RC Circuit
Examining the Properties of a Resistance-Capacitance Circuit

In this laboratory exercise you will be investigating the behavior of an RC circuit. The equations that you will use in this experiment are:

The definition of capacitance: $C = \frac{q}{V}$

The energy stored in a capacitor: $U = \frac{1}{2}CV^2$

The time constant: $\tau = RC$

Charging the capacitor: $V_C = V_{battery}\left(1 - e^{-\frac{t}{RC}}\right)$

Discharging the capacitor: $V_C = V_o e^{-\frac{t}{RC}}$

Time constant (τ) is the time for the capacitor to reach 63% of the maximum charge when charging and to lose 63% of its maximum charge when discharging.

A schematic drawing of the circuit that you will use when charging the capacitor is shown below.

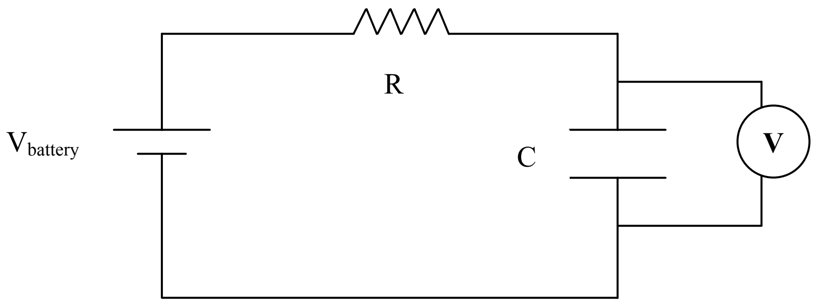


Figure 1

The capacitors and resistors that are used in this experiment are mass produced. The manufacturer states the tolerance for each when they distribute them. When a manufacturer states the resistance of a resistor is 100 ohms with a 5% tolerance they are really telling the user that the resistance could be anywhere between $100 \pm [0.05(100\ \Omega)]$ or between 95 Ω or 105 Ω.

The time constant τ is calculated by multiplying the *uncertain* R value by the *uncertain* C value, giving an understandably *uncertain* τ value. Therefore, we must determine if our experimental time constant value lies within or outside of an accepted range of combined uncertainty as determined by the manufacturer's values.

Example:

The combined uncertainty in the time constant can be calculated using the following equation:

The resistance is: $\mathrm{R} \pm (5\%)\mathrm{R}$ or $\mathrm{R} \pm (0.05)\mathrm{R}$, where R is the value of the resistance in ohms.

The capacitance is: $\mathrm{C} \pm (20\%)\mathrm{C}$ or $\mathrm{C} \pm (0.20)\mathrm{C}$, where C is the value of the capacitance in farads.

The time constant for an RC circuit is given by: $\tau \pm \Delta\tau = RC \pm RC(0.25)$. This equation is a modification of the equation given above and appropriate for our purposes.

This allows us to calculate the combined uncertainty in the time constant ($\pm\Delta\tau$) using the following equation:

$$\Delta\tau = RC\left(\frac{0.05R}{R} + \frac{0.20C}{C}\right) = RC(5\% + 20\%)$$
$$\Delta\tau = RC(0.05 + 0.20) = RC(0.25)$$

Let $R = (100 \pm 5\%)\Omega$ and $C = (2200 \pm 20\%)\mathrm{F}$

$$\tau = RC = (100\,\Omega)(2200\,\mu\mathrm{F})$$
$$\tau = 220{,}000\text{ seconds} = 2.2\times10^{5}\,\mathrm{s}$$

But, we must take the combined uncertainty into account:

$$\Delta\tau = RC(0.25) = (220000\,\mathrm{s})(0.25)$$
$$\Delta\tau = 55000\,\mathrm{s} = 5.5\times10^{4}\,\mathrm{s}$$

Therefore our experimental range for calculation τ is:

$$\tau = (220000 \pm 55000)\,\mathrm{s}$$

PURPOSE

In this laboratory exercise you will study the behavior of an RC circuit as the capacitor charges and discharges.

MATERIALS

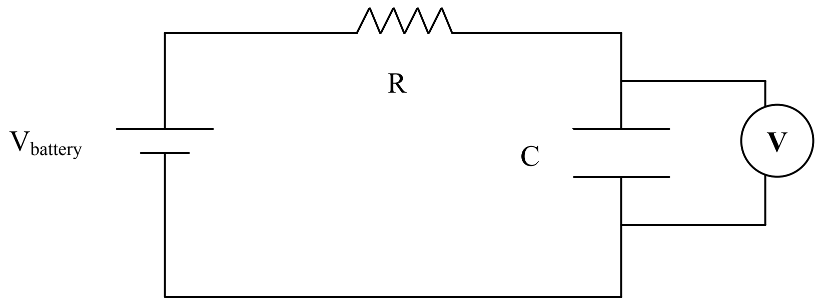
non-polarized electrolytic capacitor 2200 µC, 35 V (or similar capacitance)
47,000 Ω, (yellow, violet, orange), ½ watt resistor (or similar resistance)
2 D cell batteries and holders
digital voltmeter or digital multimeter
stopwatch
set of 5 connecting wires with clips

