**MASSACHUSETTS INSTITUTE OF TECHNOLOGY**

**DEPARTMENT OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE**

# QUIZ 2 - 6.2000 Electrical Circuit

**Nov 9, 2022**

**Total Points: 100** **Time Limit: 120 minutes**

YOUR NAME______________________________________________________________

Lab Section: 9am 11 am 1 pm 3 pm

General Instructions:

1. Please do all of your work in the spaces provided in this examination booklet. If you need additional sheets, be sure to put your name and the name of the examination on each sheet. Place your answer for each question in the space provided on this booklet.

2. Use the space immediately following each question to show your work and the answer to the question.

3. All sketches must be adequately labeled

4. You will be graded on both your solution (that is, the work shown) and your final answer. It is possible to get the right answer, but not receive full credit if your reasoning is unclear.

5. Indicate units on all numerical answers.

6. The exam is closed books but calculators and a two-sided sheet of notes and formulas are allowed.

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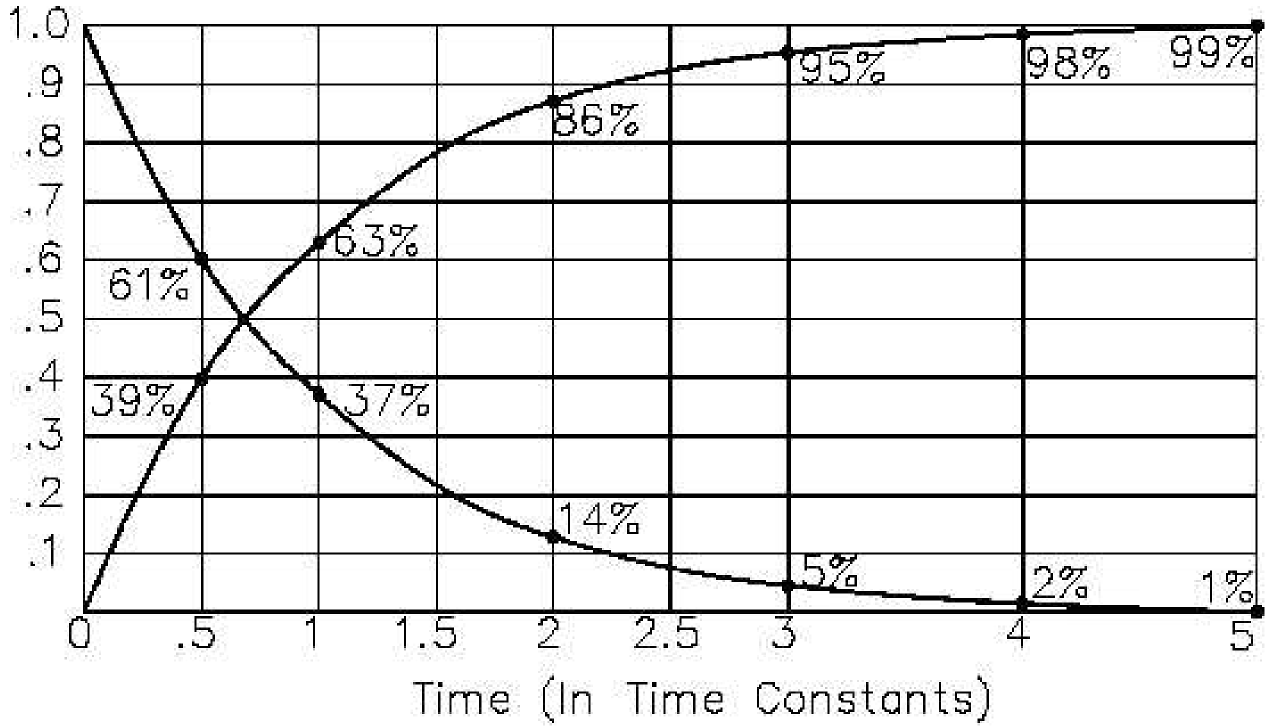
**Grade:** **Problem 1: ( /35)**

**Problem 2: ( /15)**

**Problem 3: ( /20)**

**Problem 4: ( /30)**

The following graph on the functions of $y(t)= e^{-t}$ and $y(t)=1-e^{-t}$ may be helpful for solving some problems in this quiz.



