Kirchhoff’s Rules

Lab Report 006

Professor Todd R. Gelbord
Report Written By Galib F. Rahman
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Objective

The objective of this laboratory exercise is to apply Kirchhoff's rules to multiloop circuits, verify the validity of said rules via experimentation, and observe the comparison of theoretical values with values deduced from Ohm's law.

Theory

Gustav Kirchhoff, a German physicist, developed techniques to analyze multiloop circuits. This enabled the analysis of many resistive networks that could not be simplified to series-parallel combinations nor direct evaluation with Ohm's law.

Kirchhoff's *Junction Rule* states that the (algebraic) sum of the current entering a junction must equate to zero. The *Junction Rule* is founded on the basis of the conservation of electric charge. In other words, the charges entering a junction must equate to the total charges leaving, said junction. Kirchhoff's *Loop Rule* states that the (algebraic) sum of the potential differences (voltages) in any given loop, (inclusive of the electromotive forces and resistive electrical components, must equate to zero. The *Loop Rule* is founded on the basis of the conservation energy within a circuit. As a charge moves along a loop the sum of the potential rises is equivalent to the sum of the potential drops.

Materials

Two Low Voltage DC Power Supplies	Voltmeter
Four Resistor Boxes	Two Switches
Ammeter	Wires

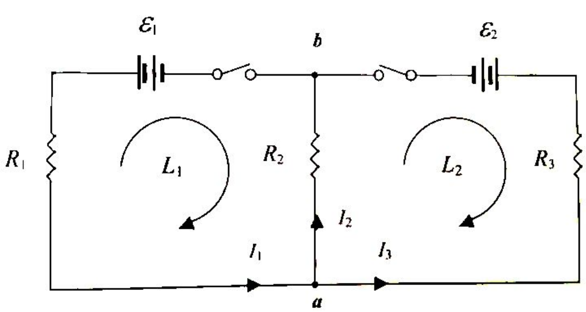
Data

Run		Resistance R,Ω	Current Experimental I_{exp},A	Current Theoretical $I_{theoretical}$,A	% Error of $I_{experiment}$ compared to $I_{theoretical}$	Voltage across Resistor V, V	Current in R from Ohm's Law	% Error of I_{Ohm} compared to $I_{theoretical}$
			$\mathcal{E}_1$= 6 Volts		$\mathcal{E}_2$= 12 Volts			
Run 001	R_1	1000	-.0001	-.0029	96.5	.105	.0001	96.5
	R_2	800	.0072	.0079	8.86	6.13	.0076	3.8
	R_3	700	-.0072	-.0082	12.2	5.4	.0077	6.1

Run		Resistance R,Ω	Current Experimental I_{exp},A	Current Theoretical $I_{theoretical}$,A	% Error of $I_{experiment}$ compared to $I_{theoretical}$	Voltage across Resistor V, V	Current in R from Ohm's Law	% Error of I_{Ohm} compared to $I_{theoretical}$
			$\mathcal{E}_1$= 6 Volts		$\mathcal{E}_2$= 12 Volts			
Run 001	R_1	1000	.00465	.005	7	4.7	.0047	6.38
	R_2	800	.00209	.002	4.5	1.32	.0017	17.6
	R_3	700	.00976	.010	2.4	6.83	.0098	2
	R_4	700	.00670	.007	4.28	4.7	.0067	4.48

Procedure

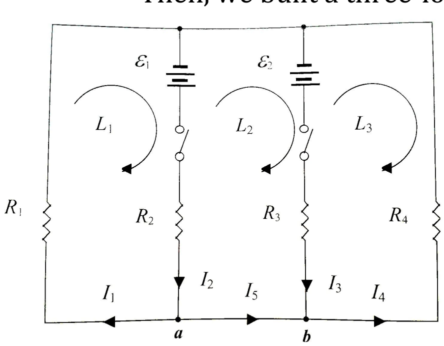
First we built the circuit as shown below:



Where R_1= 1000 Ω
R_2= 800 Ω
R_3= 700 Ω
ε_1= 6 V
ε_2= 12 V

Then we measured the currents I_1,I_2, and I_3 with an ammeter and calculated the currents using a system of equations utilizing Kirchhoff's *Junction* and *Loop* Rules, recording both values onto the data table.

Then, we built a three-loop circuit as shown below:



Where R_1= 1000 Ω
R_2= 800 Ω
R_3=R_4= 700 Ω
ε_1= 6 V
ε_2= 12 V

Then we measured the currents I_1,I_2,I_3,I_4, and I_5 with an ammeter and calculated the currents by solving a system of equations with MATLAB. Afterwards, we recorded onto the data table & compared both values.

