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Analyzing Ohm's Law: Comparison of Current and Resistance in Series and Parallel Circuits

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ABSTRACT

Purpose of the study: The purpose of this study is to analyze and compare the relationship between current and resistance in series and parallel circuits, and to verify the accuracy of Ohm's Law through experimental measurements and theoretical calculations.

Methodology: This study uses a Pre-Experimental Design (One-Group Post-Test Only Design), involving 10 series and 10 parallel circuits with resistors of varying values. Measurements of current and resistance were taken using a digital multimeter and ohmmeter. Data collection occurred at three time points (start, 5 minutes, 10 minutes). The data was compared with theoretical values based on Ohm's Law.

Main Findings: The experiment showed that in a series circuit, the current increased proportionally with the applied voltage, consistent with Ohm's Law. In parallel circuits, the current also increased with voltage, but at a higher rate compared to series circuits. The resistance measured in both circuit types was consistent with theoretical calculations, with minor percentage errors observed in both configurations.

Novelty/Originality of this study: This study offers a fresh perspective by analyzing the application of Ohm's Law in both series and parallel circuits, comparing real experimental data with theoretical calculations. It advances existing knowledge by providing a practical verification of theoretical concepts, enhancing understanding of current distribution and resistance effects in different circuit configurations, which can benefit students and professionals in electronics.

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1. INTRODUCTION

Electronics and electricity have become an integral part of human life, playing a vital role in various aspects of modern technology, such as communication, transportation, and household appliances. The existence of an efficient electrical system is highly dependent on an understanding of the basic laws of electricity, one of which is Ohm's Law [1]-[3]. This law provides a theoretical basis that can be used to analyze electric current, voltage, and resistance in a circuit [4]-[6]. In the context of physics experiments, this law is used to study how these three variables interact with each other [7]-[9]. A proper understanding of this law is essential for designing and maintaining effective and safe electrical circuits [10]. Ohm's Law, discovered by Georg Simon Ohm in 1827, describes the mathematical relationship between current (I), voltage (V), and resistance (R) in an electrical circuit [11]. This law states that the current flowing in a conductor is proportional to the applied voltage and inversely proportional to the resistance of the conductor. In its mathematical equation, this law is written as $V = I \times R$. The applications of Ohm's Law are very broad, ranging from simple circuit analysis to applications in the design of complex electronic devices.

Therefore, Ohm's Law is one of the basic concepts that every technician and electronic engineer must understand to ensure optimal device performance. In an electrical circuit, electric current will only flow if there is a voltage difference between two points, and the flow of current will be affected by the resistance value in the circuit [12]-[14]. Ohm's Law allows us to predict how voltage, current, and resistance interact in the circuit. For example, in a series circuit, the voltage will be divided between the components according to their resistance values, while the current flowing will remain the same [15]. On the other hand, in a parallel circuit, the voltage will be the same throughout the circuit branch, but the current will be divided according to the resistance of each branch. By understanding this law, we can design an electrical circuit that suits the needs of a particular application and optimize the flow of electric current.

Series and parallel circuits are two basic configurations in electronics that are often used in various applications of electrical and electronic devices. In a series circuit, the components are arranged in sequence, and the current flowing through all components is the same, but the voltage will be divided according to the amount of resistance [16], [17]. Conversely, in a parallel circuit, the components are connected in parallel, where the voltage on each branch is the same, but the current will be divided according to the resistance of each branch [18], [19]. Understanding how Ohm's law applies in both types of circuits is essential to designing efficient circuits and avoiding potential problems, such as excess current or voltage.