**Problem 1.** [35 pts]
For the circuits below, please find expressions for the specified voltage or current over the indicated time ranges in terms of the circuit parameters. Plot the waveform on the provided axes, and clearly identify the key parameters in your graph.

(A) [17pts] Consider the circuit of Fig. 1. The switch is closed for $t < 0$, open for $0 \leq t < t_1$, and closed for $t \geq t_1$, where $t_1 = 3L/R$. Find and plot the current $i_L(t)$.

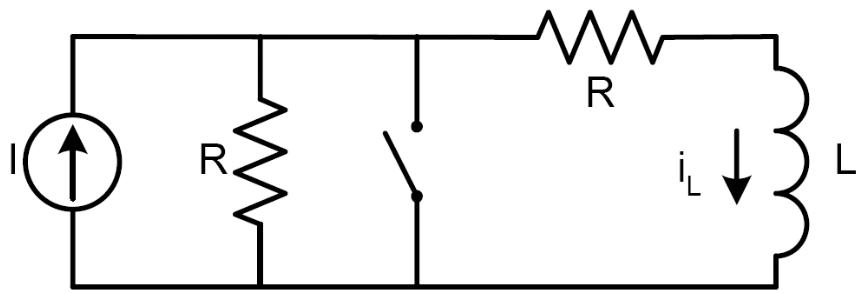


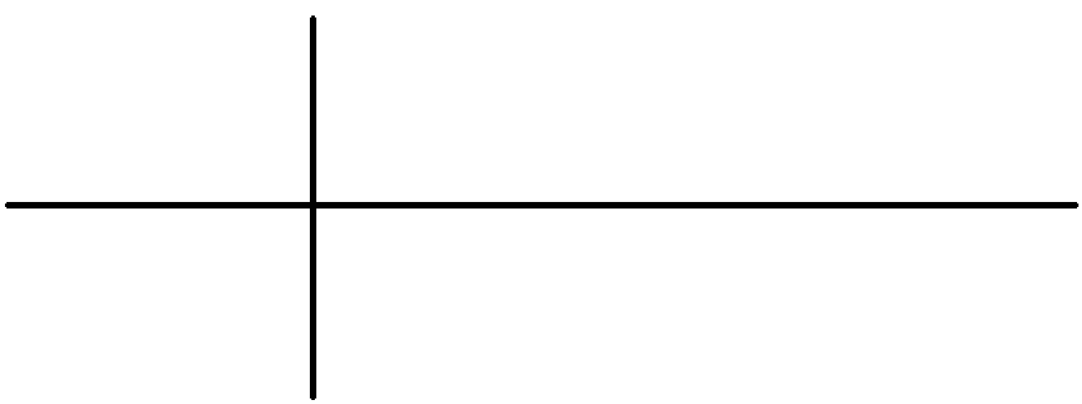

**Figure 1**

$i_L(t)$, $t < 0$ =

$i_L(t)$, $0 \leq t < t_1$ =

$i_L(t)$, $t \geq t_1$ =

Plot $i_L(t)$ over all time, indicating important waveform parameters.



(B) [18 pts] Consider the circuit of Figure 2, in which $\alpha > 0$. The switch is open for $t < 0$, and closed for $t \geq 0$. $v_C(0^-) = V_0$. Find and plot the voltage $v_1(t)$.

