Experiment 8: Series and Parallel Circuits

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Abstract

This experiment concentrates on series and parallel circuits. The first activity made use of a series circuit and yielded a 4.84% error for total resistance while the second activity, which made use of a parallel circuit, yielded a 0.83% total resistance error. An internal resistance of 2.4Ω was obtained in the third activity. The fourth activity determined the total internal resistance of cells in a series and a parallel circuit, which were 11.89Ω and 3.70Ω, respectively.

1. Introduction

A circuit, simply speaking, is a closed loop through which electricity can flow. It is composed of individual electronic components, such as resistors, transistors, capacitors, inductors and diodes, connected by conductive wires or traces through which electric current can flow. Resistors limit the flow of electrons through a circuit. A closed circuit allows for an uninterrupted flow of electricity from the source of power, passing through the conductor or wire, towards the load and back again to the source of power. The two most common types of closed circuits are the series and parallel circuits.

In a series circuit, there is only one path for electrons to flow in a counterclockwise direction. A series circuit has three resistors (labeled R_1, R_2, and R_3), connected in a long chain from one terminal of the battery to the other. Meanwhile, in a parallel circuit all components are connected across each other, forming exactly two sets of electrically common points. A parallel circuit also has three resistors, but this time they form more than one continuous path for electrons to flow. Each individual path is called a branch.

Components and wires are coded with colors to identify their value and function. A table of values is found in the laboratory manual. The colors brown, red, green, blue and violet are used as tolerance codes on 5-band resistors only (5-band resistors use a colored tolerance band). The blank or 20% band is only used with the 4-band code, which is 3 colored bands plus a blank band.

An ammeter is a measuring device used to measure the electric current in a circuit. It is connected in series with a device to measure its current. An ammeter must be connected in series because (1) objects in series experience the same current and (2) considering the fact that it must not be connected to voltage source since ammeters are designed to work under a minimal burden. On the other hand, a voltmeter is connected in parallel with a device to measure its voltage, or the difference in electrical potential between two points in an electric circuit. A voltmeter must be connected in parallel since objects in parallel experience the same potential difference.

The objectives of the experiment are the following: (1) to determine the resistance of a resistor based on its color code and (2) to verify the laws on series/parallel resistors and cells.

2. Theory

This experiment makes use of the Ohm's law. Most of the equations in this experiment are derived from this concept.

Ohm's law shows the relationship between the voltage and current in an ideal conductor. The relationship states that "the potential difference across an ideal conductor is proportional to the current through it". It can be expressed through equation 1:

$$V = I R$$

Equation 1: Ohm's Law

Where V is the potential difference between two points, I is the current flowing, and R is the constant of proportionality or resistance.

In a series circuit, where resistors are arranged in a chain, the current flows in only one direction. Therefore, the current is the same through each resistor. However, the potential difference is shared through the resistors. Since the voltage is shared throughout the resistors, when added, it makes up the total voltage. There are different resistors, thus different values of resistance. The total resistance can be obtained by adding all of the individual values of the resistors' resistance. All of these are expressed through equations 2,3, and 4, respectively:

$$I_T = I_1 = I_2$$

Equation 2: Current in a Series Circuit

$$V_T = V_1 + V_2$$

Equation 3: Voltage in a Series Circuit

$$R_T = R_1 + R_2$$

Equation 4: Resistance in a Series Circuit

Meanwhile in a parallel circuit, resistors are arranged with their heads and tails connected together. The current is distributed into different branches of the circuit and then recombined after being connected into the same wire, indicating that the current may have different values when travelling through the wire. The total current is obtained by adding different current values measured throughout the circuit. However, voltage remains the same throughout the parallel circuit. The total resistance is computed by adding the reciprocal of the sum of reciprocals of the different resistor values. These can be

$$I_T = I_1 + I_2$$

Equation 5: Current in a Parallel Circuit

$$V_T = V_1 = V_2$$

Equation 6: Voltage in a Parallel Circuit

$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}$$

Equation 7: Total Resistance in a Parallel Circuit

expressed using equations 5, 6, and 7:

In Activities 1 and 2, the total resistance in a parallel and series circuit were computed for while the voltage and current were measured using a voltmeter and an ammeter. The experimental value of the total resistance for parallel and series circuit were obtained by using equation 8 :

$$R_T = \frac{V_T}{I_T}$$

Equation 8: Experimental Total Resistance

Where RT is the total resistance, VT is the total voltage (potential difference), and IT is the total current.