PROCEDURE

1. Determine and record the capacitance and tolerance of the capacitor.

2. Determine and record the resistance and tolerance of the resistor.

3. Make sure the capacitor is discharged. Do this by connecting a wire or any conducting object across the capacitor.



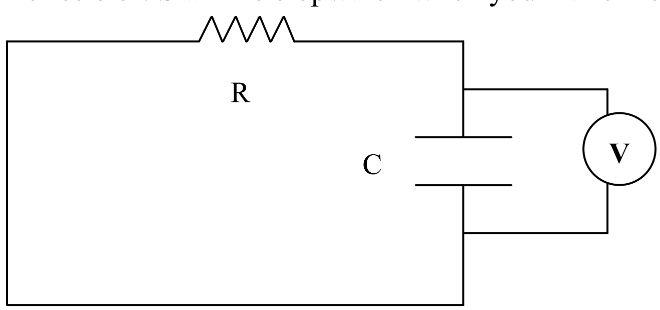
4. Construct the above circuit, but do not make the last connection to the battery until your teacher has checked your circuit and until you are ready to mark time.

5. When you are ready to start recording the time as well as the potential (voltage) reading for a total period of 6 minutes, connect the last wire to the battery and start the stopwatch.

6. Record the potential across the capacitor as a function of time at 10 second intervals in Data Table 1 on your student answer page.

7. At the end of the 6-minute charging time, disconnect the wires from the battery and record the voltage reading across the capacitor. This voltage is the initial voltage for the time during which the capacitor will be discharged.

8. When you are ready to start recording the time as well as the potential as the capacitor discharges, connect the two loose battery wires to each other. This will bypass the battery and cause the capacitor to discharge through the resistor. Start the stopwatch when you make the last connection.



9. Record the potential across the capacitor as a function of time at 10 second intervals in Data Table 2 on your student answer page.

10. Disconnect the circuit.

11. Complete the Analysis and Conclusion questions.

Name ___________________________________

Period___________________________________

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DATA AND OBSERVATIONS

Capacitance ________________ μF Tolerance _________ %

Resistance colors _______________, ______________, ______________, ______________

Resistance _________________ Ω Tolerance _________ %

Data Table 1: Charging of the Capacitor					
Time (s)	**Potential (V)**	**Time (s)**	**Potential (V)**	**Time (s)**	**Potential (V)**
0		130		260	
10		140		270	
20		150		280	
30		160		290	
40		170		300	
50		180		310	
60		190		320	
70		200		330	
80		210		340	
90		220		350	
100		230		360	
110		240			
120		250			

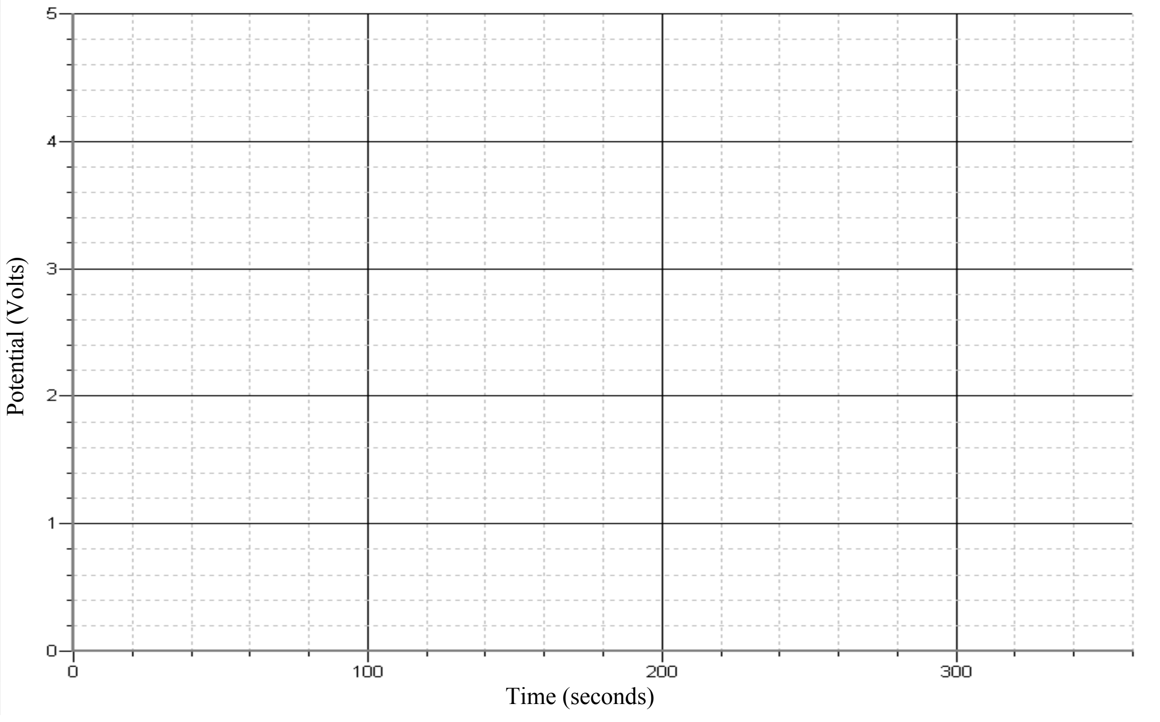
Initial voltage across the charged capacitor _______________ V