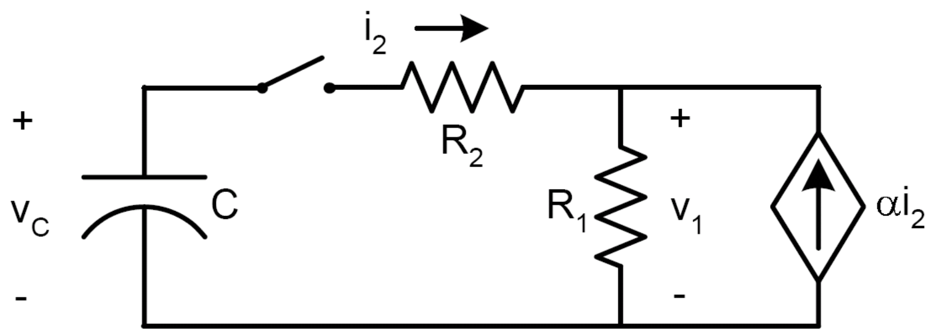
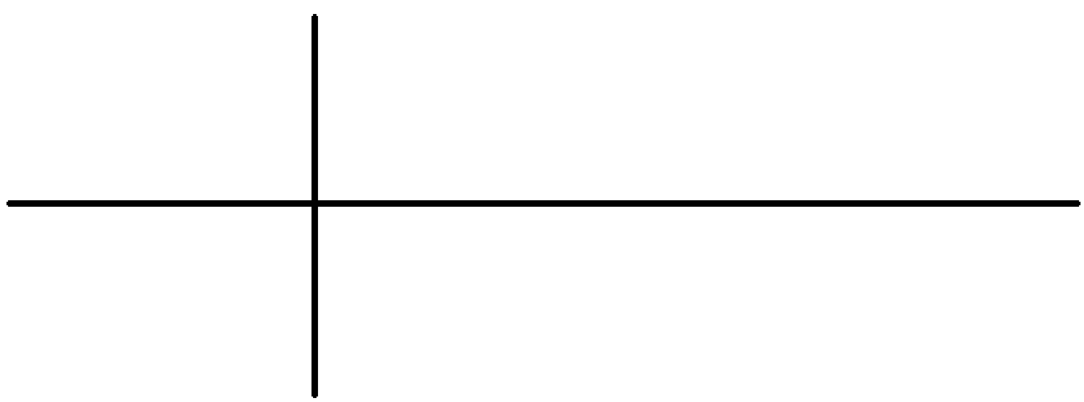



**Figure 2**

$v_1(t)$, $t < 0$ =

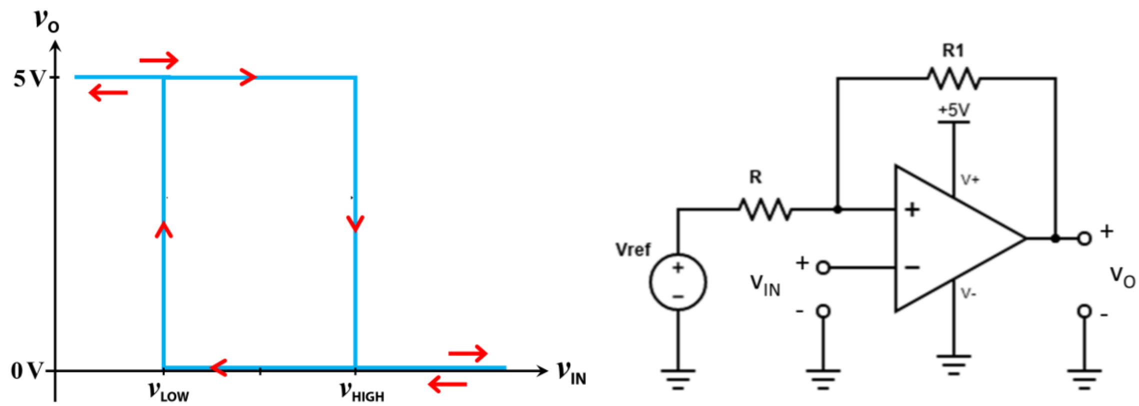
$v_1(t)$, $t \geq 0$ =

Plot $v_1(t)$ over all time, indicating important waveform parameters.



**Problem 2** [15 pts] Comparator

In this problem, you are going to work on a comparator circuit which has the input-output relationship as shown in the left figure below, where the switching voltages are $v_{LOW}$ = 1.5 V and $v_{HIGH}$ = 2.5 V. A possible comparator design for realizing this is given in the right figure below. Note that the supply voltages on the op-amp are 0 and 5V, and that $v_{LOW}$ and $v_{HIGH}$ are not centered around the mid point between 0 and 5 V. R is chosen to be 10 kΩ.



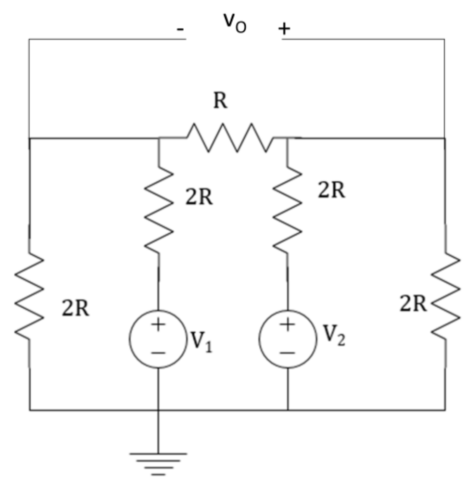

Determine the numerical values of $R_1$ and $V_{ref}$ needed for reaching the desired $v_{IN} \sim v_O$ relationship.

