Online Lab: RC Circuits

Name: Date:

Instructor: Section:

Objective:

This experiment involves learning how to Read a Resistor (Part A), Charging a Capacitor through a Resistor (Part B), and Discharging a Capacitor through a Resistor (Part C).

Theory:

Capacitors are circuit devices that can store charge. The capacitance (size) of the capacitor is a measure of how much charge it can hold for a given voltage.

$$Q = CV_C \tag{1}$$

where C is the capacitance in Farads, Q is the charge in Coulombs, and V_C is the voltage across the capacitor in Volts.
To determine how the charge on a capacitor decays in time, use Kirchhoff's Loop Rule for Figure 1 below.

$$V_o = V_C + V_R \tag{2}$$

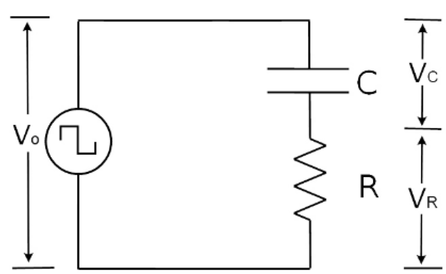


Figure 1: Scope showing the voltage across the capacitor and the output voltage

Solving Equation (1) for the voltage across the capacitor gives

$$V_C = Q/C \tag{3}$$

The voltage across the resistor is given by Ohm's Law:

$$V_R = IR \tag{4}$$

Therefore,

$$V_o = Q/C + IR \tag{5}$$

Since the applied voltage, V_o, is zero when the capacitor is discharging, Equation (5) reduces to

$$Q/C + IR = 0 \tag{6}$$

Since the current is

$$I = \frac{dQ}{dt} \tag{7}$$

Equation (6) becomes the differential equation

$$\frac{dQ}{dt} + \frac{1}{RC}Q = 0 \tag{8}$$

Solving Equation (8) for Q gives

$$Q = Q_{max}e^{-(\frac{t}{RC})} \tag{9}$$

Plugging Q into Equation (2) gives the voltage across the capacitor as a function of time

$$V(t) = V_o e^{-(\frac{t}{RC})} \tag{10}$$

where $V_o = Q_{max}/$C. The rate that voltage across a capacitor (and the charge stored in the capacitor) decreases depends on the resistance and capacitance that are in the circuit. If a capacitor is charged to an initial voltage, V_o, and is allowed to discharge through a resistor, R, the voltage, V, across the capacitor will decrease exponentially.The half-life, $t_{\frac{1}{2}}$ is defined to be the time that it takes for the voltage to decrease by half:

$$V(t_{\frac{1}{2}}) \;=\; V_o/2 \;=\; V_o e^{-(\frac{t_{\frac{1}{2}}}{RC})} \tag{11}$$

Solving for the half-life gives:

$$t_{\frac{1}{2}} \;=\; RC\ ln\ 2 \tag{12}$$

The product RC is called the capacitive time constant and has the units of seconds.

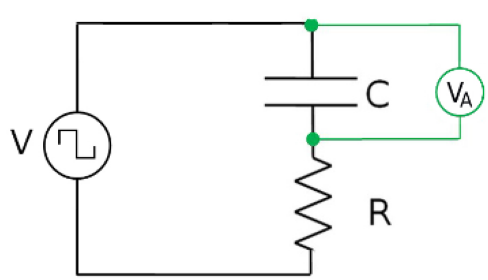
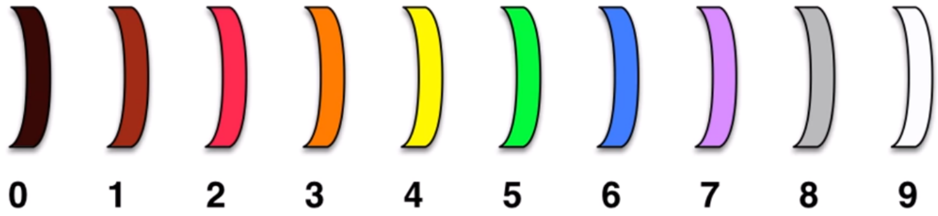


Figure 2: RC Circuit Diagram

Part - A: How to Read a Resistor

1. Each resistor has four different color bands or stripes on it.
2. When reading a Resistor, orientate it so that gold or silver is the last band on the right.
3. Each color is represented by a number.



