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UNIVERSITY OF
NEW BRUNSWICK

ELECTRICAL AND COMPUTER ENGINEERING
Room D36, Head Hall

LABORATORY / ASSIGNMENT / REPORT COVER PAGE

Course # : _____ECE2701_____________ Experiment # or Assignment # ___Lab 1___

Date: ____Friday, October 11________ Course Instructor: ____Howard Li____________

Title: _______ECE2701 Experiment 1 – An Examination of Kirchoff's Laws____________
(if applicable)

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Comments:

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Initials of Marker

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Contents

Abstract

This experiment examines Kirchoff's Voltage and Current Laws; validating their claims and improving our understanding of their characteristics. Kirchoff's Laws are stated as $\sum v_i = 0; \sum i_i = 0$. To prove this, the Test Network depicted in figure 1 was built and voltages across each element of the circuit was measured. Through these measurements, Kirchoff's Voltage Law held for this experiment, as the sum of the voltages around the loops was approximately 0. Kirchoff's Current Law is validated by summing the currents at any node. Ohm's law facilitates a more accurate calculation of currents through resistive elements than introducing a shunt. Using Ohm's law, currents through the resistors were accurately calculated, and Kirchoff's Current Law was successfully proven, as the sum of currents at Node b was approximately 0 [1].

1 Introduction

The objective of this experiment was to examine Kirchoff's Voltage and Current Laws, and prove their validity. By conducting this experiment we enhanced our understanding of Kirchoff's laws by replicating the results of equations we commonly use for circuit analysis. This leads to a deeper understanding of the topic and practical knowledge of how to implement these laws in experiments [1]. To complete this experiment properly, prerequisite knowledge was required, such as: understanding Kirchoff's Laws and Mesh Analysis. These laws are so crucial, due to their integral part in basic circuit analysis. Kirchoff's Laws demonstrate in both theory and application that the sum of voltages around a loop is equal to zero and the sum of current into a node is equal to the sum of current out of that node. The equations $\sum v_i = 0$ and $\sum i_i = 0$, clearly state that the summation of voltages around a loop equal to zero. This means that the even though the loads in the circuit drop voltage the net voltage is not negative, hence, there must be a source or sources of voltage to contract the negative net voltage [2] [3]. During this experiment we observed that Kirchoff's Laws held true and our results are proof of this, for the sum of voltages and currents around each loop are experimental values were essentially 0, factoring in the our sources of error, we can confidently state that over the course of this experiment Kirchoff's Laws functioned as intended [1].

2 Experiment

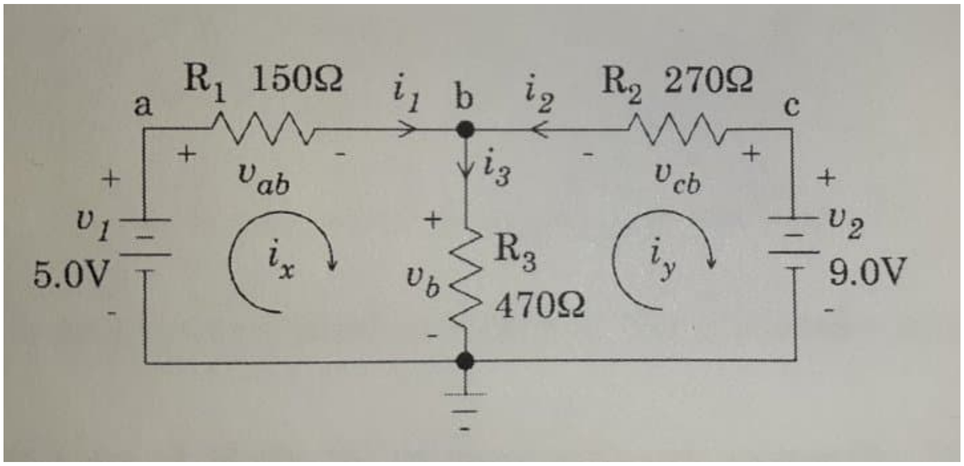

Figure 1: Schematic Diagram of the Test Network [1]

2.1 Theory and Procedure

2.1.1 Theory

Energy in a closed system is always zero. In other words, the energy entering a closed system is the same as the energy being consumed by the system [3]. This is known as the *Conservation Law of Energy*, and Kirchoff's Laws frames this in terms of electrical circuits. Kirchoff's Laws state that the sum of the voltages around any loop in a circuit equal zero, and the sum of currents about any node in a circuit equal zero. Represented as an equation, this becomes $\sum v_i = 0; \sum i_i = 0$ [2].

2.1.2 Procedure

Before any procedure was carried out in the lab, the expected values of voltage and current for each component was calculated. This is shown at the end of the report in the *Appendicies* section.

