Physics 111
Experiment #2
The Discharge of a Capacitor

Introduction
In class we have studied how a capacitor charges and how that same capacitor discharges through a resistor. In this laboratory experiment, we will investigate the discharge of a capacitor through a resistor. In addition we will investigate the how the capacitive time constant depends on the value of the resistance and capacitance. Figure 1 below shows the basic setup of the experiment. A double-pole switch S connects either the capacitor C directly to the power supply to instantaneously charge the capacitor or it connects the resistor R and capacitor C together to investigate the discharge of the capacitor. The resistor R is a variable resistance and can be changed throughout the experiment.

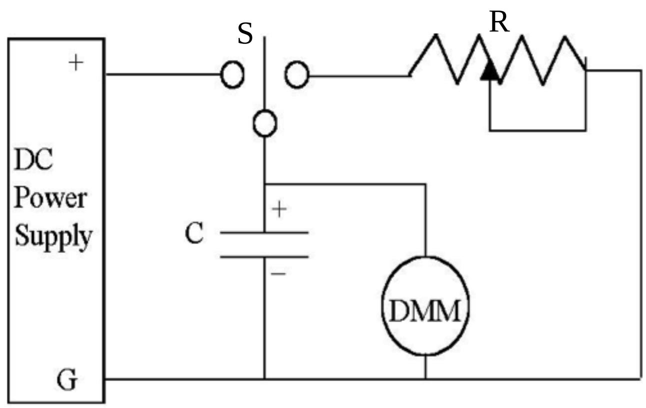

Figure 1: Schematic wiring diagram to study the discharge of a capacitor *C* through a resistor *R*.

Experiment

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

Connect the DC power supply, variable resistor decade box R, a capacitor C, the three-position switch S, and digital multimeter (DMM) as shown in Figure 1. There are two capacitors that we will use in this lab. One is a blue capacitor ($C = 10000\,mF$) and the other is a black capacitor ($C = 15000\,mF$). For this first experiment, choose the blue $C = 10000\,mF$ capacitor. Have your instructor check the circuit before you begin.

Be sure to observe the polarity of the capacitor and do not set R to zero.

To observe the discharge of the capacitor, make a careful measurement of the time dependence of the potential difference across the capacitor $V_C(t)$ as it discharges. To do this set the decade resistance box to $R = 20000W$ and using the DMM in voltmeter mode in parallel across the capacitor, record the potential across the capacitor displayed on the DMM as a function of time. When you're finished, switch the setting on the DMM to the ohmmeter setting and measure the actual resistance that was set. Plot your data on the potential difference across the capacitor as a function of time. You should notice that the plot is not linear. Construct two other plots ($\ln V$ versus t and $\log V$ versus $\log t$) and determine from the plot that linearizes the data, what is the experimental relationship between the potential difference across the capacitor as a function of time. Determine the constant of proportionality and the time constant of the circuit.

Part 2: How does the time constant depend on R for a fixed C?

Using the blue ($C = 10000\,\mu F$) capacitor that you used in part 1, set the decade resistance box to $R = 10000\,\Omega$ and measure the resistance with the DMM. Using the same initial potential difference across the capacitor, calculate the theoretical value of the time constant and then determine the experimental value of the time constant.

Repeat the previous step for resistances $R = 5000\,\Omega$, $R = 2500\,\Omega$ and $R = 1250\,\Omega$. Measure the resistance with the DMM for each value of R. Using the same initial potential difference across the capacitor, calculate the theoretical value of the time constant and then determine the experimental value of the time constant.

From these data, make a *plot of the experimental value of the time constant versus the resistance*. Using the data on the experimental values of the time constant curve fit the data with a power law (why?) and from the curve fit, determine the equation that describes the time constant as a function of the resistance. What is the exponent of the curve fit? Is this as expected? What does the constant of proportionality of the curve represent? How does the constant of proportionality compare to the value of the capacitance stamped on the capacitor? Is this as expected?

Part 3: How does the time constant depend on C for a fixed R?

For this part of the experiment, we'd like to change the value of the capacitance. Unfortunately we do not have a box of capacitors so that we can change the values at will like the decade resistor box from the last part. Here, we will in essence need to come up with a way to say increase and then decrease the capacitance from the two capacitors that we have. In order to this we'll wire the capacitors in series and then in parallel. For two capacitors wired in parallel, the capacitance will increase, while for two capacitors wired in series, the capacitance will decrease.

Set the decade resistance box to a fixed resistance of $R = 5000\,\Omega$ and using the same starting potential difference (from the previous parts) across the capacitor, calculate the theoretical value of the time constant for the black ($C = 15000\,\mu F$) capacitor and then measure the experimental value of the time constant.

Now, wire the black and blue capacitors in parallel and set a fixed resistance of $R = 5000W$. Using the same starting potential difference across the capacitor, determine the experimental value of the time constant by taking data on the discharge of the capacitor as a function of time, as you did in the very first part of the laboratory experiment. Fit the data and determine the time constant for capacitors wired in parallel.

Next, wire the black and blue capacitors in series, and again set a fixed resistance of $R = 5000W$. Using the same starting potential difference across the capacitor, determine the experimental value of the time constant by taking data on the discharge of the capacitor as a function of time, as you did in the very first part of the laboratory experiment. Fit the data and determine the time constant for capacitors wired in parallel.

From these data, make a *plot of the experimental value of the time constant versus the capacitance*, and assume that the effective capacitance for capacitors in series is 6000Ω, while for capacitors in parallel it is 25000Ω. Using the data on the experimental values of the time constant curve fit the data with a power law (why?) and from the curve fit, determine the functional form of the time constant as a function of the capacitance. What is the exponent of the curve fit? Is this as expected? What does the constant of proportionality of the curves represent? How does the constant of proportionality compare to the value of the resistance that you measured? Is it as expected?

Part 4: How does the time constant depend on R and C?

From your results of experiments 2 and 3, what are the equations that describe the time constant as functions of resistance and capacitance? How do these expressions compare the expected form of the time constant? Explain any differences.