4. In the example below Brown is 1 and Blue is 6.

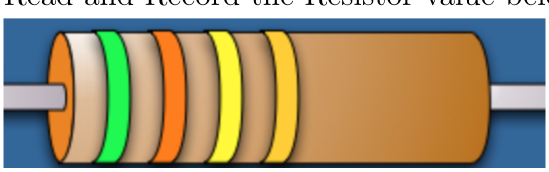
5. The 3rd stripe tells you the number of zeros to add. Orange is 3, so add 3 zero's.
6. That would be a Resistor Value of **$R = 16000\ \Omega$ or $16\ k\Omega$**
7. The 4th gold strip means that the resistor could be off by up to 5%. Ignore this for now.

Questions

1. Read and Record the Resistor value below. $R =$

2. Read and Record the Resistor value below. $R =$

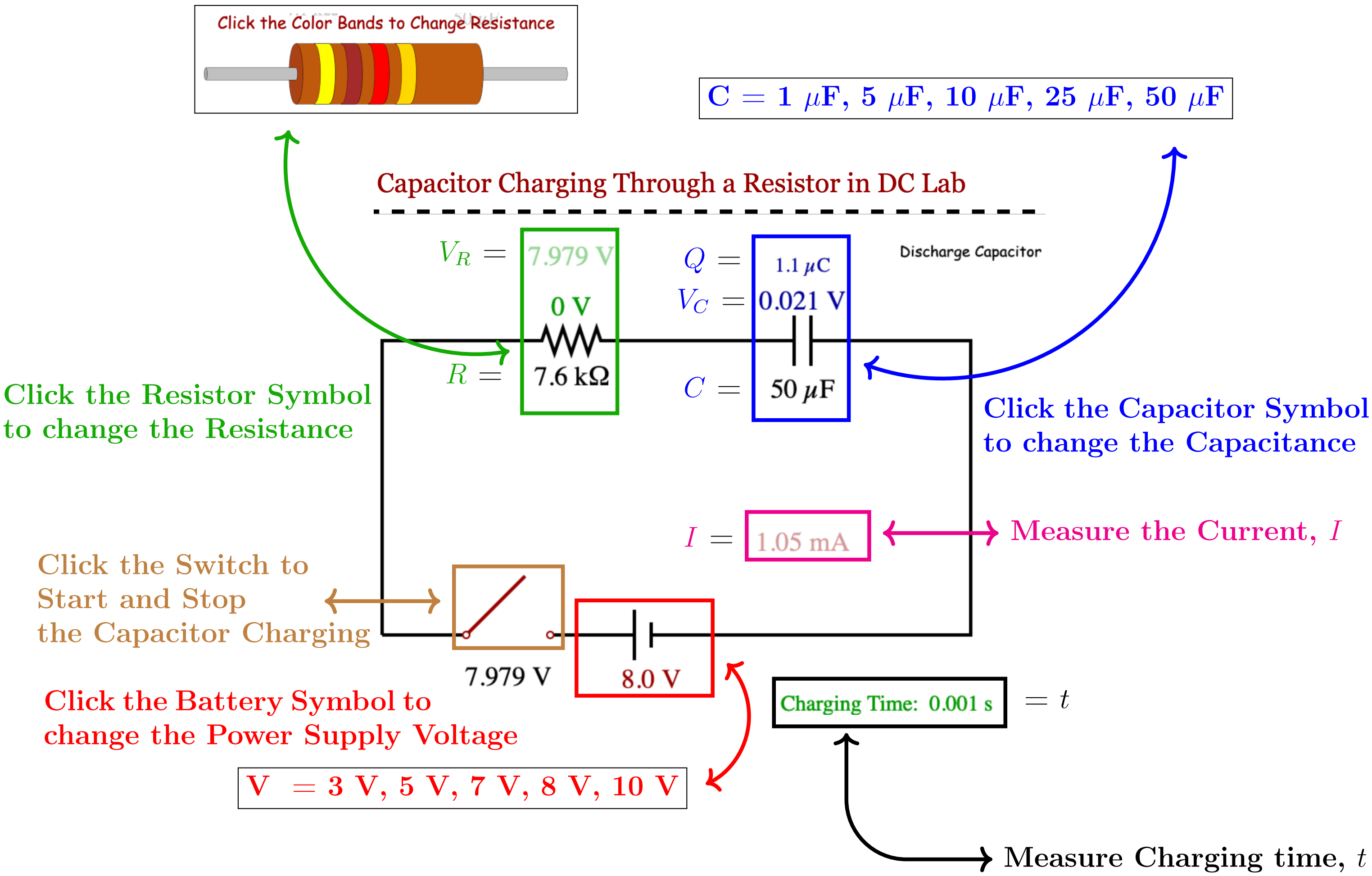
3. Read and Record the Resistor value below. $R =$