Computations & Sources of Error

Current Equations for the three-loop circuit:

$$I_1 = \frac{\mathcal{E}_1 R_3 \mathrm{R}_4 + \mathcal{E}_2 R_2 \mathrm{R}_4}{R_1 R_2 \mathrm{R}_3 + R_1 R_2 \mathrm{R}_4 + R_1 R_3 \mathrm{R}_4 + R_2 R_3 \mathrm{R}_4}$$

$$I_2 = \frac{\mathcal{E}_1 R_1 \mathrm{R}_3 + \mathcal{E}_1 R_1 \mathrm{R}_4 - \mathcal{E}_2 R_1 R_4 + \mathcal{E}_1 R_3 \mathrm{R}_4}{R_1 R_2 \mathrm{R}_3 + R_1 R_2 \mathrm{R}_4 + R_1 R_3 \mathrm{R}_4 + R_2 R_3 \mathrm{R}_4}$$

$$I_3 = \frac{\mathcal{E}_2 R_1 \mathrm{R}_2 - \mathcal{E}_1 R_1 \mathrm{R}_4 + \mathcal{E}_2 R_1 R_4 + \mathcal{E}_2 R_2 \mathrm{R}_4}{R_1 R_2 \mathrm{R}_3 + R_1 R_2 \mathrm{R}_4 + R_1 R_3 \mathrm{R}_4 + R_2 R_3 \mathrm{R}_4}$$

$$I_4 = \frac{\mathcal{E}_1 R_1 \mathrm{R}_3 + \mathcal{E}_2 R_1 \mathrm{R}_2}{R_1 R_2 \mathrm{R}_3 + R_1 R_2 \mathrm{R}_4 + R_1 R_3 \mathrm{R}_4 + R_2 R_3 \mathrm{R}_4}$$

$$I_5 = \frac{\mathcal{E}_1 R_1 \mathrm{R}_3 + \mathcal{E}_1 R_1 \mathrm{R}_4 - \mathcal{E}_2 R_1 R_4 - \mathcal{E}_2 R_2 \mathrm{R}_4}{R_1 R_2 \mathrm{R}_3 + R_1 R_2 \mathrm{R}_4 + R_1 R_3 \mathrm{R}_4 + R_2 R_3 \mathrm{R}_4}$$

Given,

R_1= 1000 Ω
R_2= 800 Ω
R_3=700 Ω
R_4= 700 Ω
ε_1= 6 V
ε_2= 12 V

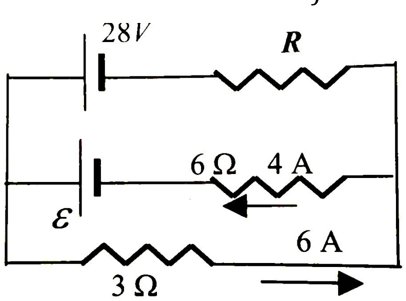
We deduced,

I_1= .005 A
I_2= .002 A
I_3= .010 A
I_4= .007 A
I_5=-.003 A

A possible source for error in this laboratory in this laboratory exercise may include the resistive values utilized in calculations. When recording the data, we did not physically measure the resistance of each resistor with an ohmmeter, and relied on the nominal values.

Questions

1. In the circuit shown in Fig 9.4 (below), find the current in the resistor, the resistance *R* and the unknown *emf* ε .



$$-\mathcal{E} + I_2(6\Omega) + I_1(3\Omega) = 0$$

$$-\mathcal{E} + 4A(6\Omega) + 6A(3\Omega) = 0$$

$$\boxed{\mathcal{E} = 42\ \mathrm{V}}$$

$$I_1 = I_2 + I_3$$

$$I_1 = 6\ A$$

$$I_2 = 4\ A$$

$$I_3 = 2\ A$$

$$-28\ V + I_3(R) - I_2(6\Omega) + \mathcal{E} = 0$$

$$-28\ V + 2A(R) - 4A(6\Omega) + 42\mathrm{V} = 0$$

$$2A(R) = 10\ \mathrm{V}$$

$$\boxed{(R) = 5\ \Omega}$$

Conclusion

In this laboratory exercise we verified the validity of Kirchhoff's *Loop* and *Junction Rules* via experimentation. We compared the measured current values to the current values deduced from the application of Kirchhoff's rules, and observed that both values were close with respect to one another. We also learned about the sign conventions one must use when applying said rules with respect to the electrical components and the direction of current flow. Overall, Kirchhoff's rules, proved to be an effective technique in deducing current and voltages when Ohm's law proved difficult to apply directly.