Fundamental Circuit Theory Laws
&
Non-Linear Resistances
Experiment 1 & 2

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Introduction

The purpose of lab 1 was to allow students to get familiar with the lab materials such as the multimeter, power source, breadboard and the various elements used in the breadboard. In addition to this, each experiment has their own purpose.

Experiment 1 focuses on verifying Kirchoff Current Law (KCL), Kirchoff Voltage Law (KVL), current divider theorem, voltage divider theorem and finding equivalent resistances. These laws and theorems will be verified using a simple circuit consisting of one resistor in series with two resistors in parallel. KCL states that the sum of all current flowing into a node is equal to all current flowing out of the same node. KVL states that in a closed circuit the sum of all voltages is zero.

Experiment 2 focuses on non-linear resistances. The non-linear resistance is observed through the use of a lamp that is provided within our lab kit. The behavior of this non-linear resistance is observed by varying the voltage supplied to the lamp and recording the resulting resistances.

Verification of Basic Laws and Derived Utilities

The circuit in figure 1 must be replicated in order to continue on in the experiment.

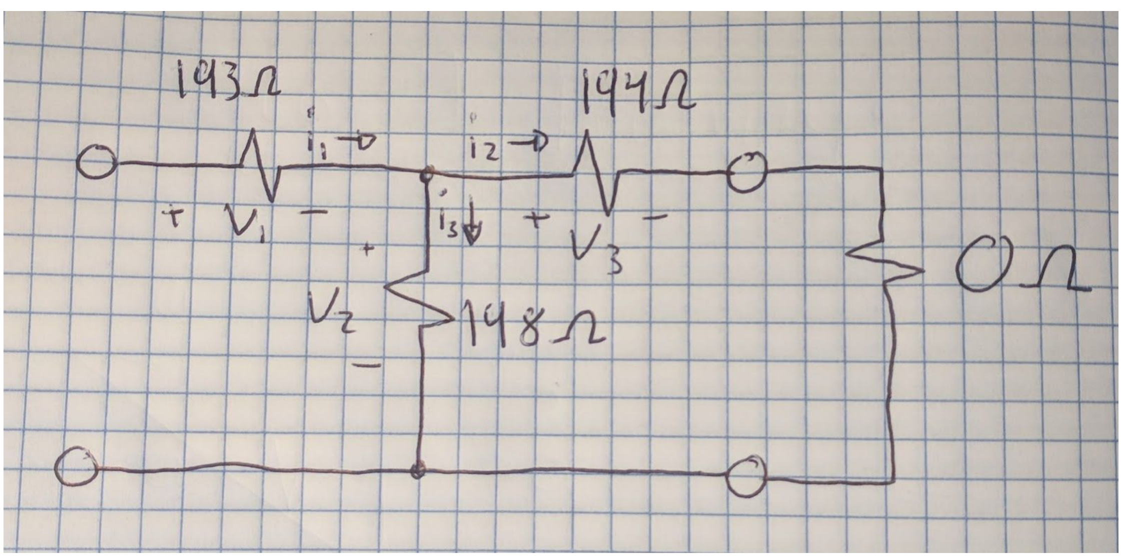

Figure 1

Resistor Circuit Schematic for Lab 1, Experiment 1

The voltage was set to a constant 10 Volts. R load was set to 0. This was done by using a wire rather than a resistor. The actual resistance of the “200” Ohm resistors were found using the multimeter. Then the voltage drop across the resistor was recorded, followed by the current through the resistor. All of these results can be seen in the following tables, **Figure 2, Figure 3, and Figure 4**, respectively.