Since Activity 1 made use of the series circuit, the theoretical yield for the total resistance was computed using equation 4. Meanwhile, since Activity 2 made use of the parallel circuit, the theoretical yield for the total resistance was obtained using equation 7. Percent error was computed as well.

In Activity 3, the internal resistance of the cell was obtained by measuring the electromotive force, voltage and the current with the use of a voltmeter and ammeter and using equation 9:

$$r = \frac{E - IR\ (or\ V)}{I}$$

Equation 9: Internal Resistance of the Cell

Where r is the internal resistance, E is the electromotive force, I is the current, R is the resistance, and V is the potential difference.

In activity 4, internal resistance was also computed for using equation 9. However, the cell is connected in a series and parallel circuit. Generalizations were made wherein it was believed that a cell in a series circuit has a stronger electromotive force compared to a cell in a parallel circuit since the internal resistance is smaller in a series circuit compared to the internal resistance of a cell in a parallel circuit.

3. Methodology

Activity 1

In the experiment, resistors, a power source and the voltmeter/ammeter were used. The values of two resistors were determined and recorded as R1 and R2. The resistors were connected in series to the power (dc) source. Using the voltmeter and ammeter, the current and voltage drop were recorded across each resistor. The total current and total voltage were also measured along the combination. The total experimental and theoretical resistance were computed. The % error was determined as well.

Activity 2

This activity was conducted similar to the first, only this time the resistors were connected in parallel.

Activity 3

The use of a cell (9V battery) and the voltmeter/ammeter was required. The electromotive force of the cell was determined by connecting the voltmeter across terminals. A known resistance (R) was connected in series with the cell. The current (I) delivered to the circuit is measured by an ammeter. The internal resistance (r) of the cell was computed.

Activity 4

The electromotive force as well as the total internal resistance of two identical cells connected in series was determined using the method given in Activity 3. This was then repeated but now connected in series. Generalizations were made regarding cells in series and parallel.

5. Results and Discussion

Activity 1: Series

Table 1. Results for Activity 1

	Voltage (V)	Current (I)
R_1=470Ω ±5%	7.4	0.015 A
R_2=330Ω ±5%	5.18	0.015 A
Theoretical R_T= 800Ω		
Experimental R_T= 838.7Ω		
% Error= 4.84%		

The resistance of the given resistors were obtained through the color codes embedded in its bodies. As shown in Table 1, the resistances are 470 and 330 and it was observed that the currents are equal regardless of the resistance. However, the voltage for each resistance varies. The theoretical total resistance was computed by adding both the resistance which yielded 800Ω while the experimental was 838.7Ω which gave a 4.84% error.

Activity 2: Parallel

Table 2. Results for Activity 2

	Voltage (V)	Current (I)
R_1= 470Ω ±5%	12.12	0.025 A
R_2=330Ω ±5%	12.12	0.025 A
Theoretical R_T= 193.88Ω		
Experimental R_T= 195.48Ω		
% Error= 0.83%		

In contrast with the data gathered in the previous activity (shown in Table 1) this activity involves parallel circuits, which means that the voltages are equal regardless of the resistance and now the currents passing through the resistors are the ones that vary. In getting the total current, all individual currents must be added together. The computation for the theoretical total resistance is also different from that of the one used in the first activity, which can be referred to as equation 7. It was shown that the theoretical total resistance and the experimental total resistance yielded 193.88Ω and 195.48Ω respectively, with an error of only 0.83%.

Activity 3

Table 3. Results for Activity 3

Electromotive Force of Cell (E)	8.19v
Known Resistance (R)	330Ω

Current (I)	0.025A
Internal Resistance of the Cell (r)	-2.4Ω

The total internal resistance of a cell used in this activity was determined using the equation given in the theory which states that the electromotive force of the cell is directly proportional to internal resistance. The internal resistance is equal to the potential difference across the terminals of the cell when no current is flowing. In this case, only one cell was used to determine its internal resistance by using its other properties like electromotive force, current, and resistance. The voltmeter of the multimeter was used to determine the electromotive force of the cell, showing 8.19V with a known resistance of 330Ω, and the current was measured to be 0.025. The internal resistance was computed using all the data gathered and is shown as -2.4Ω.

