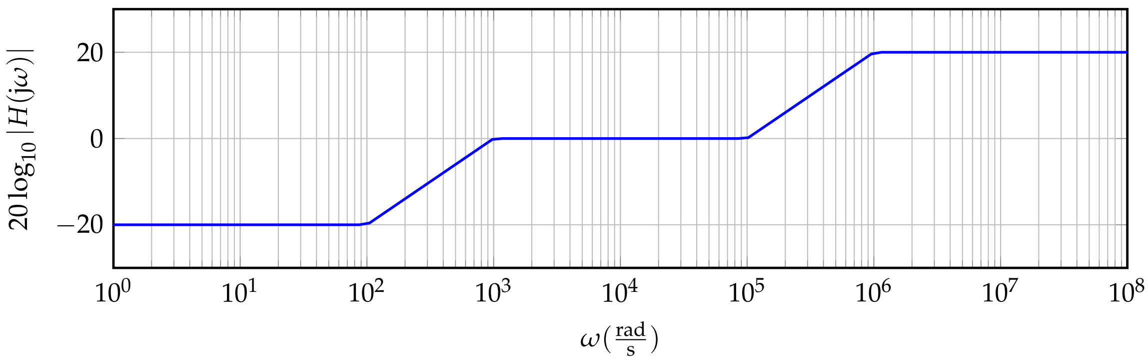
(c) (10 pts.) Suppose that the input voltage into the system with transfer function $H(\mathrm{j}\omega)$ (represented by the provided Bode plot) is:

$$v_{\text{in}}(t) = 1 + 2\cos\left(10^4 t + \frac{\pi}{3}\right) + 3\cos\left(10^8 t\right) \tag{3}$$

You are provided that $\measuredangle H(\mathrm{j}0) = \measuredangle H(\mathrm{j}10^4) = \measuredangle H(\mathrm{j}10^8) = 0$.

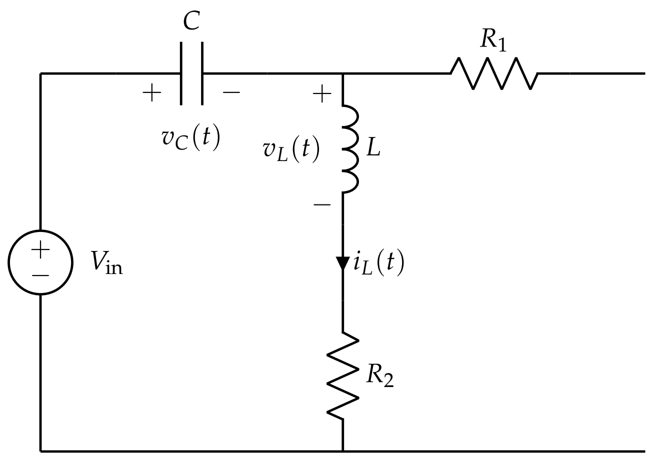
**Find $v_{\text{out}}(t)$ for the input voltage $v_{\text{in}}(t)$.**

The plot is provided once more for convenience:



**8. 2nd Order Superposition (20 pts.)**

Suppose we have the following circuit:




(a) (8 pts.) The differential equation for $i_L(t)$ can be written in the following form:

$$\frac{\mathrm{d}^2 i_L(t)}{\mathrm{d}t^2} + 2\alpha \frac{\mathrm{d}i_L(t)}{\mathrm{d}t} + \omega_0^2 i_L(t) = u(t)$$

**Solve for the constants $\alpha$, $\omega_0$, and $u(t)$ in terms of $R_1$, $R_2$, $L$, $C$, $V_{\text{in}}$.**

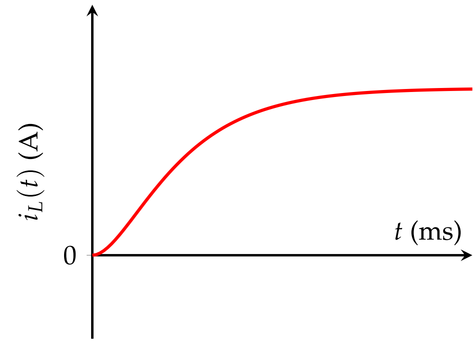
(b) (3 pts.) Now, suppose that you are told $\alpha = \frac{3}{2}$, $\omega_0 = \sqrt{2}$, and $u(t) = 0$. Also, suppose that the following information about the circuit is true:

$$i_L(0) = 3\,\mathrm{A},\ v_L(0) = 1\,\mathrm{V},\ v_C(0) = 0\,\mathrm{V},\ R_1 = R_2 = 6\,\Omega,\ L = 2\,\mathrm{H},\ C = 0.25\,\mathrm{F}$$

