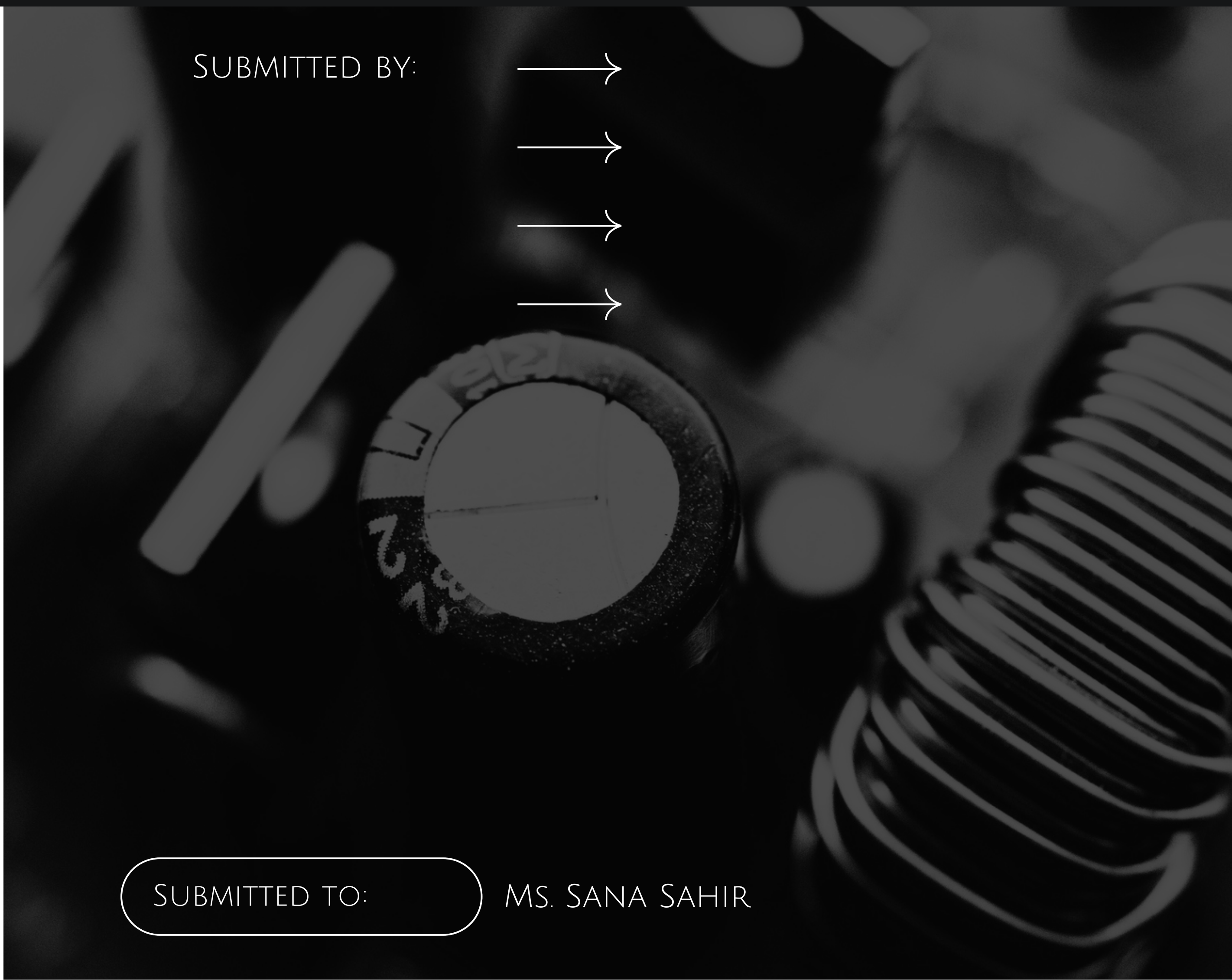
25 January 2024

Winter 2024

experiment 3

RC Circuits & Electrical Meters

University of Wollongong in Dubai



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PHYS143
Physics for Engineers

Purpose

To study the behavior of the time dependent potential difference across a capacitor in a simple RC series circuit.