Previous studies have discussed the effects of the number of resistors and voltage variations on the current and electric power in series and parallel circuits, focusing on the changes in the values of electric current and electric power as the number of resistors increases. The study showed that the difference in current between voltages decreases in series circuits and increases in parallel circuits, while the electric power absorbed decreases in series circuits and increases in parallel circuits with the addition of resistors [20]. However, this study focused more on general patterns without conducting theoretical verification based on Ohm's law. To fill the gap in previous research, the current study not only analyzes the relationship between current and resistance in series and parallel circuits, but also conducts experimental verification of Ohm's law by comparing the measurement results with theoretical calculations. Thus, the current study expands the scope of previous studies by providing a more detailed analysis and testing the accuracy of the theoretical model through an experimental approach.

This study offers a novelty in analyzing Ohm's Law by comparing the effects of current and resistance in two basic circuit configurations, namely series and parallel circuits, using laboratory experiments. Although Ohm's Law is widely known, this study provides a practical approach by directly measuring current and resistance under different conditions, and comparing experimental results with theoretical calculations to verify the accuracy of the law [21], [22]. In addition, this study introduces a more precise measurement method using a digital multimeter and ohmmeter, and identifies measurement errors in both types of circuits, providing new contributions to the application of Ohm's Law in more relevant circuit configurations in everyday electronic applications.

Therefore, experiments comparing current and resistance in series and parallel circuits are essential to confirm the application of Ohm's law in various circuit configurations. This study aims to analyze and compare current and resistance in series and parallel circuits, and to test the truth of Ohm's Law in both types of configurations [23], [24]. This experiment will measure the current and voltage that occurs in each component in series and parallel circuits using the right measuring instruments [25], [26]. In addition, this study aims to verify the results of the experiment with theoretical calculations based on Ohm's Law, to see to what extent the results of the experiment are in accordance with mathematical predictions. Through this experiment, we are expected to understand how resistance affects the flow of current in both types of circuits and evaluate how Ohm's law applies in reality.

The results of this study are expected to provide deeper insight into the application of Ohm's Law in electrical circuits. This research has great significance, both in the context of theory and practical applications. By understanding the relationship between current, voltage, and resistance in series and parallel circuits, we can design and optimize electrical circuits for various electronic applications. The results of this experiment are expected to strengthen the understanding of Ohm's Law and its applications in everyday life, especially in technologies that depend on electrical systems. In addition, this research will also contribute to electronics education, by providing experimental evidence that can be used to teach basic concepts of electrical law to students or college students. Overall, this research is expected to improve our understanding of current flow in electrical circuits and the importance of proper calculations in designing efficient electrical systems.

2. RESEARCH METHOD

The type of research that has been carried out is laboratory experimental research using the Pre-Experimental Design or One-Group Post-Test Only Design research design, where there is only one group that is given treatment, without a control group or pre-test. This design focuses directly on the experimental results after treatment to see the direct results of the treatment given and measure the dependent variable after the experiment, where the division of the two groups of research subjects, namely series and parallel circuits, is carried out randomly. The samples used in this study include ten series circuits and ten parallel circuits, each using resistors with different values.

Measurement of current strength was carried out using a digital multimeter to measure electric current in series circuits and in parallel circuits. Furthermore, resistance measurements are carried out by applying Ohm's law to experiments, namely different circuit configurations and with different voltage values. In measuring resistance, a measuring instrument called an ohmmeter is used. This ohmmeter is integrated in a multimeter, which can also measure voltage (volts) and current (amperes), so that it is able to facilitate various electrical science measurements, especially this experimental research [27]-[29].

The data collection method used in this research is direct measurement of resistance and current strength in the circuit, which is then compared with theoretical calculations using Ohm's Law. Measurements were taken at three different time points: at the start of the circuit, after 5 minutes, and after 10 minutes for each voltage used.

The tools and materials used in this research include: Digital multimeter, resistors (110Ω, 110Ω, 110Ω), conductor cable, power supply, breadboard, stop watch, and observation notes. Materials: Resistors as many as 20 pieces with different values for each circuit, as well as the conductor cable.