Resistor	Nominal (Ohm)	Measured (Ohm)	Absolute Difference (Ohm)	Relative Difference
Rt	300	290.99	9.01	3%
R1	200	193	7	3.5%
R2	200	194	6	3%
R3	200	198	2	1%

Figure 2

Values of the Resistors for the Circuit for Lab 1, Experiment 1

Voltage	Value (V)
Vs	10
V1	-6.66
V2	-3.33
V3	-3.33

Figure 3

Values of Voltage Drop Across Resistors for the Circuit for Lab 1, Experiment 1

Current	Value (mAmps)
I1	32.89
I2	16.46

I3	16.46

Figure 4

Values of Currents Across Resistors for the Circuit for Lab 1, Experiment 1

Power	Watts (W)
Ps	.34
P1	-.219
P2	-.06
P3	-.06

Figure 4

Values of Power Across Resistors for the Circuit for Lab 1, Experiment 1

Current Divider Theorem for equivalent resistances means that the current will be divided up by the number of resistors in parallel. The equation for Current Divider Theorem is as follows: $I_n=(I_{total}R_{total})/R_n$. This can be observed by 32.89 mAmps flowing through R1 is split between two equivalent resistances. The current through these two resistances is measured to be 16.46 mAmps. This current gives us a total of 32.92 mAmps. With only a .09% difference between the theoretical value (32.91 mAmps) and the experimental value (32.92 mAmps) this error can be attributed to a variation in the multimeter. What I mean by this is that the multimeter value displayed is not consistent. For current the multimeter would fluctuate with a value between 32.88 and 32.90 or 16.45 and 16.47 respectively. The slight variation of the resistor tolerances means that there is not a perfect division of current among the branches. Thus verifying Current Divider Theorem at the three branch node.

Voltage Divider Theorem for equivalent resistances means that the voltage will be divided up by the number of resistors in series. The equation for Voltage Divider Theorem is as follows: $V_{out}=(V_{in}R_n)/R_{total}$. This can be observed by 10 Volts provided by the power source flowing through the circuit. The voltage across R1 is -6.66 Volts. The voltage across R1 or R2 is measured at -3.33 Volts. Thus no matter which loop you take the total voltage in the circuit is extremely close to zero. The result is only a .1% difference between the experimental value (9.99 Volts) and the theoretical value (10 Volts). This can be attributed to a variation in the multimeter. What I mean by this is that the multimeter value displayed is not consistent. For current the multimeter would fluctuate with a value between -6.65 and -6.67 or -3.32 and -3.34 respectively. The slight variation of the resistor tolerances means that there is not a perfect division of current among the branches. Thus verifying the Voltage Divider Theorem.

KCL states that the sum of all current flowing into a node is equal to all current flowing out of the same node. KCL can be verified by observing the total current going into the parallel resistors (32.89 mAmps) and the total current leaving the two parallel resistors (32.92 mAmps). With only a .09% difference between the theoretical value (32.91 mAmps) and the experimental value (32.92 mAmps) this error can be attributed to a variation in the multimeter. What I mean by this is that the multimeter value displayed is not consistent. For current the multimeter would fluctuate with a value between 32.88 and 32.90 or 16.45 and 16.47 respectively. The slight variation of the resistor tolerances means that there is not a perfect amount of current entering and exiting the node. Thus verifying KCL.

KVL states that in a closed circuit the sum of all voltages is zero. A closer look can be taken at either of the two closed loops in this circuit. The sum of the voltages across R1 (-6.66V) and R2 (-3.33V) is -9.99V. When this voltage is added to the voltage supplied by the power source (10V) the result is .01. The result is only a .1% difference between the experimental value (9.99 Volts) and the theoretical value (10 Volts). This can be attributed to a variation in the multimeter. What I mean by this is that the multimeter value displayed is not consistent. For current the multimeter would fluctuate with a value between -6.65 and -6.67 or -3.32 and -3.34 respectively. The slight variation of the resistor tolerances means that there is not a perfect division of current among the branches. However, KVL is still verified despite this percent error.

Power conservation can be seen by comparing the power emitted by the power source to the power dissipated by each resistor. When subtracting the power dissipated by each resistor (-.219W, -.06W, and -.06W) from the power generated by the power source (.34W) the total power is equal to .001. This result is only .29% off of our expected value of zero. The variation of previous measurements would come into play when calculating power. It would also make sense that this percent error would be the highest because we are multiplying the previous values together in order to calculate power. Thus exponentially increasing the chance for error.

Non-Linear Resistances

For this experiment we will compare linear no nonlinear resistances. A fixed 200 Ohm linear resistor will be used to compare to a light with a non-linear resistance. The linear resistance for the 200 Ohm resistor can be soon in **Figure 5.** The non-linear light bulb resistance changes as voltage changes.This can be observed by the chart in, **Figure 7,** below.

