Lab 215: Ohm’s Law – Current, Voltage, and Resistance Measurements

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

1. INTRODUCTION

1.1 OBJECTIVES

To verify the proportional relationships between current, voltage, and resistance in Ohmic resistors, observe how this behavior impacts the resistance of combined resistor circuits, and observe how non-Ohmic resistors can behave.

1.2 THEORETICAL BACKGROUND

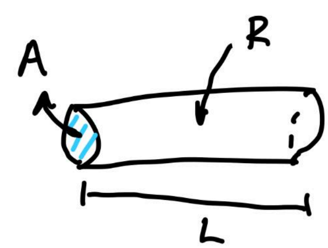
This lab goes over a couple of important topics that are important to understanding Ohm’s Law. The first is current, which is the rate of flow of charge, and is given in its unit of amperes. Current can be calculated using the following equation:

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

In this equation, I represents the current, dQ is the change of current, and dt is the change in time. The second formula is Resistance, given byu R, which is the property of a conductor to oppose charge. It’s formula can be given as:

$$R = \rho\frac{L}{A}$$

Where ρ is the resistivity, L is the length of the object, and area is the cross-sectional area. Resistivity is a fixed constant which is determined by the material of the resistor. Materials with a high resistivity are considered insulators whereas materials with low resistivity are considered conductors. It’s important to note that an object’s resistivity can change depending on temperature, and its unit is the Ohm Ω.



Ohm’s law characterizes the relationship of voltage and current. Electric potential (V) is proportional to current (I), and is shown in the following equation:

$$V = IR$$

Resistance (R) is a constant value. The relationship between V and I is linear in the cases of ohmic conductors, and has an exponential relationship with semiconductors.

2. EXPERIMENTAL PROCEDURE

Circuit kits were used to set up various configurations of resistors to form specific circuits. The circuit kit board was powered by a DC power supply. For each segment of interest in a given circuit, a voltmeter was configured in parallel with the segment, while a separate ammeter was configured in series with the segment, in order to measure the voltage across and the current through the segment simultaneously. Depending on the behavior of interest, measurements were either carried out on the same circuit segment over a varying voltage, or various segments were measured under a constant power supply of 12 V.

In the first experiment, a single 5 kΩ resistor was placed in the kit, and the current through the resistor was measured for various voltages.

In the second experiment, three 5 kΩ resistors were connected directly in series with each other. With a constant voltage of 12 V, the voltage and current were measured for the entire circuit as well as for each individual resistor.

In the third experiment, three 5 kΩ resistors were connected directly in series with each other. With a constant voltage of 12 V, the voltage and current were measured for the entire circuit as well as for each individual resistor.

In the fourth experiment, three resistors were configured such that a 5 kΩ and 10 kΩ resistor were in parallel with each other, and that the parallel configuration was itself in series with a 1 kΩ resistor. With a constant voltage of 12 V, the voltage and current were measured for the entire circuit as well as for each individual resistor.

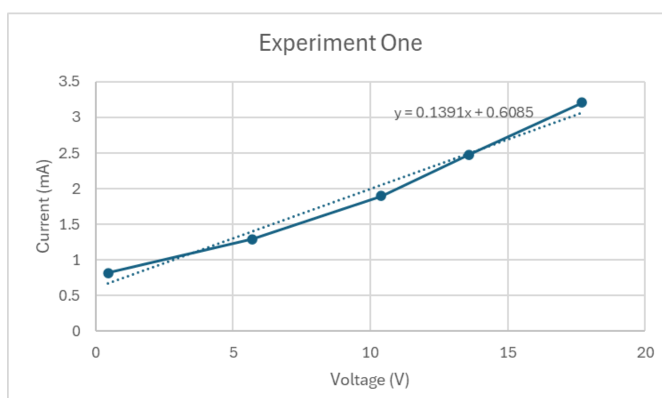
In the fifth experiment, an LED was configured in series with a 1 kΩ resistor (to protect it from an excessive current) such that the positive terminal of the LED was connected to the positive terminal of the power supply. Similar to the first experiment, the current running through the LED was then measured over various voltages.

