Student Name_____

18-100 Introduction to Electrical and Computer Engineering, Fall 2021

Exam 2

(Total of 5 Problems)

October 26th, 2021

Note:

1. ***This exam is closed-book (a two-sided 8.5 in x 11 in note sheet is allowed)***
2. ***It has to be your own work and please show your work.***
3. ***Please remember to write units for your answers wherever is needed.***
4. ***Please box your final answers***

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Score

Problem 1_____ (20 pts.)

Problem 2_____ (20 pts.)

Problem 3_____ (20 pts.)

Problem 4_____ (20 pts.)

Problem 5_____ (20 pts.)

Total_____(100 pts)

Student Name_____

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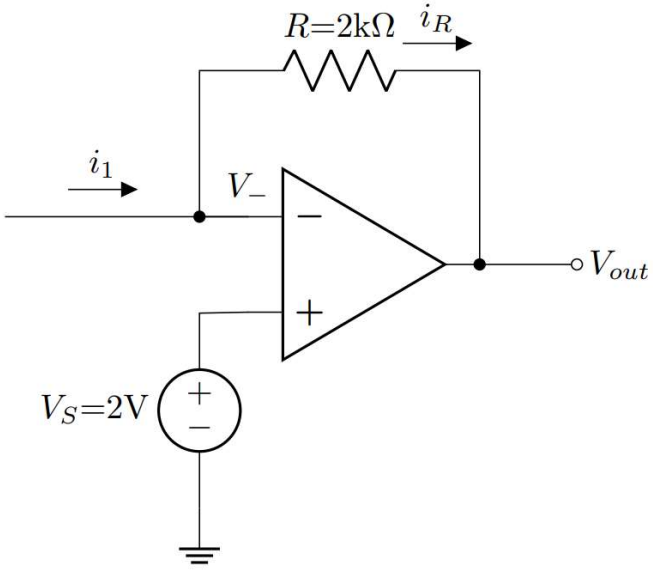
a) (20 pts) **Current-to-Voltage Converter:** Consider the circuit shown in the figure below (assume that the op amp is supplied by ±9V).



For parts ***a)***, ***b)***, and ***c)*** below, assume that i_1 = 1 mA and find:

a) (2 pts) the current i_R

b) (2 pts) V_-, the voltage at the "–" input terminal of the op amp

c) (4 pts) the voltage V_{out}

For parts ***d)*** and ***e)*** below, assume that $i_1 = -1$ mA, and find:

d) (4 pts) the current i_R

e) (4 pts) the voltage V_{out}

For part ***f)*** below find

f) (4 pts) the value of i_1 that would result in $V_{out} = -9$ V

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Problem 1 Solution:

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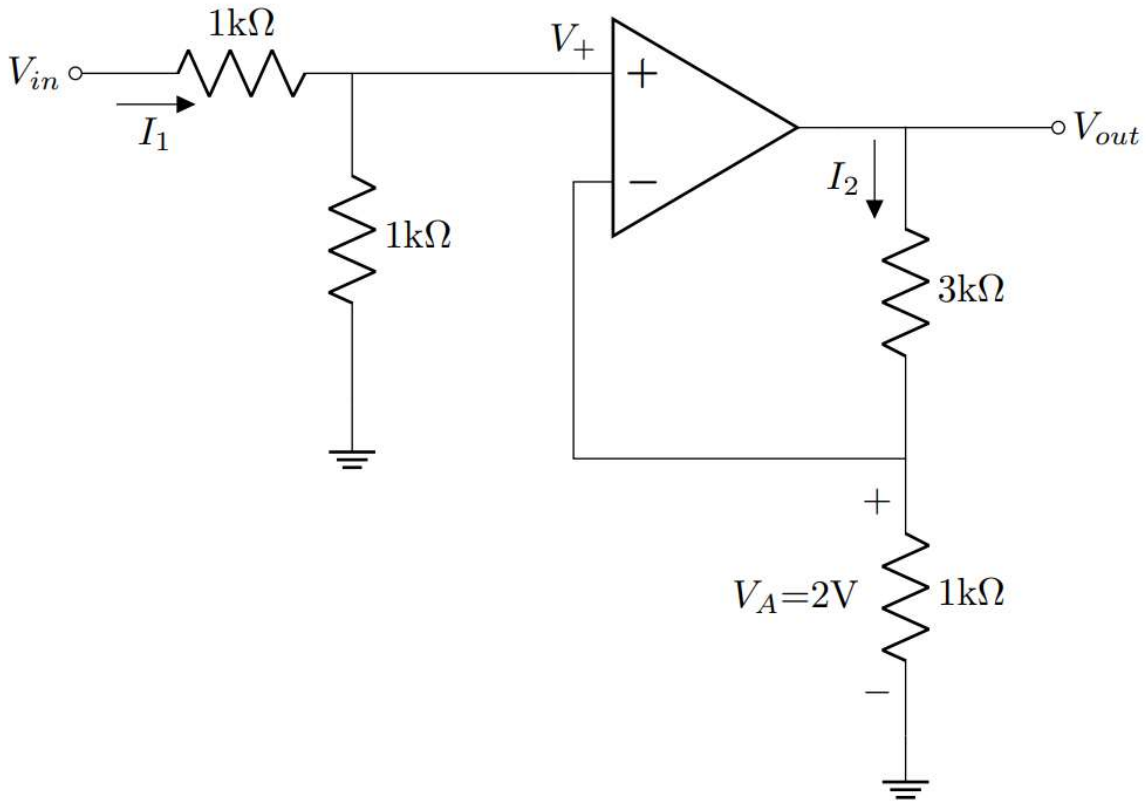
2. (20 points) **Op Amp:** Consider this circuit below. Assume that the op amp is supplied by ±9V. Note that $V_A = 2$ V is labelled across one of the resistors.



Please calculate

a) (4 pts) the current I_2

b) (4 pts) the voltage V_{out}

c) (4 pts) the voltage V_+

d) (4 pts) the current I_1

e) (4 pts) the voltage V_{in}

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Problem 2 Solution:

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(Blank page for extra work if needed – please do not write solutions here)

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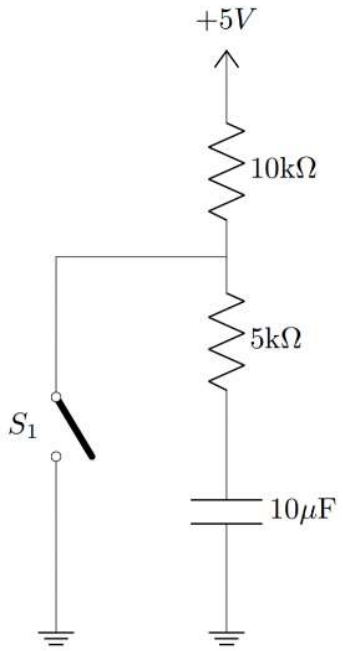
3. (20 pts) **Quiz Questions:** For the following 5 problems, please make only one choice for each problem.

a) (4 pts) The gain of an amplifier is +40 dB. If an input signal has a peak-to-peak voltage of 1 mV, what is the peak-to-peak voltage of the output signal going to be?

- ❑ 10 mV
- ❑ 40 mV
- ❑ 100 mV
- ❑ 400 mV

b) (4 pts) In this circuit, S_1 has been open for a very long time. Approximately how long will it take the capacitor to fully *discharge* when S_1 closes?



- ❑ 167 ms
- ❑ 250 ms
- ❑ 750 ms

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Problem 3 Extra space for work (if needed)

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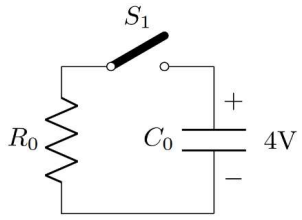
c) (4 pts) A capacitor with capacitance C_0 is charged to 4V in the diagram below. After S_1 is closed, the capacitor is allowed to discharge completely. What is the energy dissipated by R_0 during the discharge of the capacitor?



