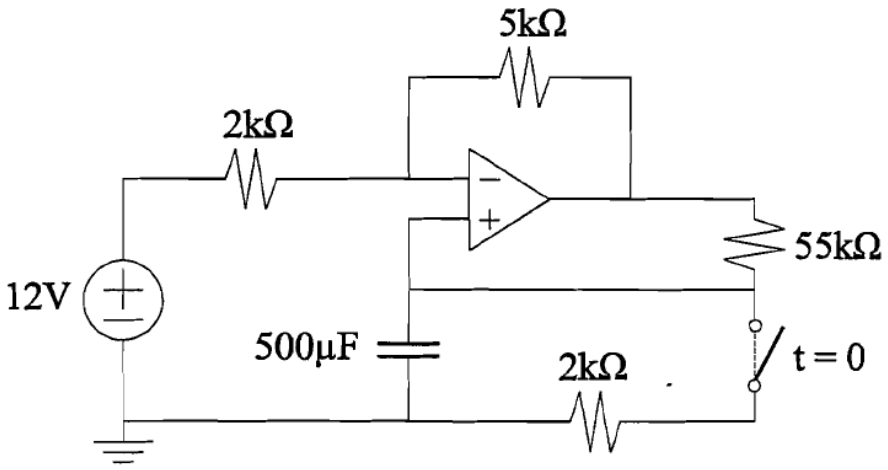
**ECSE 200: Fundamentals of Electrical Engineering**

# Assignment 6

**Winter 2006**

## Question 1

Assume the ideal op-amp circuit below is stable, and answer the following questions:
(The switch is open for all $t < 0$, then closes at $t = 0$, and remains closed for all $t > 0$.)

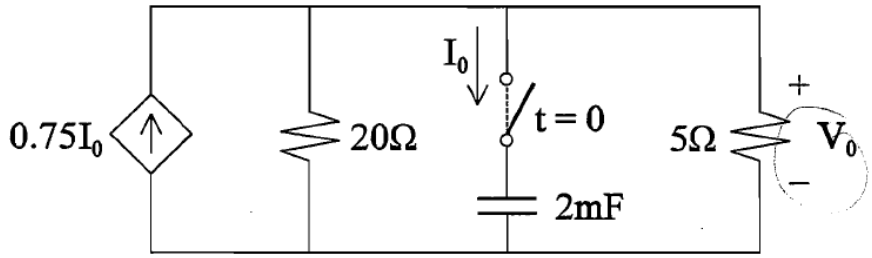



(a) Find the net charge stored on the upper plate of the capacitor at time $t = 0^-$.

(b) Find the exponential time constant of the circuit for time $t > 0$.

## Question 2

Consider the circuit shown below, with $V_0(t = 0) = 5V$, and answer the questions listed:
(The switch is open for all $t < 0$, then closes at $t = 0$, and remains closed for all $t > 0$.)

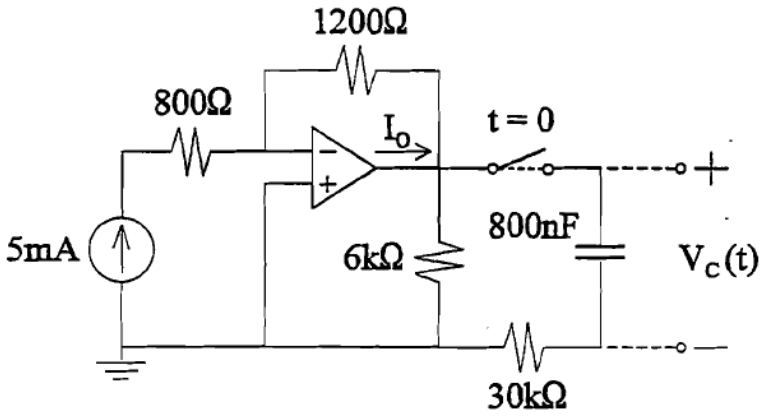



(a) Find the voltage labeled $V_0$, as a function of time t, for all time $t > 0$.

(b) Find the power absorbed by the controlled source for all time $t > 0$.

## Question 3

Consider the ideal op-amp circuit provided below and answer the following questions:
(The switch is open for all $t < 0$, then closes at $t = 0$, and remains closed for all $t > 0$.)




