Lab 217: RC Circuits

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Course: PHYS 121A 016 **Instructor: Subodh Dahal**

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1. INTRODUCTION

1.1 OBJECTIVES

To get the value of voltage across capacitors in circuits containing resistors and capacitors connected in series. This experiment's goal is to learn more about the behavior of resistor-coupled capacitors, with a specific emphasis on how a capacitor charges and discharges through a resistor.

1.2 THEORETICAL BACKGROUND

There are two states of change when dealing with a capacitor within a capacitor resistor (RC) circuit. When a current is put into a circuit, a capacitor with no initial charge will begin charging over time. A capacitor with full charge, upon the closing of the current, will begin to discharge its held charge. The equation for the discharging of a capacitor is as follows:

$$V(t) = Vi * e^{-\frac{t}{RC}}$$

Note that Vi is the initial voltage (usually at the highest value), and V(t) is the function of how much voltage is in the capacitor at any instance of time. The graph of this function is exponential in the negative direction, starting at Vi, and ending at 0. The formula for charging a capacitor is:

$$V(t) = Vi(1 - e^{-\frac{t}{RC}})$$

In the same way as before, Vi represents the initial voltage, and V(t) is the voltage at a given time. RC in both of these equations can be replaced with the variable τ, which is the time constant. This time constant is what we were solving for in much of the lab. When solving for the time constant, we can isolate each equation for $-(\frac{1}{RC}) * t$, t is the shifting variable and everything else constitutes the slope m. The relationship should be linear and not exponential because the time constant does not change. Alternatively, using the half life cycle (as we did in part two) would allow us to find RC or the time constant when multiplied by the ln(2).

2. EXPERIMENTAL PROCEDURE

A resistor and a 1000 uF capacitor are positioned at position A in Part A. The resistor fully charges the capacitor to 5 volts, and as soon as the cable from the power source is unplugged and connected to the computer, the stopwatch is activated. When the voltage dips, the timer is halted. The voltage change across the capacitor, as detected by the digital multimeter over time, had to be recorded. The capacitor in position B of the switch box is being charged in Part B. Return to position A when the capacitor has discharged. Next, using the lab-provided equipment, we are to record the voltage change across the capacitor from the digital multimeter over time.

Part A

Part B

3. **RESULTS**

3.0 **CODE**

```
R = 33e3; C = 1000e-6; tau = R*C;
t = 0 : 0.01 : 200;
V0 = 5;

% This code section is variable depending on
if the capacitor is charging or discharging.
% The corresponding code section is listed with
its corresponding data.

subplot(2,1,1); plot(t, Vt, texp, Vexp, 'x')
subplot(2,1,2); plot(t, Yt, texp, Yexp, 'x')

coefficients = polyfit(texp, Yexp, 1);
m = coefficients(1);
```

```
tauExp = -1/m;

[tau tauExp] % prints theoretical and experimental
side by side, just to compare
error = abs(tau-tauExp)/tau*100
```

3.1 **EXPERIMENTAL DATA**

Part A

Measurements:

Theoretical	Actual
33 kΩ Resistor	33.3 kΩ
10 kΩ Resistor	10.1 kΩ
0.47 μF Capacitor can not be measured. Uses theoretical value	
1000 μF Capacitor can not be measured. Uses theoretical value	

Discharging Points:

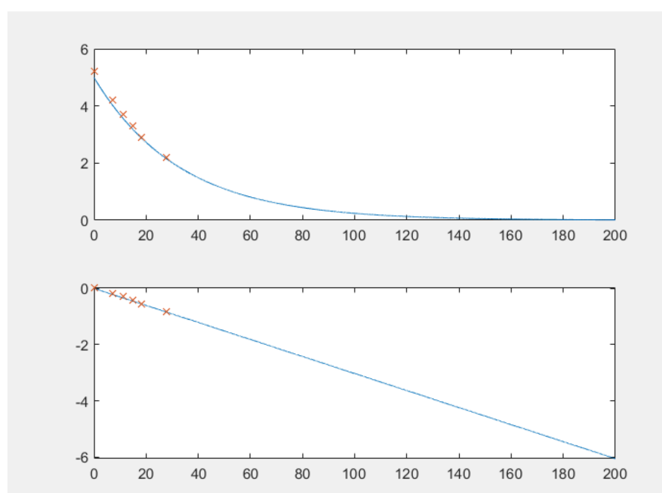
Data Points

Voltage	Time
5.2	0.00
4.2	7.17
3.7	11.09
3.3	14.85
2.9	18.33
2.2	27.79

Matlab Results

Variable Code Section:

```
texp = [0.00 7.17 11.09 14.85 18.33
27.79];
Vexp = [5.2  4.2   3.7   3.3   2.9
2.2];
Vt = V0*exp(-t/tau);
Yt = log(Vt/V0);
Yexp = log(Vexp/V0);
```