Activity 4

Table 4. Cells in Series and Cells in Parallel

	In series	In parallel
Electromotive force of the Cell (E)	18.12v	9.01v
Known Resistance (R)	330Ω	330Ω
Current (I)	0.053A	0.027A
Total Internal Resistance of cells (r)	11.89Ω	3.70Ω

Same principle from activity 3 was used.. However, the cells are now connected in two ways: Parallel and Series. In the setup where the cells are connected in series, the total electromotive force is the sum of the two electromotive force of the individual cells together. Meanwhile in the series connection of cells, determining the total electromotive force of the cells was easier since the two values for each are considered equal. It should be taken note of that even if the computation for the total electromotive force depends on the connection, the computation for the total internal resistance is the same since only one variable was changed in this activity, which is the E. A big difference in the total internal resistance was be observed by changing the way the cells are connected. From table 4, the series connection gave more total internal resistance to cells than that of parallel.

Conclusion

Ohm's law states that the current on a conductor that is between two points is directly proportional to the voltage across the two points. The resistance is independent from the value of the current and it is a constant. This law was verified in this experiment and was used to determine values for the series and parallel circuit's properties such as resistance, internal resistance, and total internal resistance. In Activities 3 and 4 it was seen that when two voltage sources (cells) having similar electromotive force are connected to a parallel circuit and a resistor, the total voltage is equal to the individual voltages but the total resistance is reduced since the internal resistances are in parallel. When voltage sources are in series facing the same direction, their internal resistances add together and their electromotive forces add algebraically.

Application

1.State the laws of series and parallel combination of resistances. Were these laws verified in your experiment?

The law for series and parallel combination of resistances were verified in the experiment and the results of the group strongly agreed to the relationship of the component of the said circuits. For parallel resistors, the total resistance of a parallel Circuit was not equal to the sum of the resistors-the total resistance in a parallel circuit is always less than any of the branch resistances and adding more parallel resistances to the paths caused the total resistance in the circuit to decrease. As for the laws of series resistors, the current flow was the same through each element of the series circuit-the combined resistance of the various loads in series is the sum of the separate resistance. Lastly, the voltage across the source or power supply was equal to the sum of the voltage drops across the separate loads in series.

2. You have 4 identical resistors, each with a resistance of 5 ohms. Determine all possible resistances that you may get using all four resistors.

Series= 20 ohms

Parallel= 1.25 ohms

3. The human body is a good conductor, being almost 70% water. A dry skin has a resistance as high 10^4 -10^6 as ohms. However, when the skin is wet, the resistance drops to 1000 ohms or less. Why? Relate this fact of a lie detector.

The resistance drops to 1000 ohms or less when the skin is wet because water allows free movement of charges. The water spreads all over our skin, increasing the surface exposure to electricity. The circuit in a lie detector is based on the fact that a person's skin resistance changes when one sweats, and sweating results from lying. Dry skin has a resistance of about one million ohms, whereas the resistance of moist skin is reduced by a factor of ten or more.

4. Compare the human circulatory system to an electric circuit.

An electric circuit is similar to your circulatory system since in order for a circuit to work, the whole circuit has to be connected, just like the circulatory system. The blood vessels, arteries, veins and capillaries of human circulatory system are like the wires in a circuit. The blood vessels carry the flow of blood through your body while the wires in a circuit carry the electric current to various parts of an electrical or electronic system. The heart is the pump that drives the blood circulation in the body and it provides the force or pressure for blood to circulate, which is similar to the action of the battery wherein it pumps the electrons around the circuit so that the bulb will work and light up. The blood circulating through the body supplies various organs, and organ systems. A battery or generator produces the force that drives currents through the circuit known as voltage.

5. Are household circuits normally wired in series or in parallel? Why?

Household circuits are normally wired in parallel, which allows one to operate each power point independently of the others. This means that the current running through any one section of the circuit stays small enough to prevent problems, since in parallel circuits the current is split up and travels along each separate path.

6. *Biomedical Application.* Discuss the working principle of ventricular defibrillator.

A ventricular defibrillator gives an electrical shock to the heart to stop ventricular fibrillation, which causes cardiac rhythm disturbances and may lead to cardiac arrest.

References

[1] Boundless. “Charging a Battery: EMFs in Series and Parallel.” Boundless Physics. Boundless, 26 May. 2016. Retrieved 16 May, 2017 from https://www.boundless.com/physics/textbooks/boundless-physics-textbook/circuits-anddirect-currents-20/resistors-in-series-andparallel-151/charging-a-battery-emfs-inseries-and-parallel-536-5597/

[2] Soclof, S. (2015) How Circuits Work. Retrieved April 30, 2015, from http://science.howstuffworks.com/environmental/energy/circuit.htm