Data Table 2: Discharging the Capacitor					
Time (s)	**Potential (V)**	**Time (s)**	**Potential (V)**	**Time (s)**	**Potential (V)**
0		130		260	
10		140		270	
20		150		280	
30		160		290	
40		170		300	
50		180		310	
60		190		320	
70		200		330	
80		210		340	
90		220		350	
100		230		360	
110		240			
120		250			

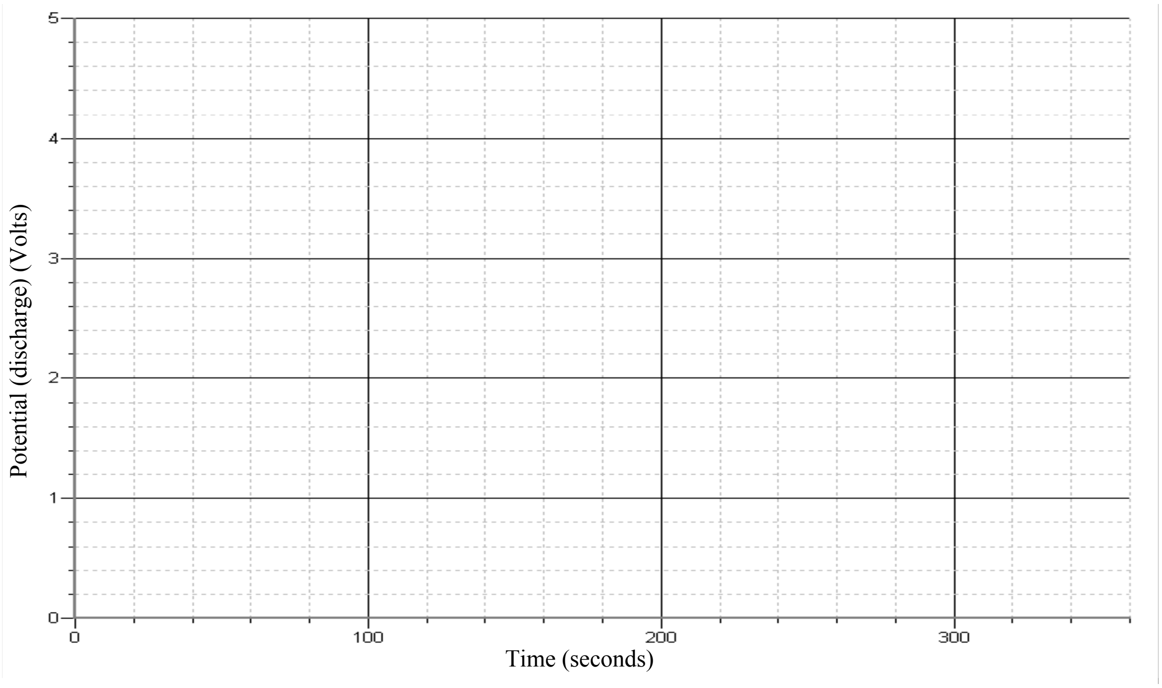
ANALYSIS

Graph the charging potential vs. time and the discharging potential vs. time on the graph axes below.

Charging the Capacitor
Potential vs. Time



Discharging the Capacitor
Potential vs. Time



1. Calculate the time constant and the combined uncertainty for your RC circuit.

2. Use the charging graph to determine the time constant.

3. Does the experimental value of the time constant lie within the uncertainty limits calculated in question 1?

4. Use the discharge graph to determine the time constant.

5. Does the experimental value of the time constant lie within the uncertainty limits calculated in question 1?

6. Use your charging graph to approximately determine the potential that the graph is approaching asymptotically.

CONCLUSION QUESTIONS

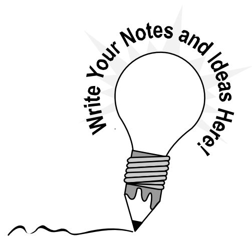
1. Compare the asymptotic potential of the charging graph to the initial potential of the discharging graph. Explain what you observe about these two potentials.

2. Calculate the charge stored on the capacitor after 200 seconds of charging.

3. How much charge does the capacitor lose in the interval between t = 50 seconds and t = 120 seconds as it discharges?

4. Calculate the energy stored in the capacitor after six minutes of charging.

5. Describe what happens to the energy stored in the capacitor as the capacitor discharges.


Write Your Notes and Ideas Here!