(a) Determine the capacitor voltage labeled $V_c(t)$ for all time $t > 0$.

(b) Determine the power supplied by the current source for all time $t > 0$.

(c) Does the op-amp output current labeled $I_o$ vary with time for $t > 0$?
(Briefly, but clearly, explain your reasoning for why or why not.)

## Question 4

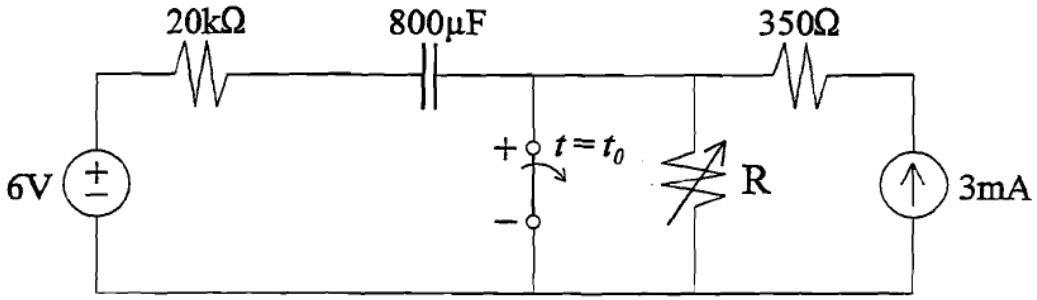
Assume that you must assemble and test the circuit illustrated below in the lab. Consider each element as ideal, and answer the following if the capacitor is initially uncharged:

(a) Find the minimum amount of time (minutes/seconds) that would be required for the capacitor to reach *dc* steady state operation after building and activating the circuit, if the switch remains closed for all time $t$.

(b) Find the voltage across the open-circuited switch for all time $t > t_0$, if R = 5kΩ. Assume that the circuit is operating in *dc* steady state just prior to time $t = t_0$.

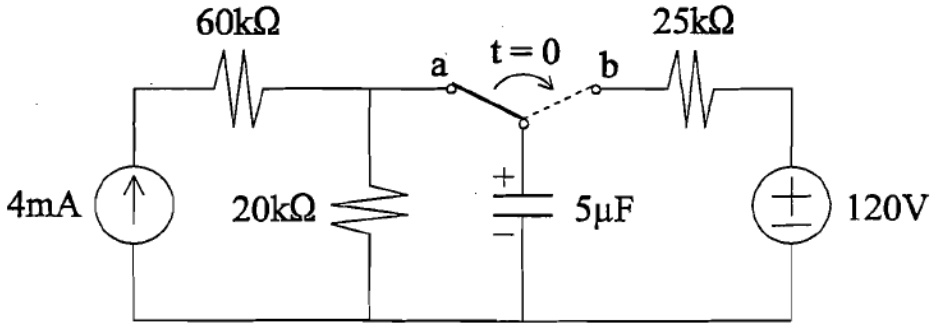
(c) Find the value of R which minimizes the energy stored by the capacitor as $t \to \infty$.

(d) Find the value of R which maximizes the energy stored by the capacitor as $t \to \infty$.




## Question 5

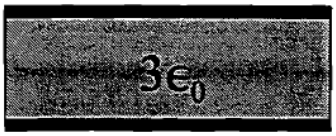
Consider the switched RC circuit provided below. The switch has been at position "a" for 2s prior to moving to position "b" at time t = 0. Assume that the switch stays at "b" for all time t > 0. Show that the circuit is effectively in DC steady-state at time $t = 0^-$. Find the voltage across the capacitor for all time t > 0. Also, calculate the values of the minimum and the maximum charge on the capacitor over all time t > 0.



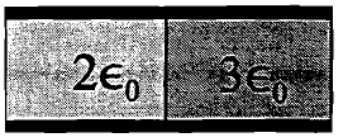
## Question 6

The four parallel-plate capacitors illustrated below are identical except for the dielectric insulators between their plates. The $2\epsilon_0$ material has a breakdown strength of 3kV/mm and the $3\epsilon_0$ material is rated at only 2kV/mm.