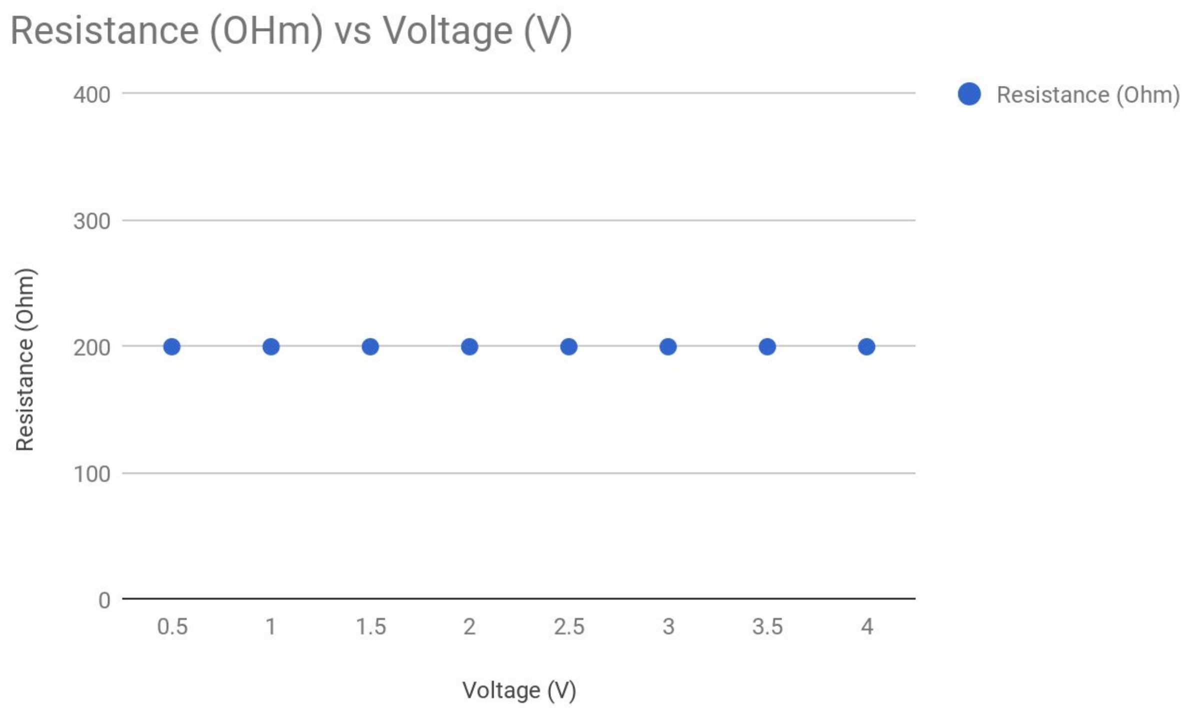

Figure 5

Graph displaying a voltage and linear resistance relationship for Lab 1, Experiment 2

How these two values affected the current can be better observed in the table, **Figure 7,** below.

Voltage (V)	Resistance (Ohm)	Current (mA)
0	0	0
.5	198	2.525
1	198	5.05
1.5	198	7.575

2	198	10.101
2.5	198	12.626
3	198	15.151
3.5	198	17.676
4	198	20.202
4.5	198	22.727
5	198	25.252

Figure 8

Table displaying the relationship between resistance, voltage, and current for Lab 1, Experiment 2