- The DMM was used to measure the actual resistance of the three resistors.
- The ciruit in Figure 1 was constructed using the power supply unit, resistors and wires at the lab station. The values of $V_1 and V_2$ were recorded in Table 2 measured column.

- Once the source voltages were recorded, the voltages across resistors $R_1, R_2 and R_3$ were measured and recorded in Table 1.
- Using the measured values from Table 1, the $\sum v_i$ around each loop was calculated. In Table 3, $\sum v_{ix}$ and $\sum v_{iy}$ were recorded. Finally, their relavence to Kirchoff's Voltage Law was commented on.
- 5. Using Ohm's Law, the current in each branch of the circuit was calculated as i_1, i_2 and i_3 and recorded in Table 4. Using Kirchoff's Current Law, the $\sum i_i$ of node "b" was calculated. Finally, the validity of Kirchoff's Current Law was commented upon.

Current was calculated based on the voltage drops across the components as this produced a more accurate measurement of current, when compared to inserting a current shunt into the circuit. The validity of Kirchoff's laws was done by comparing the sums of the measured voltages and currents about the loops and nodes, respectively, to zero. Under the situation that the sums are zero, Kirchoff's laws are met, which was the case.

2.2 Apparatus

The instruments used in this lab are listed below [1]:

Elenco XP-720 DC Power-Supply A dual output DC power-supply used to deliver power to the circuit under test. This device included a fixed $5V$ rail, and a variable output rail, which was set to $9V$ in this experiment.

Banana Connectors Seven Banana Connectors were required. Five of these were used to make electrical connections between the components of the Test Network, and the remaining two were used as probes on the multi-meter.

Digital Multimeter To measure the resistances of the resistor components and the voltage voltage drops across them, a single auto-scaling multi-meter was used.

Resistor Blocks For convenience over bare resistor components, resistor blocks were used in the Test Network. These consisted of a resistor connected to two female banana plugs, all embedded within a small block of wood. Three different resistor blocks were needed to build the Test Network, these consisted of the following values:

- 150Ω - R1
- 270Ω - R2
- 470Ω - R3

These pieces of equipment slightly vary from that listed in the lab manual. Instead of resistor blocks, single resistors are listed in the lab manual, which do not contain female banana plugs. In addition, banana connectors were completely omitted from the lab manual. This discrepancy introduced resistances which the lab procedure did not account for, which introduced errors in the results [1].

2.3 Calculations and Results

Using the multimeter, the resistance values of the resistor blocks were directly measured. This accounted for the manufacturing tolerances of the resistors as well as the additional resistance introduced from the banana plugs [1] [2]. Measuring was done while the resistor blocks were at room temperature and pressure. As a result, although this provided more accurate resistor values, it did not account for temperature fluctuations caused by power dissipation in circuit. The results of this measurement process are listed in table 1.

Table 1: Network Component Values [1]

Resistor	**Listed Value**	**Measured Value**
R1 (Ω)	150	150.0
R2 (Ω)	270	268.3
R3 (Ω)	470	465.7

Once the components were configured in the Test Network, and the network was powered with both rails, the voltage drops across components was measured. Knowing the voltage drops across the components, and the component values, the currents flowing through each component was calculated. Using this strategy, no additional shunt resistance was inserted in series with the component, allowing for a more accurate current measurement [1]. Table 2 depicts the measured results of this procedure and the calculated voltages in the Test Network.

Table 2: Test Network Voltages [1]

Quantity	**Calculated Value**	**Measured Value**
$v_1(V)$	5.000	5.064
$v_{ab}(V)$	-0.334	-0.3037
$v_b(V)$	5.334	5.367
$v_{cb}(V)$	3.666	3.638
$v_2(V)$	9.000	9.00

Calculations of the currents through each component are shown below:

$$i_1 = v_{ab}/R_1 = -0.3.037V/150.0\Omega = -2.024mA$$
$$i_2 = v_{cb}/R_2 = 3.638V/268.3\Omega = 13.56mA$$
$$i_3 = v_b/R_3 = 5.367V/465.7\Omega = 11.42mA$$

The results of applying Kirchoff's Voltage Law to the two meshes of the network:

Table 3: Kirchoff's Voltage Law Check

Quantity	$\sum v_i(V)$	**Equation**	**Comment**
$i_x Mesh$	-0.063	$v_1 + v_{ab} + v_b$	$\sum v_i \approx 0V \Rightarrow$ KVL holds
$i_y Mesh$	-0.006	$v_2 + v_{cb} + v_b$	$\sum v_i \approx 0V \Rightarrow$ KVL holds

The results of applying Kirchoff's Current Law at Node b are shown in table 4.