The stages used in this research begin with observing the background related to this research. Then proceed with preparing the material tools and research work scheme. Furthermore, conducting research, and the last stage is recording data and research results and comparing the results with previous research. adapun

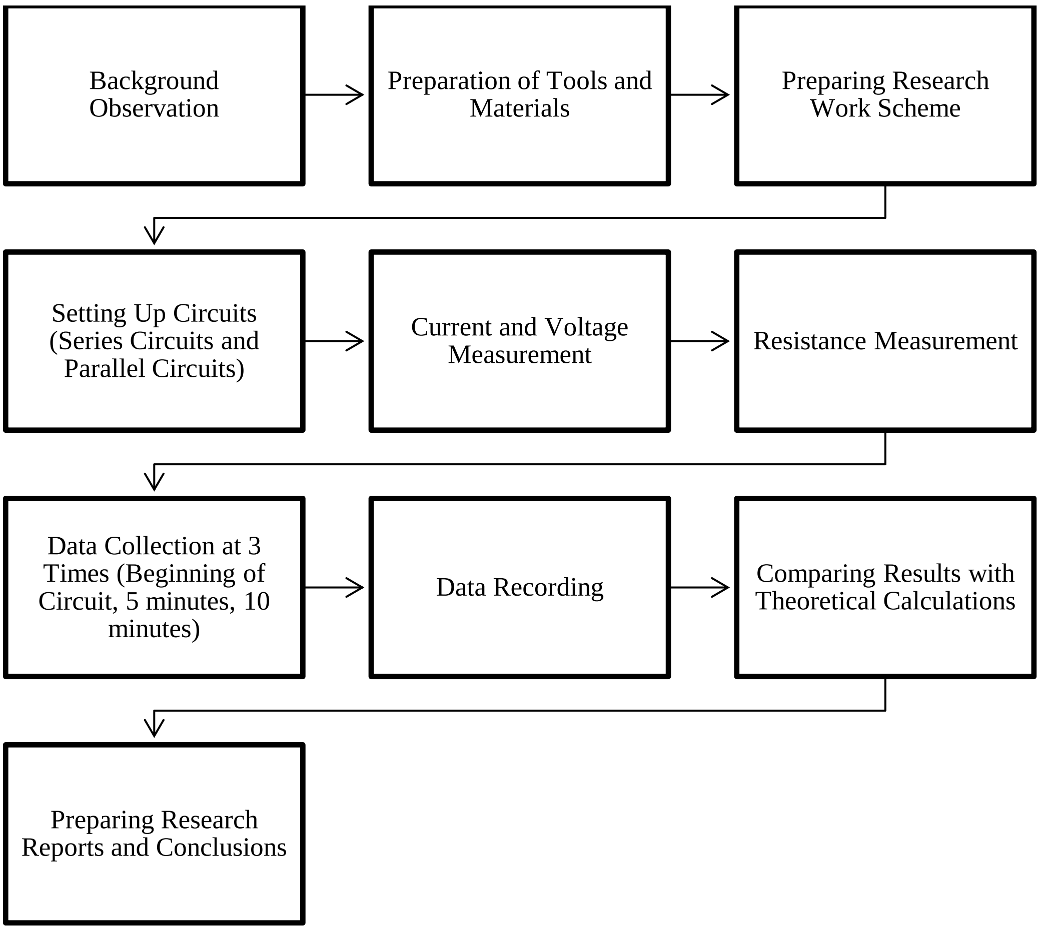


Figure 1. Research procedures

3. RESULTS AND DISCUSSION

In this section, it is explained the results of research and at the same time is given the comprehensive discussion. Ohm's Law by utilizing series and parallel circuit configurations. Each configuration was assembled using predetermined resistors, and measurements were taken with a digital multimeter. Variations in the voltage applied made it possible to obtain the value of the current flowing in each circuit. The results of these observations were then analyzed by researchers to calculate the total resistance and understand more about the relationship between the value of voltage, the magnitude of current, and the value of resistance in accordance with Ohm's law.