τ_{exp} = 32.0043

error = 3.0173

Charging Points:

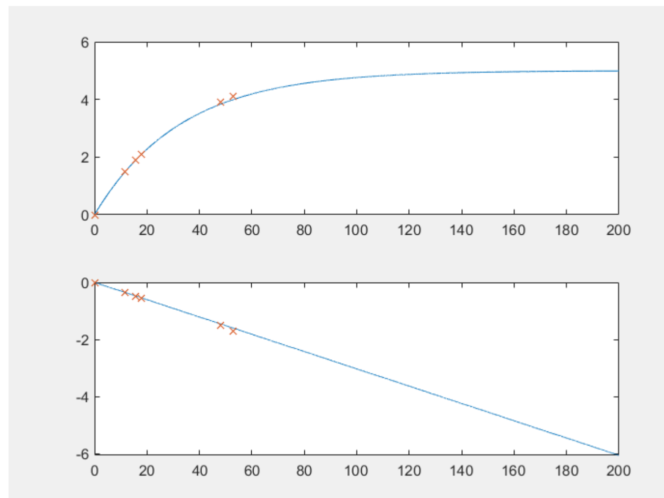
Data Points

Voltage	Time
0.0	0.00
1.5	11.59
1.9	15.53
2.1	17.78
3.9	48.17
4.1	52.70

Matlab Results

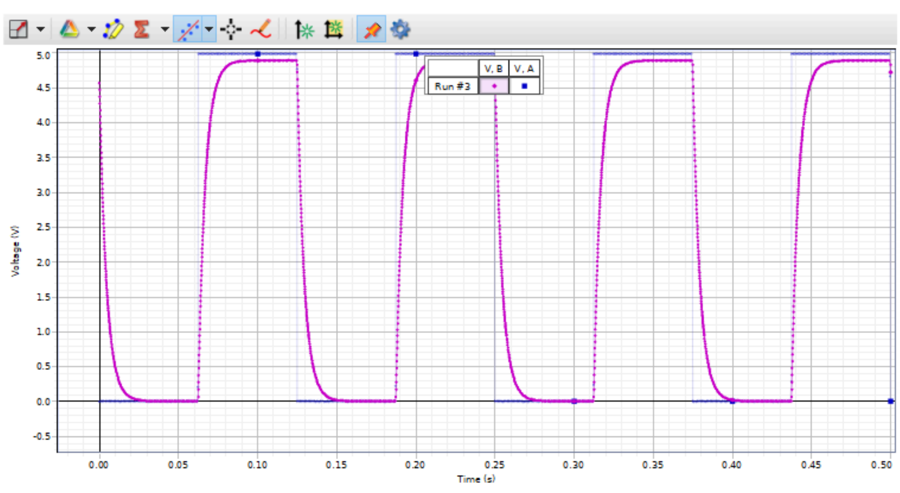
Variable Code Section:

```
texp = [0.00 11.59 15.53 17.78 48.17
52.70];
Vexp = [0.0   1.5   1.9   2.1   3.9
4.1];
Vt = V0*(1-exp(-t/tau));
Yt = log(1-Vt/V0);
Yexp = log(1-Vexp/V0);
```