Table 4: Kirchoff's Current Law Check

Quantity	$\sum i_i(mA)$	**Equation**	**Comment**
Node b	-0.086	$i_1 + i_2 + i_3$	$\sum i_i \approx 0mA \Rightarrow$ KCL holds

2.3.1 Analysis

Tables 3 and 4 illustrate that both Kirchoff's current and voltage laws hold. Again, these laws are that the sum of the currents at any node, and the sum of the voltages around any loop are, respectively, zero. Although the results of our experiment are not exactly zero, they are extremely close to zero, and therefore validate both laws [2]. The deviations from zero that we expected are well within the accuracy of our apparatus, and the errors causing any discrepancies are discussed below.

3 Discussion

Firstly we measured our resistors for their actual resistance, R_1 was exactly 150.0Ω, whereas $R_2 = 268.3\Omega$ a 0.6296% error and $R_3 = 465.7\Omega$ a 0.9149% error based off of the given values of R_1, R_2 and R_3. Following that our measured values for V_{ab}, V_b and V_{cb} were close to the calculated values. $V_{ab} = -0.3037V$ a percent error of 9.07%, $V_b = 5.367V$ a percent error of 0.6187% and $V_{cb} = 3.638V$ a percent error of 0.7638%. Percent error calculated by comparing calculated and measured values from *Table 2* using the equation $|V_{calculated} - V_{measured}|/V_{calculated}$. From these voltages, we extrapolated that the $\sum V_i \approx 0$ our measured values (shown in *Table 3*) were nearly 0 leading us to conclude that Kirchoff's Voltage Law held. After measuring out voltage drops we used our knowledge of Ohm's Law and Kirchoffs's Current Law to firstly calculate i_1, i_2 and i_3 which had percent errors of 9.238%, 0.2950% and 0.6167% respectively (values shown in *Table 4*). Using these values we calculated that the $\sum i_{in} \approx \sum i_{out}$ accounting for our sources of error we were able to state that Kirchoff's Current Law held. Along with the aforementioned sources of error, we also recognized that we measured the voltage across out power supply was only carried out once - this value may have fluctuated as the load was placed on the circuit, since all components, including the power supply changed temperature. As well as neglecting the voltage drops across each of the connections in the circuit, we did not account for the variation of the resistance of the resistors based on their positive temperature coefficient [2].

4 Conclusion

In this experiment, Kirchoff's voltage and current law were examined using a Test Network of resistors, $5V$ and $9V$ rails from a DC power-supply, a Digital Multimeter, and banana connectors [1]. The voltage drop across each resistor of a known value was measured and used to calculate the current through each component. Next, to prove Kirchoff's Voltage and Current Laws ($\sum i_i = 0; \sum v_i = 0$),the voltages around each loop and the currents about the centre node were respectively summed. It was found that the sum of the voltages around the two loops of interest were $-0.063V$ and $-0.006V$, and the sum of the currents about Node b was $-0.086mA$ [1]. Although these results are not exactly 0, they are extremely close, and lie well within the accuracy of the apparatus. The discrepancies between our results and the expected value of 0 can be attributed to the systematic errors in the experiment, as the resistance of all connections was not accounted for, and the Digital Multimeter had a finite accuracy [1]. To improve these results, a more accurate multimeter could be used and the intrinsic properties of the connections accounted for. As a result, Kirchoff's Voltage and Current Laws were proven and better understood through an accurate examination of their characteristics.

5 Summay of Roles

Justen G. Di Ruscio

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3. Experiment
4. Conclusion
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Stephen W.W. Cole

1. Abstract
2. Introduction
3. Discussion
4. Procedure

References

[1] I. Veach, *EE2701 Experiment 1. An Examination of Kirchoff's Laws*, September 2011.

[2] H. Li, "Ece2701 lectures," September 2019.

[3] N. Hall, "Conservation of energy," May 2015.

[4] H. Li, "Lab marking scheme," Winter 2008. EE3312.

6 Appendicies

6.1 Prelabs

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Course No. ECE2701 | Assignment No. 1 | Date 11/09/2019

Problem No. | By [signature]

$V_{ab} =$

$V_b = 5.6v$

$V_{cb} =$

$i_1 =$

$i_2 = 0.12A$

$i_3 =$

$R_1 = 150\Omega$

$R_2 = 270\Omega$

$R_3 = 470\Omega$

$V_1 = 5.0V$

$V_2 = 9.0V$

$V_a = 5.0V$

$V_b = 9.0V$

$$\frac{(V_a - V_b)}{150\Omega} + \frac{(V_c - V_b)}{270\Omega} = \frac{V_b}{470\Omega}$$