Part B - Online Experiment Setup Instructions

1. Part A of today's Online Lab we are going to use one of the physicsaviary.com simulations. Go to the following website:
https://www.thephysicsaviary.com/Physics/Programs/Labs/RCinDCChargingLab/

2. Click **Begin** on the bottom right of the simulation.
The figure below shows what you should see on your screen



Procedure: Charging a Capacitor Through a Resistor

1. Click on the Resistor and Set the first three bands to **Blue - Purple - Brown**. Verify the value of the resister is now 670 Ω.
2. Verify the Capacitor is set to 50 μF and the Battery voltage is set to 8.0 V.
3. Click the Switch and watch the Capacitor begin to Charge. How much time does it take for the Capacitor to reach a full voltage, V_C of 8.0 V?
4. Click **Discharge Capacitor** to reset the simulation.
5. Click the Switch to Start and Stop after ∼ 0.002 seconds. For this part try to pause and record as close as possible to the Target Capacitor Voltage, V_C given in Column 1.
6. Read and Record the measurements for the Voltage across the Capacitor V_C, the Voltage across the Resistor, V_R the Capacitor Charge Q, the Current I and the Charging Time t.
7. Repeat the previous two steps until the Table below is complete.

Table 1: Data Analysis: Charging a Capacitor

Target Voltage V_C **(V)**	**Capacitor Voltage** V_C (V)	**Resistor Voltage** V_R **(V)**	**Capacitor Charge Q (**μ**C)**	**Current I (mA)**	**Charging Time t (s)**
0.5 V					
1.5 V					
2.5 V					
3.5 V					
4.5 V					
5.5 V					
6.5 V					
7.5 V					

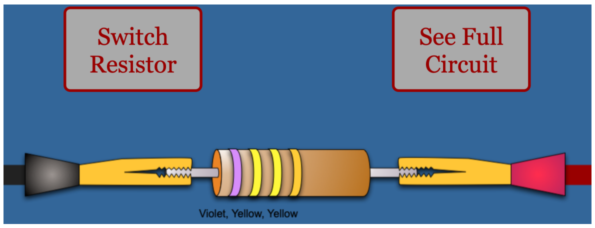
Observation and Analysis:

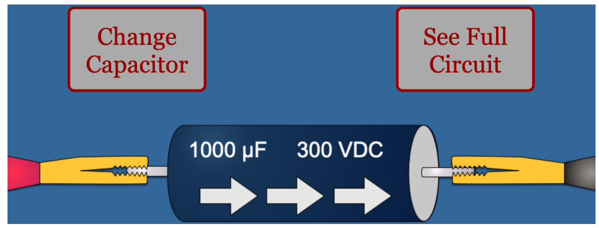
1. For the 4.5 V row of the table, use your results to calculate the Capacitance, $C = \frac{Q}{V_C}$. Record your result here.
2. For the 4.5 V row of the table, use your results to calculate the Resistance, $R = \frac{V_R}{I}$. Record your result here.
3. Do your values to questions 1 and 2 agree?
4. If you add V_R and V_C at any given time, what does it equal?