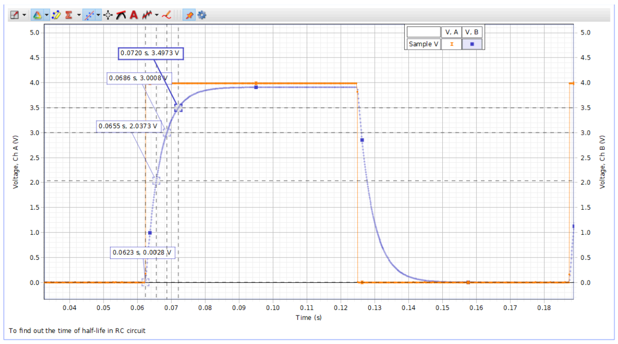


τ_{exp} = 30.9664
error = 6.1625

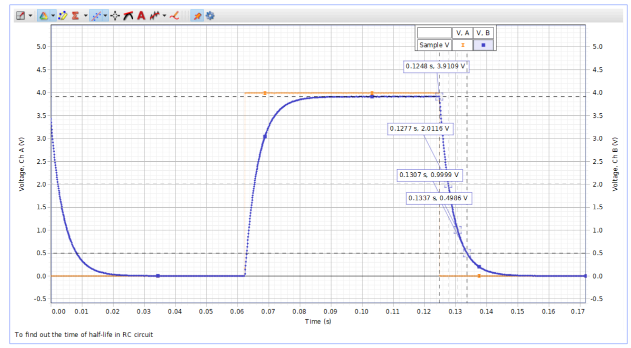
Part B



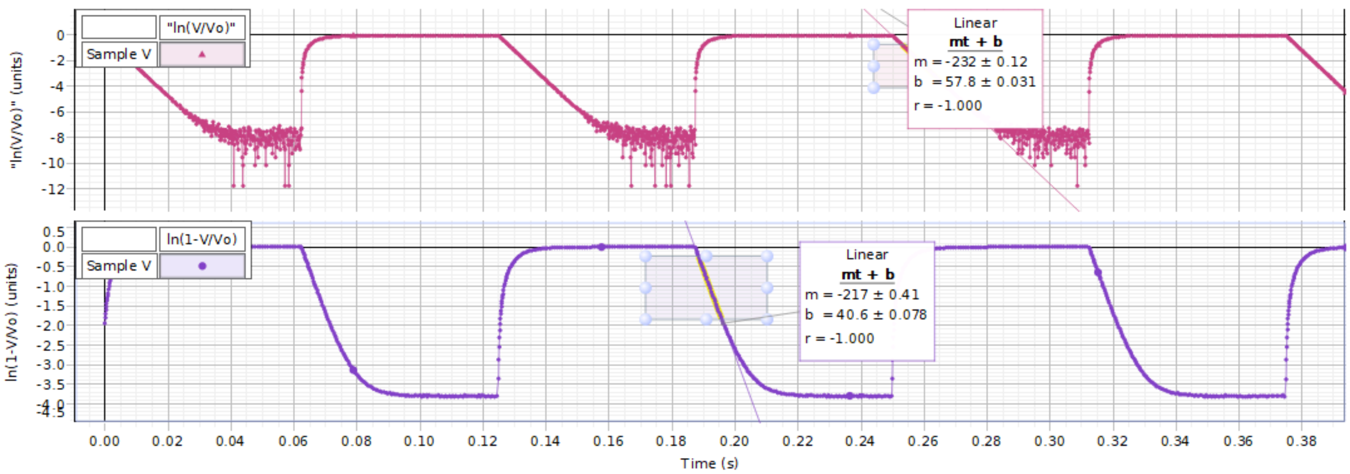
Alternating Series Diagram for Part Two



Four Points for Charging



Four Points for Discharging



First Slope is for Discharging: m = -232

Second Slope is for Charging: m = -217

3.2 **CALCULATION**

Part A

All calculations were computed in MATLAB, so there is no direct manipulation of equations to report.

Part B

Charging	Discharging
m = -217 = $-\frac{1}{RC}$ $217 = \frac{1}{RC}$ $RC = \frac{1}{217} = 0.0046s$	m = -232 = $-\frac{1}{RC}$ $232 = \frac{1}{RC}$ $RC = \frac{1}{232} = 0.0043s$

Average RC Value:

$$\frac{\frac{1}{217}+\frac{1}{232}}{2} \simeq 0.00446$$

4. ANALYSIS and DISCUSSION

In this lab we learned about RC circuits. An electrical circuit made up of passive parts like resistors and capacitors that are powered by either a current or voltage source is known as a resistor-capacitor circuit (RC Circuit). Furthermore, we had to understand how MATLAB works in order to properly create, edit, and print the figures. When the code structure is compared to the voltage and capacitance formula $V(t) = Vi * e^{-\frac{t}{RC}}$, each program produces a coordinate space in a straightforward manner.This experiment's outcomes confirmed the validity of its hypothesis. We confirmed our knowledge about potential and the operation of RC circuits from this lab.

By contrasting the theoretical predictions with the actual data, we find that the charging and discharging processes exhibit exponential increase and decrease, respectively. The rate at which the capacitor charges or discharges is determined by the time constant τ=RC. The correctness of the RC circuit model is demonstrated by the close match between the experimental results and theoretical expectations for both large and small time constants. The percent error in both parts of the lab, while significant, was small, and the calculated time constants clearly reflect the magnitude of the theoretical constants to one or two significant figures. Wire resistance was one potential cause of inaccuracy.