$V = IR$

$$\frac{5.0V - V_b}{150\Omega} + \frac{9.0V - V_b}{270\Omega} = \frac{V_b}{470\Omega}$$

$$\frac{1}{30} - \frac{V_b}{150\Omega} + \frac{1}{30} - \frac{V_b}{270\Omega} = \frac{V_b}{470\Omega}$$

$$\frac{1}{15} = \frac{V_b}{470\Omega} + \frac{V_b}{270\Omega} + \frac{V_b}{150\Omega}$$

$$\frac{1}{15} = Vb(0.0125)$$

$Vb = 5.334v$

$$i_3 = \frac{5.334}{470\Omega} = 0.01135A \text{ or } 11.35mA$$

$V_{ab} = (V_a - V_b) = 5.0V - 5.334V = -0.334$

$V_{cb} = (V_c - V_b) = 9.0v - 5.334v = 3.666v$

$$i_1 = \frac{-0.334v}{150\Omega} = -0.00223A$$

$$i_2 = \frac{3.666v}{270\Omega} = 0.0136A$$

$i_3 = 0.01137$

.1764%

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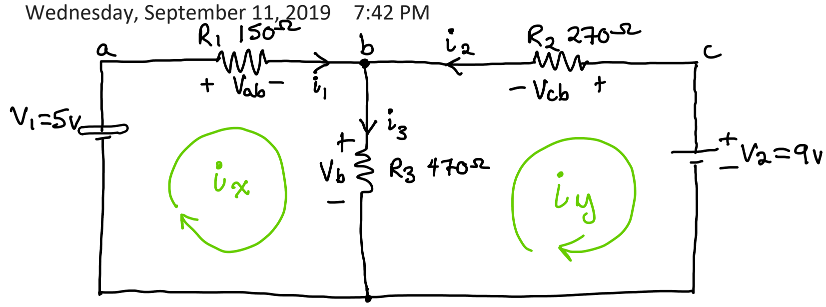

① $V_1 = V_{ab} + V_b$

$V_1 = i_x R_1 + i_x R_3 - i_y R_3$

$V_1 = i_x (R_1 + R_3) - i_y R_3$

$$\frac{V_1 + i_y R_3}{R_1 + R_3} = i_x$$

② $V_2 = -i_y R_2 - i_y R_3 + i_x R_3$

$V_2 = -i_y (R_2 + R_3) + i_x R_3$

$$\frac{V_2 - i_x R_3}{R_2 + R_3} = -i_y$$

$$i_y = \frac{i_x R_3 - V_2}{R_2 + R_3}$$

Subbing ① into ②:

$$i_y = \left[\left(\frac{V_1 + i_y R_3}{R_1 + R_3}\right) R_3 - V_2\right]\left(\frac{1}{R_2 + R_3}\right)$$

$$i_y = \frac{V_1 R_3 + i_y R_3^2 - V_2 (R_1 + R_3)}{(R_1 + R_3)(R_2 + R_3)}$$

$$i_y - \frac{i_y R_3^2}{(R_1 + R_3)(R_2 + R_3)} = \frac{V_1 R_3 - V_2 (R_1 + R_3)}{(R_1 + R_3)(R_2 + R_3)}$$

$$i_y \left(1 - \frac{R_3^2}{(R_1 + R_3)(R_2 + R_3)}\right) = \frac{V_1 R_3 - V_2 (R_1 + R_3)}{(R_1 + R_3)(R_2 + R_3)}$$

$$i_y \frac{(R_1 + R_3)(R_2 + R_3) - R_3^2}{\cancel{(R_1 + R_3)}\cancel{(R_2 + R_3)}} = \frac{V_1 R_3 - V_2 (R_1 + R_3)}{\cancel{(R_1 + R_3)}\cancel{(R_2 + R_3)}}$$

$$i_y = \frac{V_1 R_3 - V_2 (R_1 + R_3)}{(R_1 + R_3)(R_2 + R_3) - R_3^2} = \frac{(5V)(470\Omega) - (9V)(150\Omega + 470\Omega)}{(150\Omega + 470\Omega)(270\Omega + 470\Omega) - (470\Omega)^2}$$

$$i_y = -13.57713325 mA$$

Solving for i_x:

$$i_x = \frac{(5V) + (-13.58 \times 10^{-3} A)(470\Omega)}{(150\Omega + 470\Omega)} = -2.227827 mA$$

By inspection:

$i_1 = i_x = -2.227827 mA$ $\quad$ $i_2 = -i_y = 13.57713325 mA$

$\approx -2.23 mA$ $\quad$ $\approx 13.58 mA$

$$i_3 = i_1 + i_2 = (-2.23mA) + (13.58mA) = 11.3493064mA$$

$$\approx 11.35mA$$

Voltages:

$$V_{ab} = i_1 R_1 = (-2.23 \times 10^{-3} A)(150\Omega) = -0.334174V$$

$$\approx -0.334V$$

$$V_{cb} = i_2 R_2 = (13.58 \times 10^{-3} A)(270\Omega) = 3.6658V$$

$$\approx 3.666V$$

$$V_b = i_3 R_3 = (11.35 \times 10^{-3} A)(470\Omega) = 5.33417V$$

$$\approx 5.334V$$