Physics 11 Laboratory #3
Discharging a Capacitor

Introduction

In your text it is shown that the charging and discharging curves for a resistively loaded capacitor are exponential curves. That is, if a capacitor C is discharged through a resistor R, as shown in Figure 1, the time dependence of the potential difference across the capacitor V_C is given by

$$V_C(t) = V_o e^{-t/RC} \qquad (1)$$

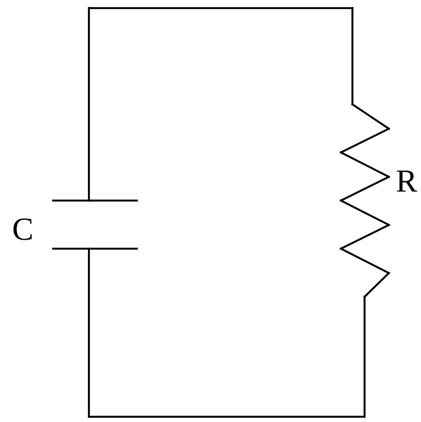

Figure 1

where V_o is the initial (t = 0) potential difference across the capacitor and t is the time. The denominator in the exponent RC, is called the **capacitive time constant** of the circuit and is represented by the symbol, τ.

Part 1: Time dependence of the potential difference across the capacitor

Connect the DC power supply, variable resistor decade box (set to ~ 10 kΩ), capacitor (large blue cylinder, 10,000, uF at 50 volts), three position switch, and digital multimeter (DMM) as shown in Figure 2. **Be sure to observe the polarity of the capacitor and do not set R to zero.** Observe the discharging of the capacitor (throw the switch to the left [to charge] and then to the right [to discharge]). Next, make a careful measurement of the time dependence of the potential difference across the capacitor $V_C(t)$, as it discharges. Plot "V_C vs t". Find a way to plot the data so that (according to theory) the curve should be linear. Interpret the slope and the intercept. Do the plot.

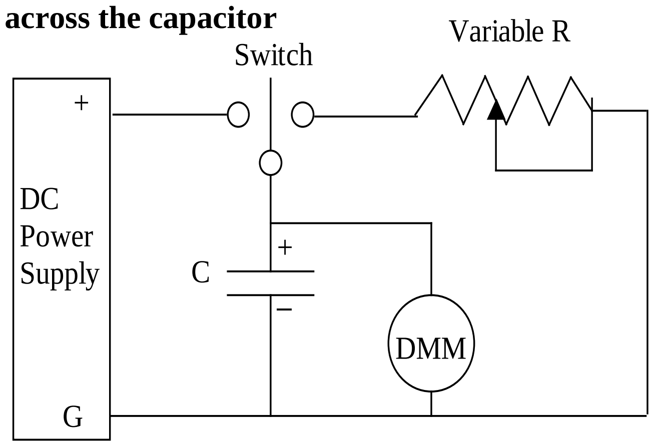

Figure 2

Part 2: How does the capacitive time constant depend on R? (qualitative)

Set the decade resistance box to 5 kΩ and note the change in the time constant; repeat for 2.5 kΩ. You should be able to make these observations <u>without</u> taking numerical data. How? Are these qualitative results consistent with your expectations? Explain

Part 3: How does the capacitive time constant depend on R and C? (quantitative)

This part of the experiment will be performed by two groups working together.

a. Place two capacitors in series and then connect the combination in series with the decade resistor box which is set at 10kΩ. Measure the time constant by measuring the voltage across the two capacitors in series. You need not draw a curve as you did in part 1. A single measurement should be sufficient! Change the R to 5 kΩ and repeat. Explain the results. For each case, what would you expect the results to be based on how capacitors add in series?

b. Connect two capacitors in parallel and connect the combination in series with the decade resistor box set at 10 kΩ. Measure the time constant. You need not draw a curve as you did in part 1. A single measurement should be sufficient! Change the R to 5 kΩ and repeat. Explain the results. What would you expect the results to be based on how capacitors add in parallel.

Familiarity with the ideas involved in working out the following exercises will aid you in doing and understanding this experiment.

Questions to address:

1. If the time dependence of the potential difference across the capacitor is given by Equation (1), show that the natural logarithm of the potential difference is linear in time (Hint: take the natural logarithm of both sides of Eq. 1)

2. Verify that the product RC has the units of time.

3. Suppose that the time required for the potential difference across the capacitor to drop to half of its original value is known. How would you extract the capacitive time constant, τ = RC, from this value?

   (Hint: set $V_C = \frac{V_o}{2}$ in Eq.1, then proceed as in question 1.)

4. Can you think of any other physical situations that are characterized by exponential decay or exponential increase?