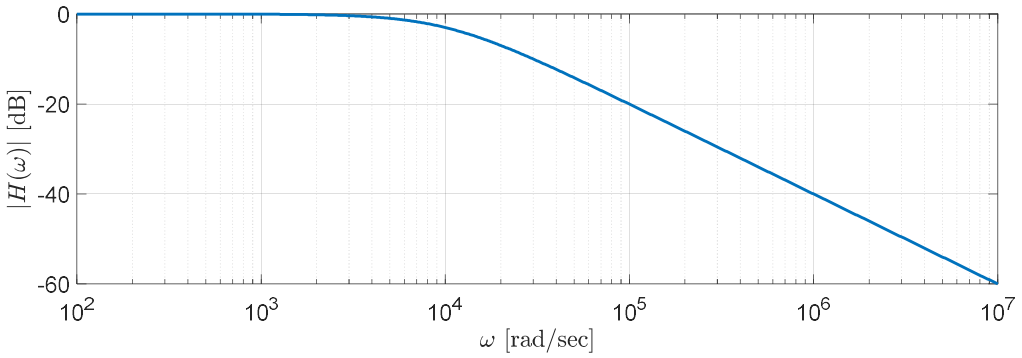
- ❑ $16C_0$ (J)
- ❑ $8C_0$ (J)
- ❑ $4C_0$ (J)

d) (4 pts) The signal $v_{in}(t)$ was applied to the input of a first-order *lowpass* filter and the signal $v_{out}(t)$ was measured at the output. What is the filter's cutoff frequency?

$$v_{in}(t) = 5\cos(10^5 t)\ \text{(V)}$$
$$v_{out}(t) = 0.005\cos\left(10^5 t - \frac{\pi}{2}\right)\ \text{(V)}$$

- ❑ $\omega_c = 10^2$ rad/sec
- ❑ $\omega_c = 10^3$ rad/sec
- ❑ $\omega_c = 10^4$ rad/sec

e) (4 pts) The magnitude of the frequency response of a lowpass filter is plotted below. What is this filter's cutoff frequency?



- ❑ $\omega_c = 10^3$ rad/sec
- ❑ $\omega_c = 10^4$ rad/sec
- ❑ $\omega_c = 10^5$ rad/sec

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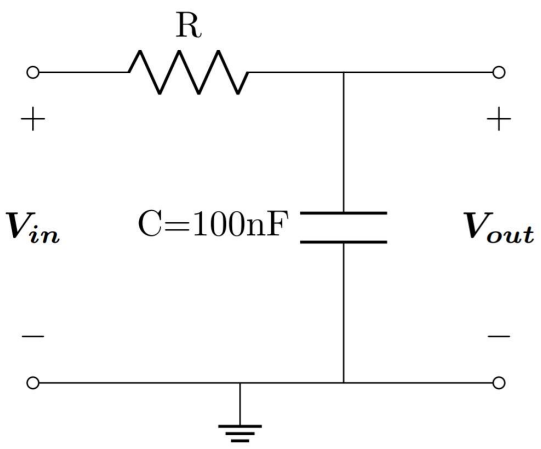
4. (20 pts) **Filter:** Your small group TA gives you the lowpass RC filter pictured below, and you use Scopy to measure a cutoff frequency of $\omega_c = 10^4$ radians/second.



a) (4 pts) If C = 100 nF, what is the value of the resistor R in this filter?

b) (4 pts) What is the complex impedance of the capacitor (i.e., what is Z_c) at the cutoff frequency of $\omega_c = 10^4$ radians/second?