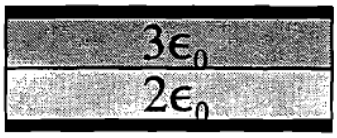
(a)



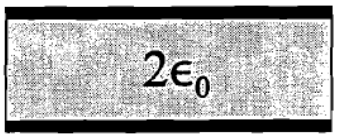

(b)




(c)




(d)




(a) Determine the relative ordering of the capacitance values for the four devices. (Mark an "X" in <u>one</u> of the boxes provided below to indicate your answer.)

- ☐ C(a) < C(c) < C(b) < C(d)
- ☐ C(a) < C(b) < C(c) < C(d)
- ☐ C(d) < C(c) < C(b) < C(a)
- ☐ C(d) < C(b) < C(c) < C(a)
- ☐ C(b) < C(d) < C(a) < C(c)
- ☐ C(b) < C(a) < C(d) < C(c)
- ☐ C(c) < C(d) < C(a) < C(b)
- ☐ C(c) < C(a) < C(d) < C(b)

(b) Assume that all four capacitors can be charged to at least 6V without breakdown. Determine which capacitor would be charged from 0V to 4V in the <u>shortest time</u>, if it was connected to a <u>practical</u> 6V source of emf.

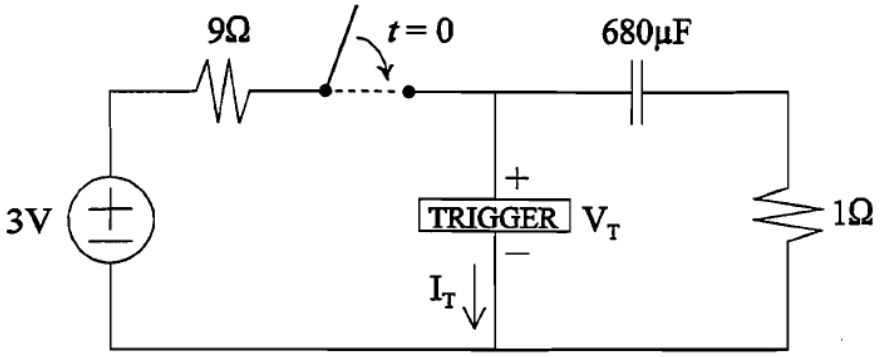
☐ (a) ☐ (b) ☐ (c) ☐ (d) ☐ All four charge in the <u>same</u> time.

(c) Determine which capacitor has the <u>lowest</u> maximum charge storage capacity.

☐ (a) ☐ (b) ☐ (c) ☐ (d) ☐ All four have the <u>same</u> capacity.

## Question 7

Consider the switched *RC* circuit shown below. This system represents a simple strobe light designed to flash on and off repeatedly, after it is activated by closing the switch at time $t = 0$. The electronic flash bulb is modeled by the 1Ω resistor, and the "TRIGGER" mechanism operates like a binary switch: it acts like an *open-circuit* when it is OFF, and a *short-circuit* when it is ON. The trigger can *only* be turned ON by raising the voltage across its terminals to 2V; once ON, the trigger can *only* be turned OFF by reducing the current through the device to 0.4A. The electronic bulb will provide uninterrupted light as long as it absorbs 160mW or more, but at lower power levels no light is generated.



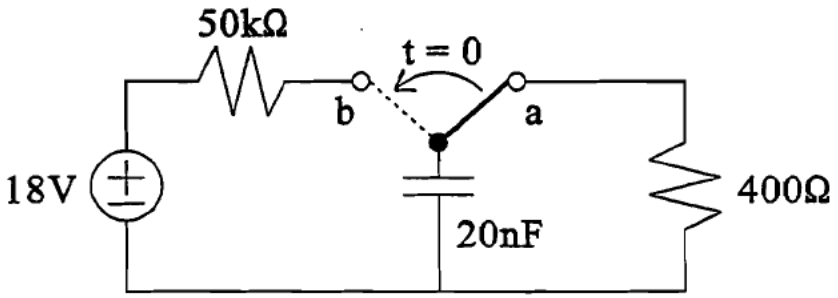

At $t = 0^-$, the capacitor is uncharged, the trigger is OFF and the circuit is in steady-state.

a) Explain how the trigger operates in this circuit based on the charge on the capacitor: specifically, describe how the energy flows through the circuit for the initial charge, discharge and then recharge operations of the capacitor following the switch closure.

b) Calculate the maximum power and total electric energy absorbed by the bulb during the period of the first light pulse emitted by the bulb, i.e., while the bulb is illuminated.