$R_1$ =

$V_{ref}$ =

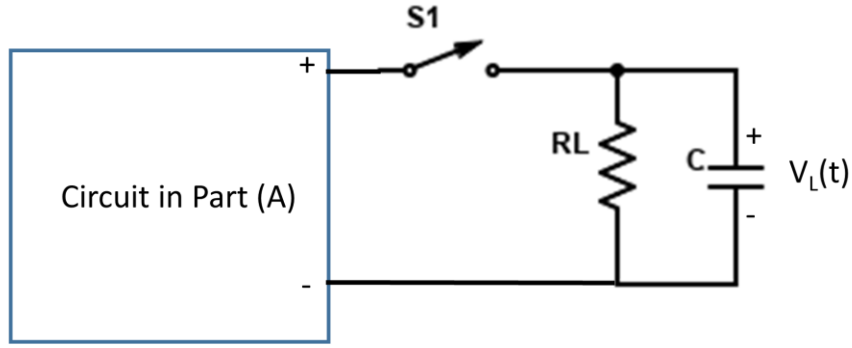
**Problem 3** [20 pts]

(A) [8pts] The schematic below shows a similar circuit as the one used in our Lab 2 for converting digital signal to analog signal, except with a different output port location. Express $v_O$ as a function of $V_1$ and $V_2$.




| |
|---|
| $v_o$ = |

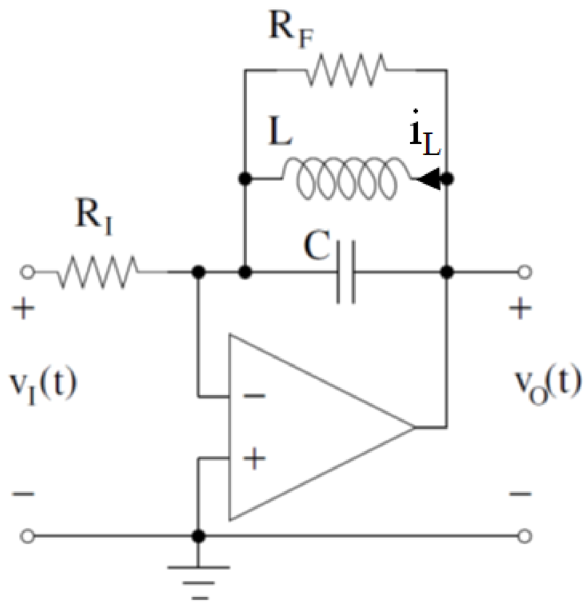
(B) [12pts] The circuit in part (A) is used to drive a load that is a parallel combination of resistance $R_L$ and capacitance C. The switch S1 remains open for a long time before t = 0 so that the circuit is in a stable state. At t = 0, S1 closes. For t > 0, express the load voltage $v_L(t)$.



$v_L(t) =$

**Problem 4.** [30 pts]

The inverting amplifier shown in the figure below has a parallel combination of a resistor, a capacitor, and an inductor in its negative feedback path. You may assume that the op amp is ideal.




(A) [10pts] In the box provided below write a differential equation relating the inductor current $i_L(t)$ to the input voltage $v_I(t)$.

(B) [8pts] Assume that $R_F = \frac{1}{10}\ \Omega$ , $R_I = \frac{1}{8}\ \Omega$, C = 1 F, and L = $\frac{1}{9}$ H.
Is this system
1. overdamped?
2. critically damped?
3. underdamped?

Circle your answer and provide an explanation of your choice in the space provided below.

(C) [12pts] Use the device parameters specified in part B. Assume that both the inductor current and the capacitor voltage are zero at time $t = 0$. At time $t = 0$ a step of height $V_I$ appears at the input: $v_I(t) = u(t)V_I$ . In the box provided below write an expression for the value of the output voltage for all $t > 0$.

Hint: Compute the inductor current first and then derive the output voltage from your inductor current expression.

| |
|---|
| $v_O(t) =$ |

**(Additional Work)**