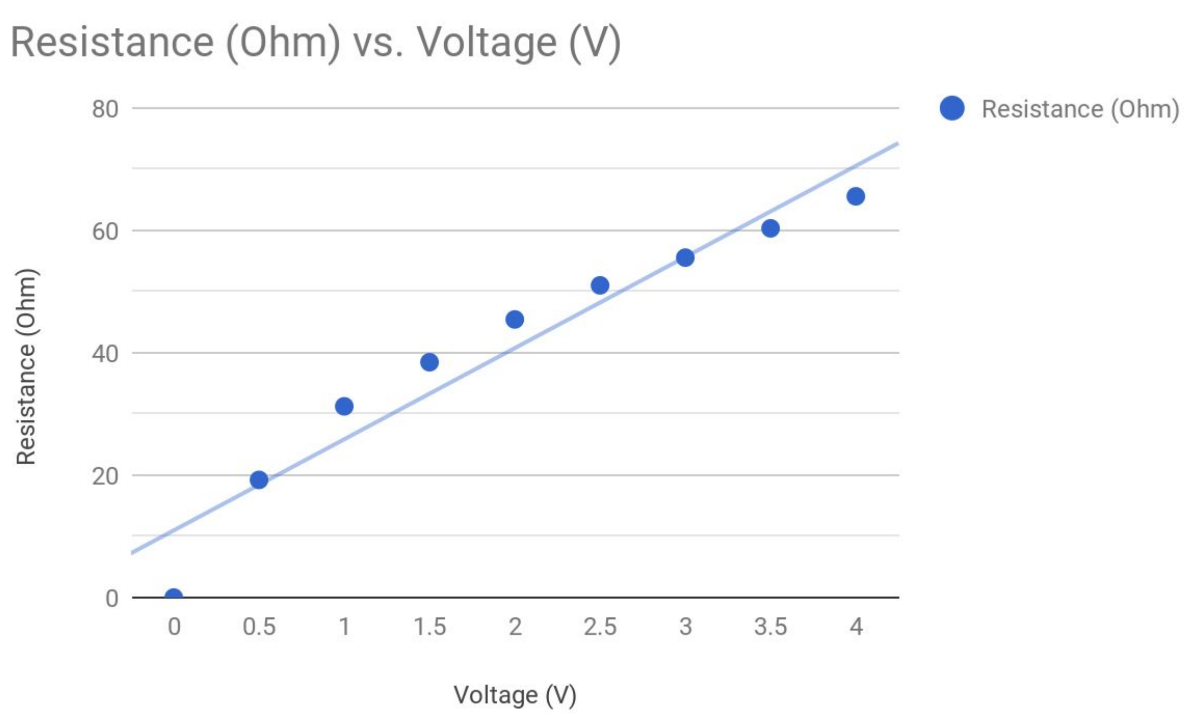

Figure 7

Graph displaying a voltage and non-linear resistance relationship for Lab 1, Experiment 2

How these two values affected the current can be better observed in the table, **Figure 8,** below.

Voltage (V)	Resistance (Ohm)	Current (mA)
0	0	0
.5	19.23	26
1	31.25	32
1.5	38.46	39
2	45.45	44
2.5	51.02	49
3	55.55	54
3.5	60.34	58
4	65.57	61
4.5	Burn Out	Burn Out
5	XXXXX	XXXXX

Figure 8

Table displaying the relationship between resistance, voltage, and current for Lab 1, Experiment 2

From **Figure 7** and **8** we can see that the light bulb resistance is nonlinear. The resistance increases as we increase the voltage. This can be proven quantitatively by observing the difference between the linear solid blue trend line and the nonlinear resistance. If the resistance were linear it would follow the trendline.

Superposition theorem states that the current and voltage for any element in the circuit is the sum of the currents and voltages produced independently. We know that some constant times the voltage equals the some constant times IR (kV=kIR). When we use values obtained in the linear resistor we find this equation to be true.However, when using numbers obtained using the nonlinear resistor this equation does not hold up. Thus the sum of the currents and voltages independently can not equal the current and voltages obtained together. Thus proving analytically that the lightbulb does not obey superposition, but the linear resistance does.

Conclusion

I had an extremely successful lab in lab 1. I became very familiar with the in lab equipment as well as my breadboard. I was able to complete all portions of both experiment 1 and 2.

For experiment 1 I successfully verified KCL as well as KVL. I noted that the resistances for my 3 200 Ohm resistors varied slightly. This could be due to the age of the resistor, inconsistencies in the material, or inconsistencies in how I was measuring the resistances. I was able to verify the law of power conservation by showing that the total power is 0. Lastly, I was able to verify the current and voltage divider theorems.

For experiment 2 I was able to create a two dimensional graph that displayed that varying conductance based upon the differing DC voltage. I also analyzed superposition and reasoned as to why this would not apply no non-linear resistances.

This was a great lab, I accomplished and learned a lot.