

Physics 121 Lab 7: The Time Constant of an RC Circuit

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.

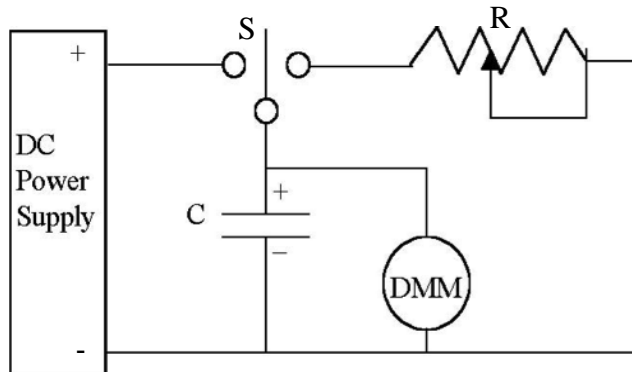


Figure 1: Schematic wiring diagram to study the discharge of a capacitor C through a resistor R .

Experiment

Part 1: Time dependence of the potential difference across the discharging 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 ($C = 10000\text{ mF}$) and the other is a black capacitor ($C = 15000\text{ mF}$). For this first experiment, choose the blue $C = 10000\text{ mF}$ 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 $R = 10000\Omega$ and place a DMM in voltmeter mode in parallel across the capacitor. Record the potential across the capacitor displayed on the DMM as a function of time. Using the DMM on the ohmmeter setting, measure the actual resistance that was set.

Make a *plot of the potential difference across the discharging capacitor as a function of time*.

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

For the blue ($C = 10000\text{ mF}$) capacitor that you used in part 1, now set the decade resistance box to $R = 5000\Omega$ 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 $R = 2500\Omega$ 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*. On the same graph, *plot the theoretical value of the time constant versus the resistance*.

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. In order to do this we'll wire the capacitors you have 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.

Before we wire the two capacitors we have in series and parallel, 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 ($C = 15000\text{ mF}$) capacitor and then determine the experimental value of the time constant.

Now, wire the black and blue capacitors in parallel and set a fixed resistance of $R = 5000\Omega$. Using the same starting potential difference across the capacitor, calculate the theoretical value of the time constant and then determine the experimental value of the time constant.

Next, wire the black and blue capacitors in series, and again set a fixed resistance of $R = 5000\Omega$. Using the same starting 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 capacitance*. On the same graph, *plot the theoretical value of the time constant versus*

the capacitance. 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 do the slopes of each of the curves represent? How do the slopes compare to the value of the resistance that you measured? Are these as expected?

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

From your results of experiments 2 and 3, what is the functional form of the time constant?

Part 5: Time dependence of the potential difference across the charging capacitor

As a last experiment, let us study how a capacitor charges. Wire the circuit shown below in Figure 2, by connecting the DC power supply, variable resistor decade box R, a capacitor C, and digital multimeter (DMM) as shown. For this first experiment, choose the blue $C = 10000\text{ mF}$ 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.

In order to observe the charging cycle of the capacitor make a careful measurement of the time dependence of the potential difference across the capacitor $V_C(t)$ as it charges. To do this set the decade resistance box to $R = 10000\Omega$ and place a DMM in voltmeter mode in parallel across the capacitor. Record the potential across the capacitor displayed on the DMM as a function of time. Using the DMM on the ohmmeter setting, measure the actual resistance that was set.

Make a plot of the potential difference across the charging capacitor as a function of time.

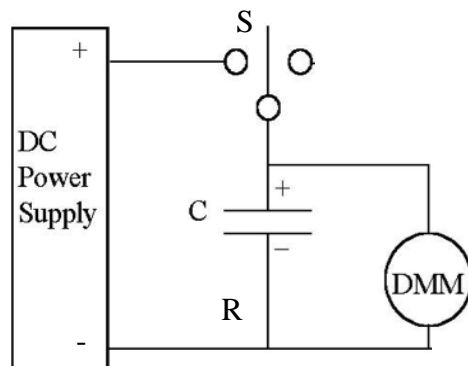


Figure 2: Schematic wiring diagram to study the charging of a capacitor C through a resistor R.