**RC CIRCUIT EXPERIMENT**

**Short description:**
The purpose of this experiment is to study the behavior of the current and voltages in an *RC* circuit.

**Equipment:**
- Pasco power supply
- One large capacitor (about 2500µF), Resistance box.
- Multimeter
- 4 banana cables
- Stopwatch (online)

When a capacitor is **charged** through a resistor by a constant voltage source, the voltages across the capacitor and resistor change exponentially with time. That is,

\[
V_C = V \left(1 - e^{-\frac{t}{RC}}\right)
\]

\[
V_R = Ve^{-\frac{t}{RC}}
\]

where *V* is the applied voltage.

Likewise, when a capacitor is **discharged** through a resistor, the voltages are given by

\[
V_C = V_0 e^{-\frac{t}{RC}}
\]

\[
V_R = -V_0 e^{-\frac{t}{RC}}
\]

where *V₀* is the initial voltage across the capacitor.

The rate at which the capacitor charges or discharges can be characterized by the time constant \( \tau = RC \). When **charging**, \( RC \) is the time that it takes for the capacitor voltage to increase from zero voltage to 0.632 times the charging voltage, since at \( t = \tau = RC \)

\[
V_C = V \left(1 - e^{-1}\right) = V(1 - 0.368) = 0.632V, \quad \text{the 63\% of } V
\]

Similarly, when **discharging**, \( RC \) is the time for the voltage to drop to 0.368 times its initial value, since at \( t = RC \)

\[
V_C = V_0 e^{-1} = 0.368V_0, \quad \text{the 36.8\% of } V_0
\]
Procedure:

1. Set the resistance of the resistance box to 5000 Ω. Check its actual value with the multimeter. If you read a bad value (~ M Ω) change the resistance. Try in the range 4000 to 7000 Ω.

   \[ R = \phantom{0} \text{Ω} \]

   For the lab you will use the above resistor and a capacitor with a capacitance of the order 2500 μF. What is the time constant for this \( RC \) combination?

   \[ \tau = \phantom{0} \text{sec} \]

**PART 1 – CHARGING A CAPACITOR**

2. Before starting check the DC voltage of the power supply – it should be set at 5V. Measure the voltage using the multimeter. Record the applied voltage.

   \[ V = \phantom{0} \text{V} \]

3. First we need to make sure the capacitor is discharged. What does it means that a capacitor is discharged?

   To discharge it, simple connect both ends of the capacitor using one cable as shown in the picture below (and wait about 5 seconds):

   ![Capacitor Discharge](image)

   Question:
   Why does connecting both ends of a capacitor discharge it?
4. **Turn off** the power supply and build the circuit. Take a close look at the circuit diagram below. It is important that you connect the negative output of the DC power supply to the end of the capacitor that has a minus sign “−” on it and the positive output of the DC power supply to the resistor and then the resistor to the end of the capacitor that has a plus sign “+” on it. If you do not connect the components accordantly to the right polarity, the capacitor might blow up and be dangerous (if you’re not sure, ask the instructor to check). Set the multimeter to measure DC voltages across the capacitor $V_C$ by connecting it as show in the diagram below:

![Circuit Diagram]

5. **Take the measurement:**

Search online for a web–based stopwatch, or use an app on your phone to measure time intervals. Make sure the stopwatch has the lap function and know how to use it to record different times as an event takes place. You will measure several time intervals as $V_C$ increases from 0 to the voltage provided by the power supply. Set the power supply ready: disconnect the two cables from the power supply, turn on the power supply and adjust it to 5V, turn off the power supply, re-connect the cables. Now it’s all ready. Turn on the power supply and the capacitor will start to charge. Read several values of $V_C$ on the multimeter and measure the times that $V_C$ takes to reach these values. Use the lap function to measure these time intervals. Collect your data in the table below. The voltage will increase faster at the beginning of the charging process, so try to take most of the time measurements between 0V and 2V. Repeat the charging to improve your data.

| $V_C$ | 0V | | | | 5V |
|-------|----|---|---|---|
| Time  |    |   |   |   |

6. **PLOT 1:** Using Excel, plot $V_C$ as a function of time. Looking at the plot determine $RC$ by estimate the time at which the voltage has increased to 63% of the power supply value. Assume that you do not know the capacitance, calculate it from the measured resistance $R$ and the time constant you just determined.

$$C = \underline{\text{__________}} \mu F$$

% Error = $|\text{measured} - \text{expected}| / |\text{expected}| \times 100 \% = \underline{\text{_______}}$

**PLOT 2:** Now plot this same data in semi-log format. Plot the natural log of $(1 - V_C/\overline{V})$ on the vertical axis and $t$ on the horizontal axis. Draw a single “best fit” straight line through your data and determine $RC$ from this line. What capacitance does this correspond to?

$$C = \underline{\text{__________}} \mu F$$

% Error = $|\text{measured} - \text{expected}| / |\text{expected}| \times 100 \% = \underline{\text{_______}}$
7. Set the resistance of the box to about half of the value you just used. Repeat the measurement described in step 5. How the time to charge the capacitor is different in this case?

**PART 2 – DISCHARGING A CAPACITOR**

We need to start with the capacitor charged. To charge it connect it to the power supply (set at 5V) and no resistor as show in the figure below (wait about five seconds):

![Circuit diagram](https://via.placeholder.com/150)

In order to discharge the capacitor in the RC circuit unplug the two cables from the power supply, add the resistance box, set at 5000 Ω and get ready to connect the cables to each other. Make sure also you have the stop watch ready.

8. Connect the cable and using the lap function, measure several time intervals for the capacitor voltage $V_C$ to drop to about 0V. Again, try to take most of the measurements at the beginning of the discharging process. Repeat the discharging if needed. Collect you data in the table below:

<table>
<thead>
<tr>
<th>$V_C$</th>
<th>5V</th>
<th></th>
<th></th>
<th></th>
<th>0V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9. **PLOT 3:** Using Excel, plot $V_C$ as a function of time. Determine $RC$ by finding the time at which the voltage has dropped to 36.8% of the original value. Assume that you do not know the resistance and use the given value of $C$ to calculate the resistance $R$.

$$R = \text{___________} \ \Omega$$

% Error = |measured - expected| / |expected| x 100 % =

10. **PLOT 4:** Now plot this same data in semi-log format. Plot the natural log of $V_C$ on the vertical axis and $t$ on the horizontal axis. Draw a single “best fit” straight line through your data and determine $RC$ from this line. Again use the given value of $C$ to calculate $R$.

$$R = \text{___________} \ \Omega$$

% Error = |measured - expected| / |expected| x 100 % =

11. Set the resistance of the box to about half of the value you just used. Repeat the measurement described in step 8. How the time to discharge the capacitor is different in this case?