3. RESULTS

3.1 EXPERIMENTAL DATA

Experiment One

	Voltage (V)	Current (mA)
1	0.45	0.82
2	5.71	1.29
3	10.4	1.90
4	13.6	2.48
5	17.7	3.21



Experiment Two

	Voltage	Current
V_{R1}	4V	0.74mA
V_{R2}	3.8V	0.73mA
V_{R3}	4V	0.74mA
V_{Total}	11.8V	0.74mA

Experiment Three

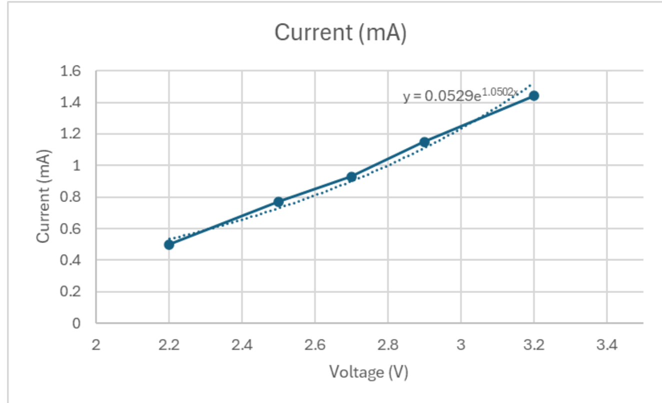
	Current	Voltage
I_{R1}	2.18mA	12V
I_{R2}	2.18mA	12V
I_{R3}	2.18mA	12V
I_{Total}	7.2mA	11.9V

Experiment Four

	Voltage	Current
V_{Total}	12V	2.64mA
V_{A}	9.4V	1.71mA
V_{B}	9.4V	0.95mA
V_{AB}	9.4V	2.64mA
V_{C}	2.5V	2.64mA

Experiment Five

	Voltage (V)	Current (mA)
1	2.2	0.50
2	2.5	0.77
3	2.7	0.93
4	2.9	1.15
5	3.2	1.44



3.2 **CALCULATION**

Experiment One does not require any calculations

<u>Experiment Two:</u>

Actual

I = 0.74A at all parts of the circuit (because it's in series)

Theoretical

$R_1 + R_2 + R_3 = R_{eq}$

$5k\Omega + 5k\Omega + 5k\Omega = 15k\Omega$

$V = IR \rightarrow I = \frac{V}{R}$

$I = \frac{11.8V}{15k\Omega} = 0.78A$

Error Calculation: $\frac{|0.74 - 0.78|}{0.78} * 100\% = 5.1\%$

<u>Experiment Three:</u>

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$R_{eq} = (\frac{1}{5k\Omega} + \frac{1}{5k\Omega} + \frac{1}{5k\Omega})^{-1} = 1.66k\Omega$$

$V = IR \rightarrow I = V/R$

$I = \frac{12V}{1.66k\Omega} = 7.2A$

Error Calculation: $\frac{|7.4 - 7.2|}{7.2} * 100\% = 2.77\%$

<u>Experiment Four:</u>

$R_{eq} = (\frac{1}{Ra} + \frac{1}{Rb})^{-1} + R_c$

$R_{eq} = (\frac{1}{5600} + \frac{1}{10000})^{-1} + 1000$

$R_{eq} = 4590\Omega$

$V = IR \rightarrow I = \frac{V}{R}$

$I = \frac{12V}{4590\Omega} = 2.6A$

Error Calculation: $\frac{|2.18-2.6|}{2.6} * 100\% = 16.1\%$

<u>Experiment Five:</u>

R = $\frac{dV}{dI} = \frac{3.2-2.5}{1.44-0.77} = \frac{0.7}{0.67} = 1.04\Omega$

4. ANALYSIS and DISCUSSION

Ohm's Law is supported by the graph above, which shows a linear connection between voltage and current. For every resistor, the computed resistance values nearly correspond to the nominal resistance values.