Part C - Online Experiment Setup Instructions

1. Part B of today's Online Lab we are going to use the physicsaviary.com simulations.
   Go to the following website:
   http://www.thephysicsaviary.com/Physics/Programs/Labs/RCCircuitLab/

2. Click Begin on the bottom right of the simulation.
   The figure below shows what you should see on your screen

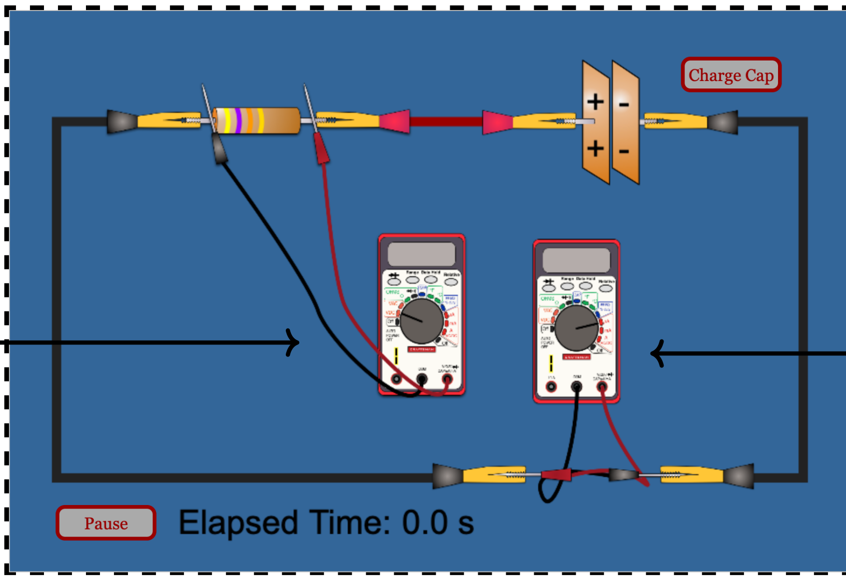


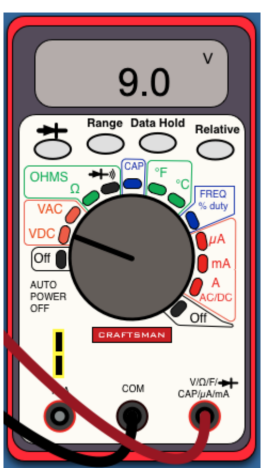


Click the Resistor to change the Resistance value. This brings up the box above. Click Switch Resistor to get another Resistor. When finished, click See Full Circuit to return to the Circuit.

Click the Capacitor to change the Capacitance value. This brings up the box above. Click Change Capacitor to get another Capacitor. When finished, click See Full Circuit to return to the Circuit.

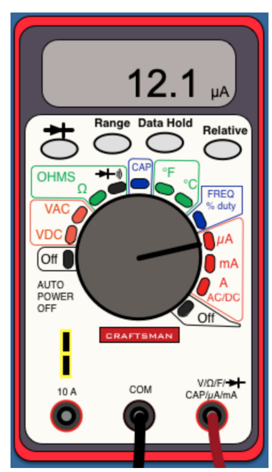
RC Circuit Lab





CLICK on the Left device to,
Measure the Voltage, V

CLICK on the Right device to,
Measure the Current, I



NOTE: The Simulator MUST be paused to to Read and Measure the Voltage and Current.