If an input voltage to this filter has the following form:

$$v_{in}(t) = 4\cos(10^3 t) + 4\cos(2 \times 10^6 t) \text{ (V)}$$

Then the output voltage has the following form:

$$v_{out}(t) = A_1\cos(10^3 t + \phi_1) + A_2\cos(2 \times 10^6 t + \phi_2) \text{ (V)}$$

c) (4 pts) Determine the amplitude A_1 and show your work.

d) (4 pts) Determine the amplitude A_2 and show your work.

e) (4 pts) How would you change the value of *R* in the filter to reduce (attenuate) A_2 by an additional -20 dB? What would A_1 be if *R* is changed to this value?

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Problem 4 Solution

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5. (20 points) The circuit below shows a square-wave source voltage connected in series with a resistor and an inductor. The square-wave source voltage, also plotted below, has a period of 10ms and an amplitude of 5V, i.e. at t=0, voltage changes instantaneously from 0V to 5V and at t=5ms, voltage changes instantaneously from 5V back to 0V, so on and so forth. The source voltage is zero for all $t < 0$.

a) (4 pts) What is the inductor current I_L, as labeled in the figure, at $t=0^+$, right after the source voltage changes from 0V to 5V? What is the voltage V_A at the same instance?

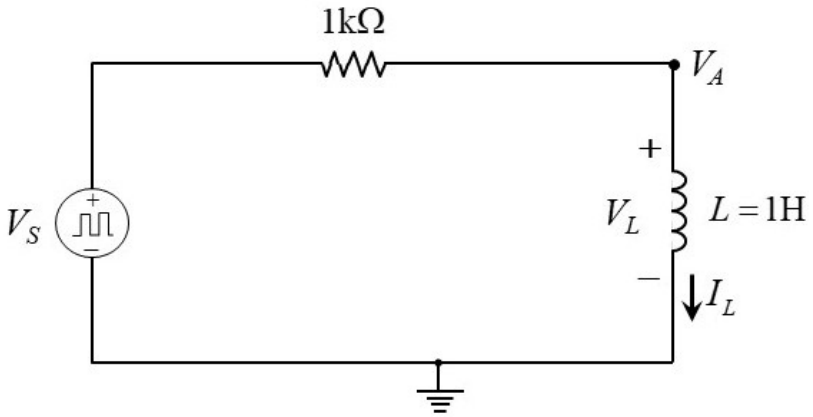
b) (4 pts) Calculate the inductor current, I_L, and the voltage V_A, both at t =1 ms.

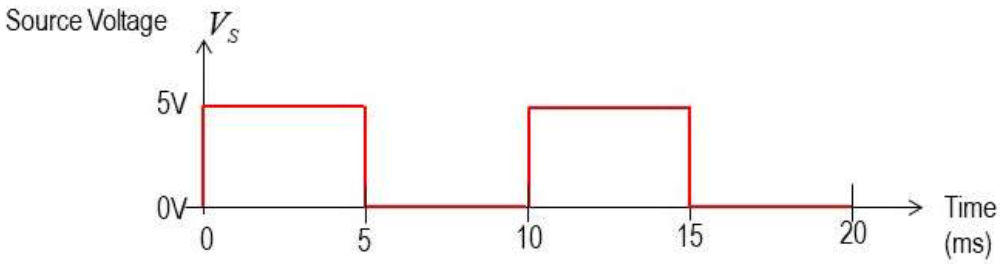
c) (4 pts) What is the inductor current I_L, at $t=5^+$ ms, right after the source voltage changes from 5V to 0V? What is the voltage V_A at the same instance?

d) (4 pts) Calculate the inductor current, I_L, and the voltage V_A, both at t=6 ms.

e) (4 pts) Using the axes drawn on the last page of this test, sketch the current I_L and voltage V_A as function of time from t=0 to t=20 ms.

(Note: V_A is measured with respect to ground and is also the voltage across the inductor, V_L, as labeled in the figure below. Also note: 1ms = 10^{-3} second).





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Problem 5 Solution

(Continue on Next Page)

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