## Question 8

Consider the circuit illustrated below. The switch has been in position *"a"* for 1.5s prior to moving to *"b"* at time $t = 0$. Calculate the maximum value of the charge stored by the capacitor over all time $t > 0$. Also, starting at $t = 0$, how much time does it take for the capacitor to reach 99% of this maximum value.




## Question 9

Consider the circuit given below. Assume that the switch has been in position *"a"* for a long time prior to moving to position *"b"* at $t = 0$.

(a) Calculate the value of the voltage labelled $V_1$ at time $t = 0^-$.

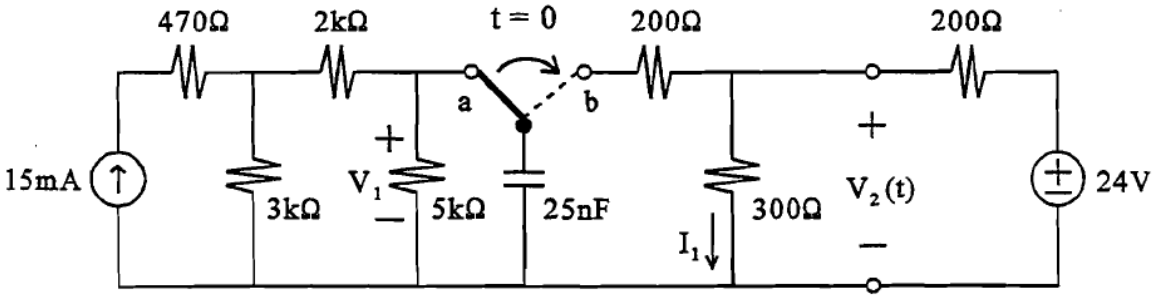
For the following parts of this problem, assume that $V_1 = 4.8$ volts at time $t = 0^-$ (instead of whatever value you calculated for part (a) above).

(b) Calculate the value of the current labelled $I_1$ at time $t = 0^+$.

(c) Calculate the steady-state ($t \to \infty$) value of the current labelled $I_1$.

(d) Calculate the value of the time constant for the $t > 0$ circuit.

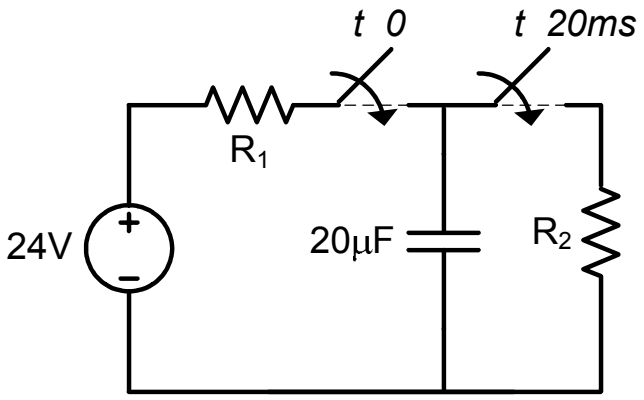
(e) Find the voltage labelled $V_2(t)$ for all time $t > 0$.



## Question 10

Consider the switched RC circuit illustrated below. Assume the capacitor is uncharged at time $t = 0$. Find the value of Resistor $R_1$ that causes the circuit to charge the capacitor to exactly 320μC at time $t = 20$ms. Then, find the value of the resistor $R_2$ that will force the capacitor to remain charged at that same value for all time $t > 20$ms.

Hint: Take some time to understand how this circuit works before starting to answer




## Question 11

Consider the switched RC circuit below. Assume the capacitor is ideal, and electrolytic with the polarity indicated. Find the power supplied by the source, as a function of time, for all time t > 0, if the capacitor charge is set to an initial stored energy of 32J at t = 0. Note: The switch closes at time t = 0, and then remains closed for all time t > 0.