5. CONCLUSIONS

The goal of this experiment was to investigate the logarithmic connection between resistor-capacitor (RC) circuit voltage as a function of time. A capacitor takes the same amount of time to charge as it does to discharge. Furthermore, the negative of the product of resistance and capacitance is inversely proportional to the slope of this logarithmic relationship.This experiment effectively illustrated how RC circuits behave when they are charged and discharged. We validated the RC circuit model's validity and the processes' exponential character by analyzing data and comparing it with theoretical predictions.Overall, the lab findings were successful in demonstrating the correlations in RC circuits and match these principles. The time constant of the voltage as a function of time may be found by entering the voltage measurements taken with the voltmeter during the circuit's charging and discharging phases into Matlab. The slope of the two was obtained by entering the data from the charging up run and the discharging run. The results showed that charging up produced a positive slope and discharging produced a negative slope, as predicted.

6. RAW DATA

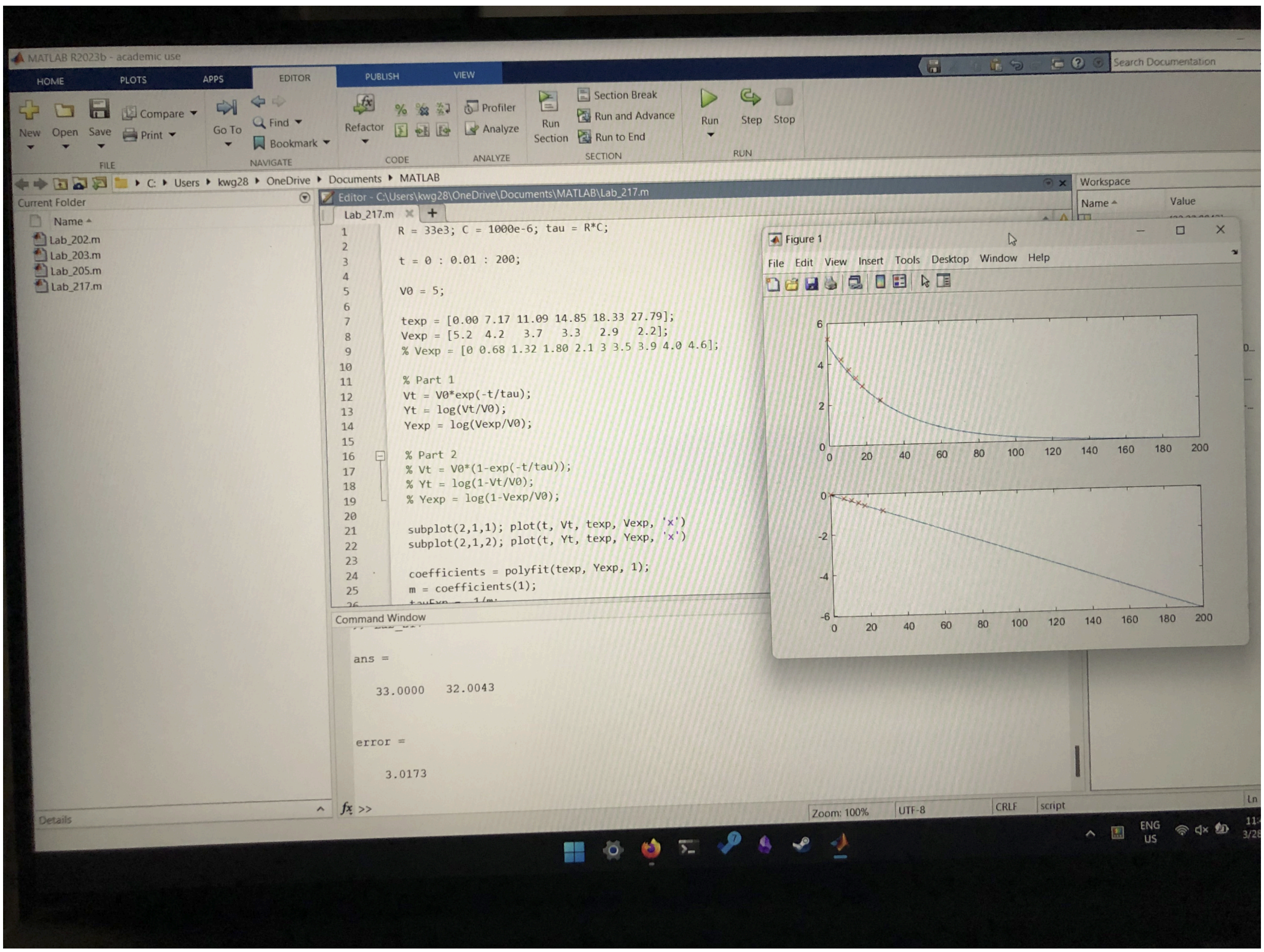
Measurements

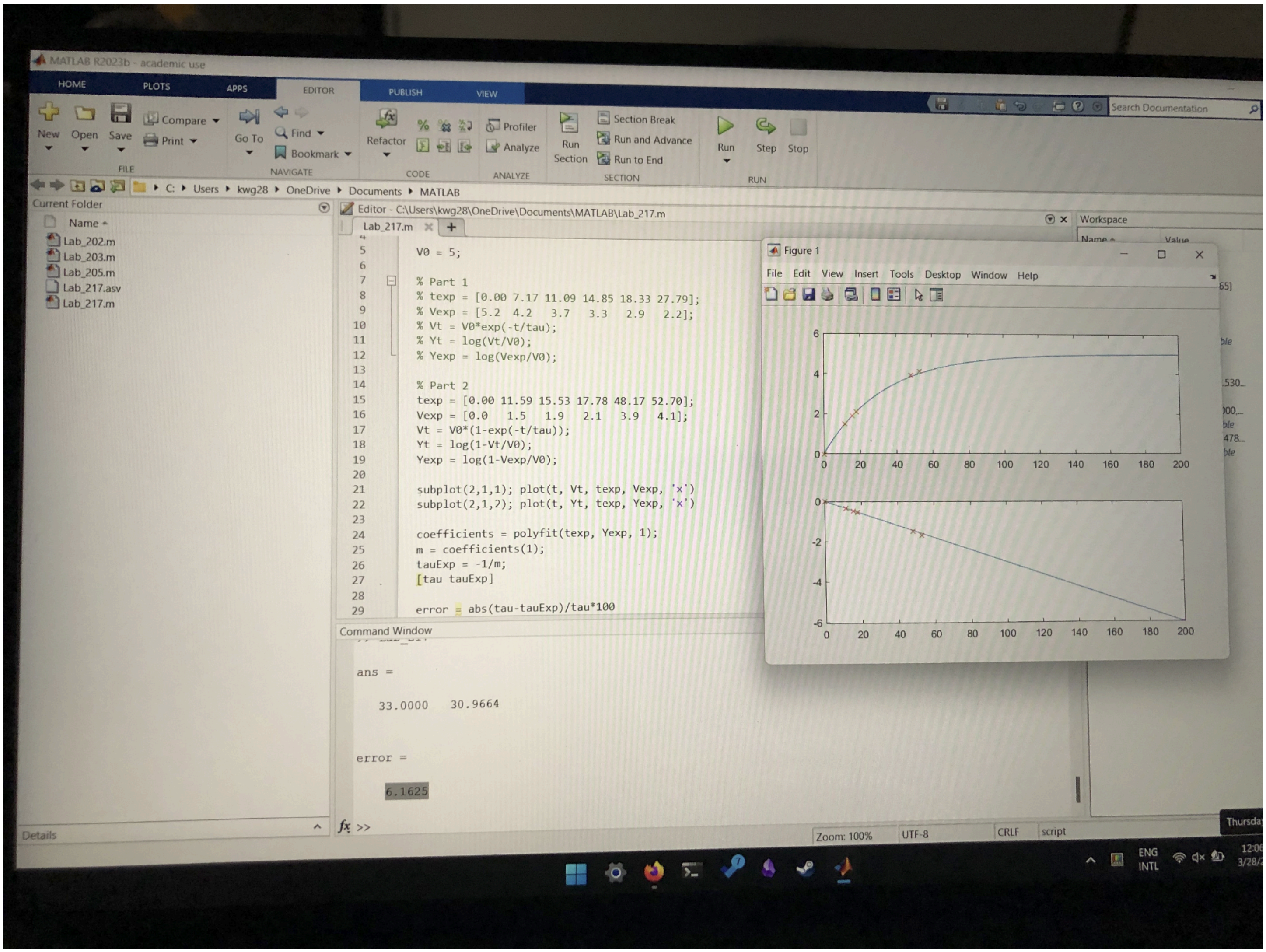
33K Ω R = 33.3 K Ω

10 K Ω R = 10.1 k Ω

0.47 μF C can not be measured

1000 μF C can not be measured





Part B

$$m = \left(+217 = +\frac{1}{RC} \right)^{-1}$$

$$RC = \frac{1}{217}$$

$$m = -232 = -\frac{1}{RC}$$

$$RC = -\frac{1}{m}$$

$$RC = \frac{1}{232}$$