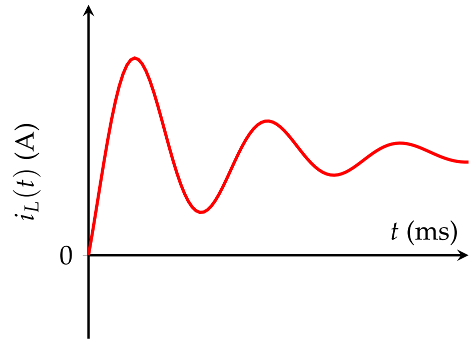
**Find** $\left.\frac{\mathrm{d}i_L(t)}{\mathrm{d}t}\right|_{t=0}$ **(one of the initial conditions necessary for solving $i_L(t)$).**

(c) (5 pts.)

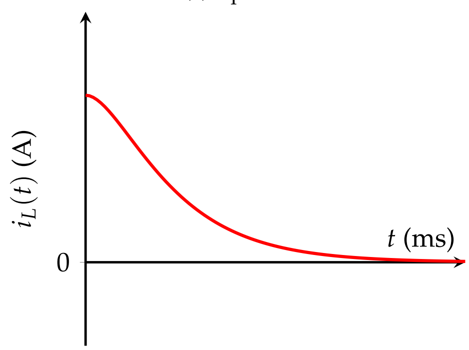
Using the values from the previous part, **state the option below that best describes** $i_L(t)$ *and* **briefly justify your choice.**



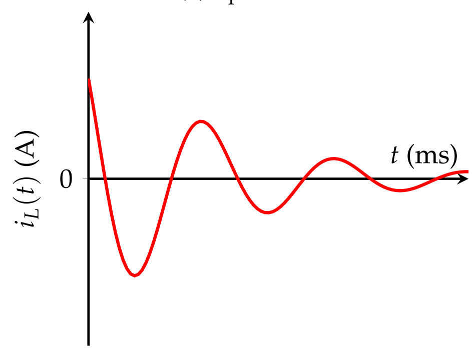

**(a)** Option 1




**(b)** Option 2

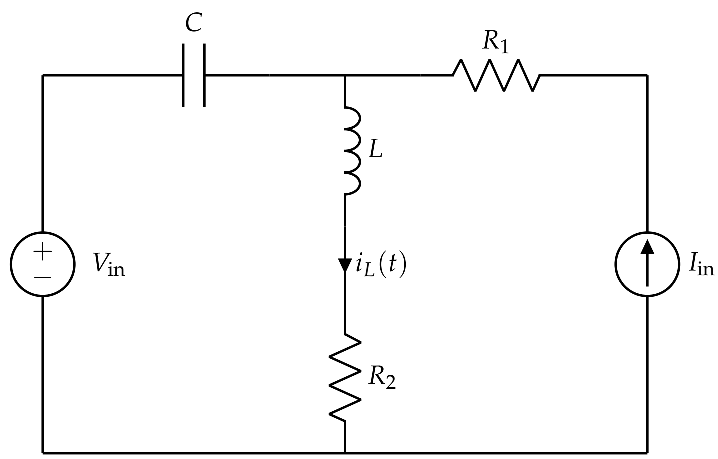



**(c)** Option 3




**(d)** Option 4

(d) (4 pts.) Now, we add a current source to the circuit.




**What is the steady state current $i_{L,\text{SS}}$ (the current through the inductor as $t \to \infty$) of this circuit?** Express in terms of $I_{\text{in}}$, $V_{\text{in}}$, $L$, $C$, $R_1$, $R_2$. (Note that $V_{\text{in}}$ and $I_{\text{in}}$ are DC sources.)

[Doodle page! Draw us something if you want or give us suggestions or complaints. You can also use this page to report anything suspicious that you might have noticed.

If needed, you can also use this space to work on problems. But if you want the work on this page to be graded, make sure you tell us on the problem's main page.]

[Extra page. If you want the work on this page to be graded, make sure you tell us on the problem's main page.]