Hypothesis Statement

As the capacitor discharges, the voltage progressively decreases over time. The rate at which the capacitor is discharged or charged is indicated by the time constant given by $\tau = RC$, which is the product of the resistance and the capacitance.

Materials

- D.C. power supply
- One large capacitor (about 2500 μF)
- Resistance box
- Multimeter
- 4 banana cables
- Stopwatch

Procedures

1. Set the resistance of the resistance box to 5000Ω. Check its actual value with the multimeter. Change the resistance if the value is incorrect. Try in the range of 4000Ω to 7000Ω.

   R = 4700Ω

2. Use the above resistor and a capacitor with a capacitance of the order 3300μF.

   τ = 15.51 s

3. 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 = 4.7 V

4. Ensure the capacitor is discharged by simply connecting both ends of the capacitor using a cable as shown in Figure 1 and wait for about 5 seconds.

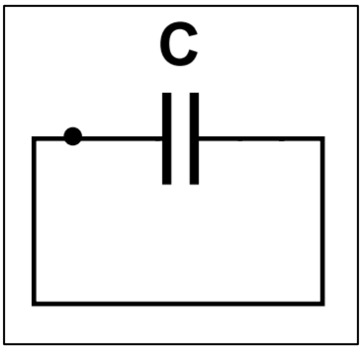

Figure 1: Procedure to discharge a capacitor.

5. Turn off the power supply and build the circuit as shown in Figure 2. It is important to connect the negative output of the DC power supply to the end of the capacitor that displays a "minus" sign (-), which corresponds to the shorter side of the capacitor, and the positive output of the DC power supply to the end of the capacitor that displays a "plus" sign (+), which corresponds to the longer side of the capacitor. If the components are not connected according to the correct polarity, the capacitor could blow up and cause damage. Set the multimeter to measure DC voltage and connect it as shown in Figure 2.

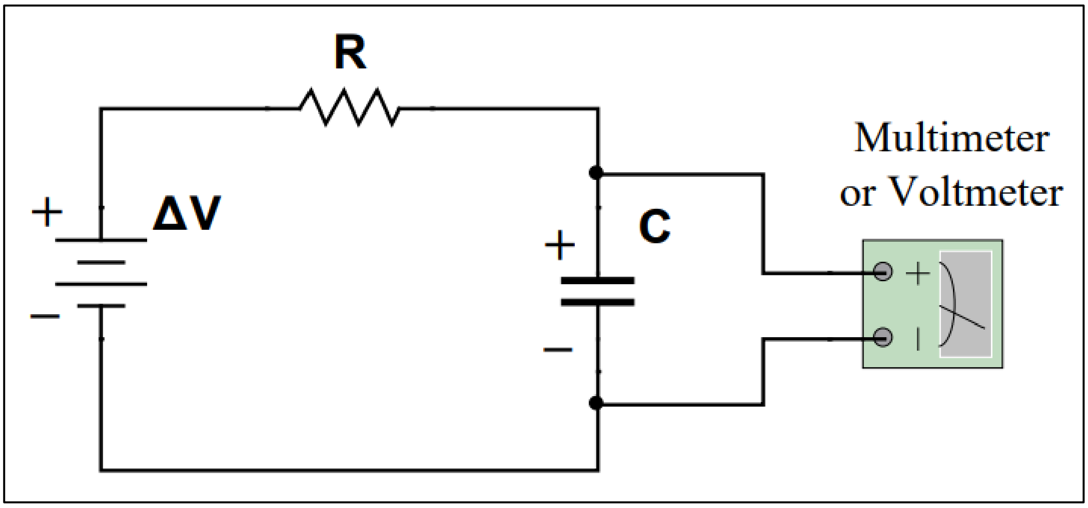

Figure 2: Circuit diagram to connect the resistor, capacitor, and the multimeter.

