Capacitors

What relationship exists between the charge Q on a capacitor plate and the charging voltage and size of the capacitor? The goal of this experiment is to determine the generic relationship charge and capacitor size.

A basic capacitor circuit is shown below. The resistor has no net effect on the circuit but just protects the capacitor.

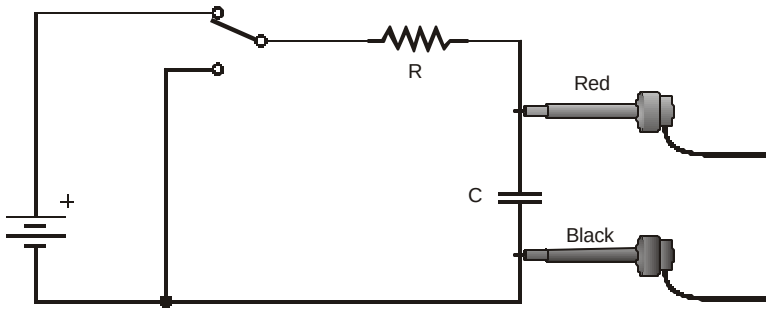

Figure 1

It is impossible to directly measure the charge flowing in and out of a capacitor. (think about it….electrons are very small) However, the time it takes the capacitor to charge is an indirect measurement of the charge being moved into or out of the capacitor. (Therefore, we will assume that more times means more charge; twice as much time will be the equivalent as twice as much charge)

In this experiment, you will analyze the time it takes for the capacitor to reach maximum voltage as a function of capacitor size and charging voltage. From the graphs of this data, you should be able to determine what type of relationships exists.

Preliminary Questions

1. Consider a candy jar, **initially empty**. You are going to fill the jar with 1000 pieces of candy. You walk past it once each hour. The first hour, you add 100 pieces. Every hour after that you add 10% less than you did the hour before. Sketch a graph of the number of candies for a few hours. Do you ever completely move all 1000 pieces of candy?

2. Imagine now that the jar was full and you were removing them. Sketch a graph that shows the number of candies in the jar if you first removed 100 candies and then subsequently removed 10% less each hour.

3. How would the graph in number 2 change if instead of removing 10% of the candies, you removed 20%? Sketch your new graph.

PROCEDURE

1. Open up the applet at http://www.phy.ntnu.edu.tw/java/rc/rc.html

   Some key points:

   - Leave the resistor at 100 KΩ

- Set the capacitor to 50 μF
- Set the voltage to 10 V
- You can stop the applet by right clicking in the applet window.
- After right clicking, you can move the mouse along the graph to get readings for V and t.

2. Click on the red "switch" in the program to connect the circuit to the battery. The applet does a nice job of simulating charge flow. You can watch the "yellow" charges. When they stop moving, or are barely moving at all, you can assume that the capacitor is "full".

3. Watch the red line on the graph. This is measuring the voltage (energy) of the capacitor as a function of time. You need to record the time it takes for the capacitor to be 60 %"full". (Full is the equivalent of max. voltage). See notes above for how to get time measurements.

PART A:

4. You are going to use the applet to determine the effect of capacitor size on charge stored. Re-run the applet for different values of capacitors while holding the voltage constant. **You must click on the update button for this change to take effect**. You then have to open and then close the red switch by clicking on it twice to get the simulation to run again. Record the time for each case.

   IMPORTANT HINT: scroll down to the bottom of the page. There is an option where you can manually set the voltage and/or capacitance of the system. This will allow you to collect more data points.

PART B:

5. We would also like to see the effect of battery voltage on the amount of charge stored in the capacitor. We cannot use the applet to make measurements. However, the applet does a wonderful job of showing what occurs. Run the applet at a capacitor level of 100 μF and observe the moving charges. Now, reset the applet and run it at a battery voltage of 5 V. Jot down your observations concerning the number of charges stored.

ANALYSIS (PART A)

1. Using Excel, graph your data.

   - Graph 1: The effect of capacitor size on charge stored (time)

2. What type of relationship do you have? Linear, power, exponential? Use the trend line to determine the best fit. (Should the intercept be zero?)

3. Print out your graph.

4. Based on your graph, propose a reasonable equation that relates charge to capacitance and charge to voltage.

ANALYSIS PART B:

5. What general observations did you notice about battery voltage and the amount of charge stored? Using your knowledge of electric potential, explain why your observation makes sense.

QUESTIONS

1. Why is the graph of voltage in the capacitor vs. time non-linear? (As seen in the applet)

2. Propose a possible graph that would show voltage in a capcitor vs. time for a discharging capacitor. Explain your reasoning.

3. In the applet, for every yellow dot that enters the capacitor, another one is ejected on the other side. Is this a reasonable occurrence? Explain.