Procedure: Discharging a Capacitor

Data Set 1

1. Click on the Capacitor and Set the value to 2200 μF.
2. Click on the Resistor and Select a Resistor at random.

   Record the colors of the first 3 bands here:

   Read and Record the first Resistor value here: $R_1 =$
3. Click the Charge Cap Button to charge the Capacitor.
4. Measure the Voltage V and the Current I that will be coming out of the Capacitor at the moment it was charged. Record these values in Table 2 in the Data Set 1, Meas 1 row.
5. Click Resume to start the Capacitor discharging. Hit Pause after ~10-20 seconds.
6. Read and Record the measured Current I, the Voltage V and the elapsed time t.
7. Repeat the last two steps until you have 6 Measurements.

Data Set 2

8. Click on the Resistor and Select a Resistor at random.

   Record the colors of the first 3 bands here:

   Read and Record the second Resistor value here: $R_2 =$
9. Click the Charge Cap Button to charge the Capacitor.
10. Measure the Voltage V and the Current I that will be coming out of the Capacitor at the moment it was charged. Record these values in Table 2 in the Data Set 2, Meas 1 row.
11. Click Resume to start the Capacitor discharging. Hit Pause after ~10-20 seconds.
12. Read and Record the measured Current I, the Voltage V and the elapsed time t.
13. Repeat the last two steps until you have 6 Measurements.

Data Set 3

14. Click on the Capacitor and Set the value to 470 μF.
15. Click the Charge Cap Button to charge the Capacitor.
16. Measure the Voltage V and the Current I that will be coming out of the Capacitor at the moment it was charged. Record these values in Table 2 in the Data Set 3 section.
17. Click Resume to start the Capacitor discharging. Hit Pause after ~10-20 seconds.
18. Read and Record the measured Current I, the Voltage V and the elapsed time t.
19. Repeat the last two steps until you have 6 Measurements.

Table 2: Data: Discharging a Capacitor

Data Set #	**Measurement** #	**Capacitance C** (μF)	**Voltage** V **(V)**	**Current** I **(**μ**A)**	**Charging Time t (s)**
1	Meas 1	2200 μF			
	Meas 2	2200 μF			
	Meas 3	2200 μF			
	Meas 4	2200 μF			
	Meas 5	2200 μF			
	Meas 6	2200 μF			
2	Meas 1	2200 μF			
	Meas 2	2200 μF			
	Meas 3	2200 μF			
	Meas 4	2200 μF			
	Meas 5	2200 μF			
	Meas 6	2200 μF			
3	Meas 1	470 μF			
	Meas 2	470 μF			
	Meas 3	470 μF			
	Meas 4	470 μF			
	Meas 5	470 μF			
	Meas 6	470 μF			

Conclusions

1. Show that the capacitive time constant RC has units of seconds.

2. Using your data in Table 1, create a scatter graph of V_C on the Y-axis versus Time t on the X-axis. Label the x-y axes including units and Title your graph "**Charging Capacitor Voltage vs Time**". Upload it with this Lab Report in D2L. Comment on the graph.

3. Using your data in Table 1, create a scatter graph of V_R on the Y-axis versus Time t on the X-axis. Label the x-y axes including units and Title your graph "**Charging Resistor Voltage vs Time**". Upload it with this Lab Report in D2L. Comment on the graph.

4. Using your data in Table 1, create a scatter graph of Current, I on the Y-axis versus Time t on the X-axis. Label the x-y axes including units and Title your graph "**Current vs Time**". Upload it with this Lab Report in D2L. Comment on the graph.

5. Using your results in Table 2, create a scatter graph of V_C on the Y-axis versus Time t on the X-axis for each Data Set. Label the x-y axes including units and Title your graph "**Discharging Capacitor Voltage vs Time**" if all 3 data sets are on the same graph or "**Discharging Capacitor Voltage vs Time - Set 1**" with the data set number included in the title. Upload it with this Lab Report in D2L. Comment on the graph.

6. **Take a photo or scan a copy showing all of your calculations and upload it with this Lab Report in D2L.**