6. Open the stopwatch at https://tools.arantius.com/stopwatch. Turn on the power supply (which should be kept at 5V), look at the multimeter for the value of V_c, the voltage across the capacitor and measure the time that V_c takes to reach 4.5V. Then charge the capacitor and repeat this step to measure the time it takes to discharge to 4V, 3.5V....1V.
7. Plot V_c as a function of time. Determine *RC* by finding the time at which the voltage has decreased to 36.8% of the power supply value. Assume that the capacitance is unknown and calculate it from the measured resistance R and the time constant that was just determined.

C = 1260 μF

8. Plot the same data in semi-log format. Plot the natural log of $(1-\frac{V_C}{V})$ on the vertical axis and time on the horizontal axis: $y=\ln(1-\frac{V_C}{V})$ and $x=t$. Draw a single "best fit" straight line through your data and determine *RC* from this line. Record the capacitance it corresponds to.

C = 813 μF

Data & Graphs

Voltage across Capacitor, V_c (V)	Time (s)
1.0	6.171
1.5	4.5
2.0	3.9
2.5	3.0
3.0	2.436
3.5	2.488
4.0	2.540
4.5	1.6

Table 1: Potential difference for various distances along the positive electrode

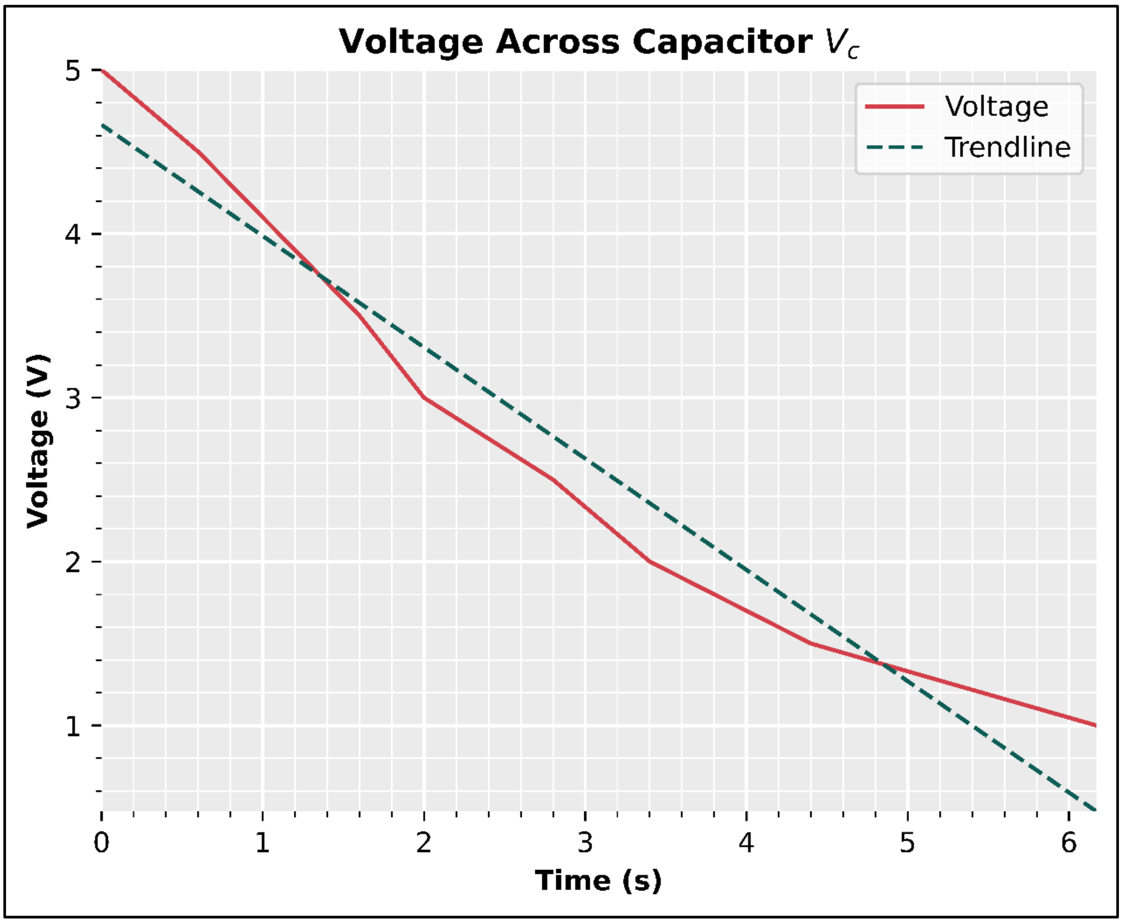

Figure 3: Voltage across capacitor against time.

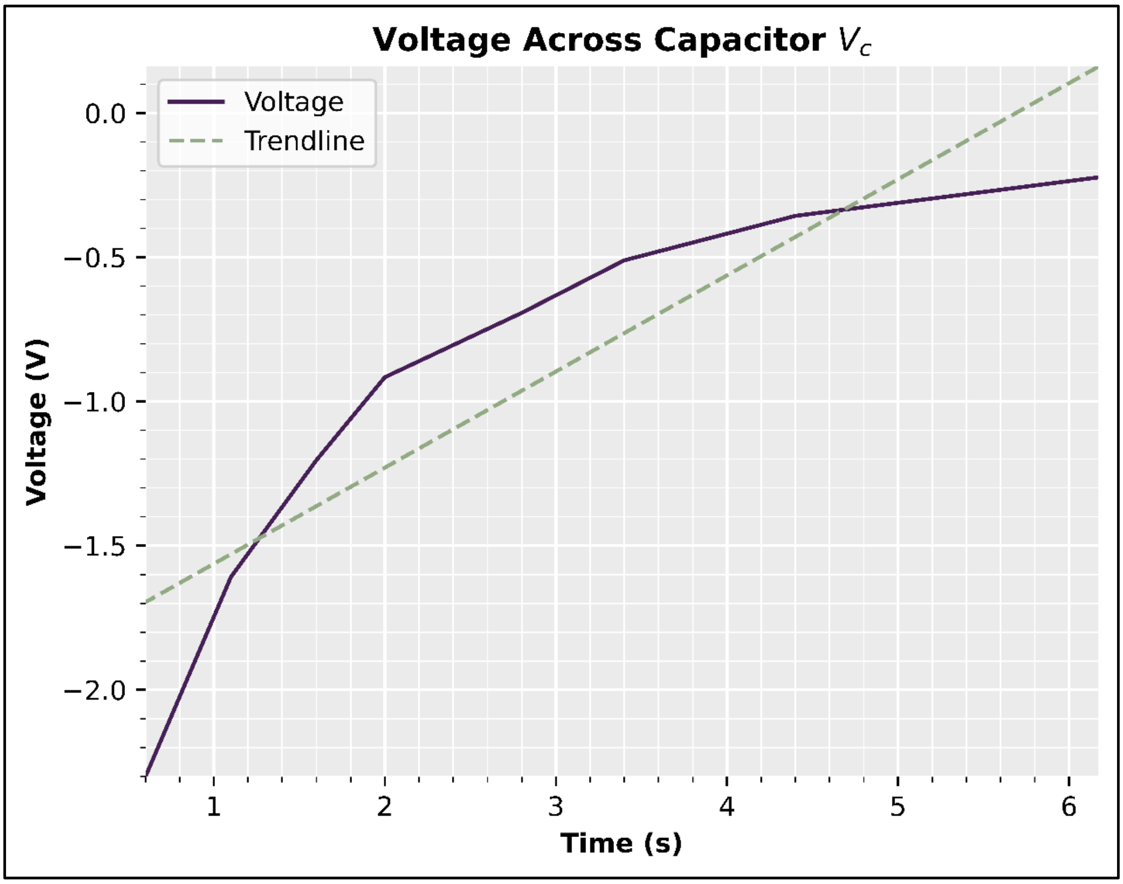

Figure 4: Plot in log format.