The measured resistance of each resistor in Part 1 of the lab tended to be lower than the resistance that was stated. Since the percent error I computed was less than 5%, I can say with certainty that the measurement on the resistor is accurate. In Part 2, we determined the voltages and currents coming from the 1.5kΩ resistor using the multimeter. The resistor's multimeter reading was quite close to the actual value. I was able to determine the voltage and current slopes and determine the resistor value to be as near as feasible. The amount that I determined using slope analysis is greater than the value that was measured and published. We chose the larger value given since the multimeter kept switching readings, which might have been caused by rounding mistakes when we recorded the results. The total resistance of the resistors in series, parallel, and a combination of the two had to be measured in Part 3. I discovered that the quantities in my calculated and real values were comparable. They differed by under 5%.

There is some error analysis to consider for this lab as well, which are located in the calculations sections. The highest percentage comes from experiment four, which we believe was an issue with the measurement of the current, but since the difference was minimal during the lab experiment (less than 10% from the intended), we were told to continue using the values that we had gotten. Overall however, this lab was a good visual way to understand Ohm's law, Electric voltage and Electric current. Before we could input the code into MATLAB and make changes, we had to understand its purpose and the desired result. 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 current formula V=IR and Ohm’s law, each program produces a coordinate space in a straightforward manner.This experiment's outcomes confirmed the validity of its hypothesis. We gained a lot of knowledge about potential and the operation of electric Voltage from this lab.

5. CONCLUSIONS

The variable resistor's resistance varied at different places, but overall it obeyed Ohm's law, demonstrating a linear connection between resistance and applied voltage. By calculating the wire's area and determining its diameter, the resistivity of the material in the variable resistor was ascertained. However, there are unknowns around this conclusion because of possible inaccuracies in the measurements and presumptions regarding the shape of the resistor and the homogeneity of the wire. We have successfully confirmed Ohm's Law for resistors with this experiment. The linear relationship seen in the displayed data shows that the link between voltage, current, and resistance in an electrical circuit is valid. This experiment demonstrates the essential qualities of Ohm's Law and how useful it is in real-world circuits. If we were to do this lab again, we would recommend trying different shapes on the conductive plates and working with a different voltage level. Overall, this experiment enhanced our understanding of fundamental electrical principles and also demonstrated the relationship between voltage and equipotential surfaces in a real-world scenario.

6. **RAW DATA**

Experiment One

1)

	V	I
1	0.45	0.82
2	0.71	1.29
3	10.4	1.90
4	13.6	2.48
5	17.7	3.21

Experiment Two

2) $V_{R1} = 4V$ $I = 0.74A$

$V_{R2} = 3.8V$ $I = 0.73A$

$V_{R3} = 4V$ $I = 0.74A$

$V_{tot} = 11.8V$ $I = 0.74A$

Experiment Three

3) $A_{R1} = 2.18\ A$ $V = 12\ V$

A_{R2} $2.18A$ $V = 12V$

$A_{R3} = 2.18A$ $V = 12V$

$A_{tot} = 7.2A$ $V = 11.9V$

Experiment Four

4) $V_{tot} = 12\ V$ $I_{tot} = 2.64\ A$

$V_A = 9.4V$ $I_1 = 1.71\ A$

$V_B = 9.4\ V$ $I_2 = 0.95A$

$V_{AB} = 9.4\ V$ $I_3 = 2.64A$

$V_c = 2.5V$ $I_{12} = 2.64A$

$R_1 = 5k\ \Omega$ $R_2 = 10k\ \Omega$

$R_3 = 1k\ \Omega$

Experiment Five

5)

V	I
2.2	0.50
2.5	0.77
2.7	0.93
2.9	1.15
3.2	1.44