Observations

It was observed that there was an instantaneous drop in voltage across the capacitor. As time elapsed, the voltage gradually started to decrease. This is in line with what would be observed in a discharging capacitor V-T graph. However, the time interval did not match with the theoretical value of time taken to reach 36.8% of the original voltage of an RC circuit with R=4.7 kΩ and C=3300μF. When referring to the graph generated by the data gathered during the lab, it was found that the hypothetical unknown value of the capacitor (1260μF) was significantly less than the actual value of the capacitor(3300μF)

This may have been due to the following sources of errors:

- Errors in the circuit.
- Discrepancies in the time measurements due to the instantaneous drop in voltage.
- Improper calibration of the multimeter.
- The wire could have been connected to the resistor directly without knowledge.
- The capacitor was not fully charged before being discharged.

Analysis Questions

1. **When a capacitor is charged through a resistor by a constant voltage source, what is the voltage across the capacitor and a resistor?**

   When a capacitor is charged through a resistor by a constant voltage source, the voltages across the capacitor and resistor change exponentially with time. This is given by the formula:

   $$V_C = V(1 - e^{-t/RC})$$

   $$V_R = Ve^{-t/RC}$$

2. **When a capacitor is discharged through a resistor by a constant voltage source, what is the voltages across the capacitor and a resistor?**

   Similar to the question above, when a capacitor is discharged through a resistor, the voltage is given by the formula:

   $$V_C = V_0 e^{-t/RC}$$

   $$V_R = -V_0 e^{-t/RC}$$

Conclusion

1. What was the purpose of the lab?
The purpose of the lab was to study the behavior of the time dependent potential difference across a capacitor in a simple RC series circuit.

2. How does the lab we performed relate to what we are studying in class?
In the classroom, students are being taught about direct current circuits involving capacitors and resistors. The notion of resistor-capacitor circuits and electrical meters is explained in the current lab experiment 3, which immediately provides a hands-on and practical learning experience.

3. Give a brief recap of the procedure used.
Set the resistance box to 5000 Ω, set the DC voltage of the power supply to 5V and verify the voltage output. Discharge the capacitor, turn off the power supply, and build the circuit. Turn on the power supply, measure the V_C value on the multimeter, and measure the time to reach 1V. Charge the capacitor, then discharge, and measure the time to discharge to 4.5V, 4V….1V. Plot voltage as a function of time and determine the time at which the voltage has decreased to 63.2% of the power supply value.

4. What problems did you have during the lab? Did you have to modify your procedure?
The problems we faced in our lab are plenty. This includes, but is not limited to, a possibly bad capacitor which charged and discharged significantly faster than the theoretical time required.

5. Do your results make sense? What are the sources of error?
No, the results do not make sense at all. The lab performed does not remotely represent the theory learnt in the lecture. Sources of error include but are not limited to errors in the circuit, discrepancies in the time measurements due to the instantaneous drop in voltage, improper calibration of the multimeter.

6. What did you learn from this lab?
We learnt that when a capacitor charges through a resistor, it causes exponential voltage changes over time. The rate of charging is characterized by the time constant RC, which is the time it takes for the capacitor voltage to increase from zero to 0.632 times the charging voltage, and to fall to 0.368 times its initial value while discharging.

7. If you were to repeat this lab in the future, how would you modify or improve the procedure?
In the event that this lab had to be redone, we would make sure the cables are firmly inserted into the breadboard and linked to the multimeter. Before proceeding, we would also make sure the capacitor was completely discharged. We would also eliminate any possible sources of error among other measures to be taken.