In a series circuit, the current flowing through each resistor is the same, while the total voltage is the sum of the voltages across each resistor. Increasing the number of resistors has caused the total resistance value to increase, it will cause a reduction in the value of the current if the value of the voltage is fixed. The following data shows the measurement results in series and parallel circuits.

The following are the results and discussion of researchers who have presented in the form of tables, below is the first table, where the value and content of the data has been obtained from researchers conducting experiments on electrical and electrical circuits, namely series circuits.

Table 1. Measurement Results on Series Circuits

Experiment	1	2	3
$V_{measure}$	7.55	7.55	7.54
V_{total}		22.64 V	
$R_{measure}$	110 M Ω ± 0.5 %	110 M Ω ± 0.5 %	110 M Ω ± 0.5 %
R_{total}		330 M Ω ± 0.5 %	
$R_{measure}$	16.43	16.42	16.42
R_{total}		49. 27 J/K/mol	
$I_{measure}$	0.45	0.45	0.45
I_{total}		0.135 A	

In a series circuit, the current flowing through each component is the same, while the total voltage is the sum of the voltages on each resistor. Based on the observation results, it has been found that the value of each resistor used has a resistance value of 110 MΩ ± 0.5%. Then the research results have shown that the resistance value is the same and consistent. With consistent resistance, the current measured in this circuit reaches 0.45 A with a voltage of 7.55V. These results have shown that an increase in voltage will result in an increase in current value, this is in line with the sound of ohm's law which states that the voltage value will be directly proportional to the value of the current.

After understanding the pattern of current flow and voltage distribution in the series circuit, the researchers switched to observing the parallel circuit. In this circuit, the voltage value on each branch remains the same and has a consistent value, while the value of the current flowing has been known to have different values, this is because in parallel circuits, the current value depends on the resistance of each electrical circuit. In parallel circuits, researchers have proven that the application of Ohm's law in this study is successful. This can be proven by the results and discussion that researchers will present in the form of an observation table.

The following is the content of the second table, where the content of the data has been obtained by researchers at the time of practice by conducting experiments on the value of resistance, the value of current, and the magnitude of the voltage against the type of circuit that has been made, namely the parallel circuit.

Table 2. Measurement Results on Parallel Circuits

Experiment	1	2	3
$V_{measure}$	7.5	7.5	7.5
V_{total}		22.64 V	
$R_{measure}$	110 M Ω ± 0.5 %	110 M Ω ± 0.5 %	110 M Ω ± 0.5 %
R_{total}		36.6 M Ω ± 0.5 %	
$R_{measure}$	1/1.83	1/1.83	1/1.83
R_{total}		49. 27 J/K/mol	
$I_{measure}$	13.72	13.72	13.72
I_{total}		0.135 A	

Based on the measurements taken, the resistance of each resistor remains at 110 MΩ ± 0.5%, with a current of 13.72 A at a voltage of 7.5V. These results are consistent with the theory that in parallel circuits, the lower the total resistance, the greater the current flow. It also shows that the total resistance in the parallel circuit is smaller than each resistor, so the resulting current is greater than the series circuit at the same voltage.

In addition, in a parallel circuit, the total resistance is always smaller than the smallest resistance among the resistors, because the current flow is divided among several paths. This pattern shows that the more branches in a parallel circuit, the smaller the total resistance, resulting in a larger current. Thus, parallel circuits are more efficient in distributing current, especially in applications that require even distribution of current across multiple components.

The relationship between voltage (V), current (I), and resistance (R) in an electrical circuit is described by Ohm's law which states that voltage is equal to the product of current and resistance

$$V = I \times R$$

In a series circuit, the current passing through each component is the same, while the total voltage is the sum of the voltage across each resistor. This means that if the resistance increases, the voltage will also increase if the current remains constant. Meanwhile, in a parallel circuit, the voltage across each resistor is the same, but the current passing through each resistor varies according to its resistance. The total current in a parallel circuit is the sum of the current flowing in each branch, while the voltage in each branch remains constant. Understanding the relationship between voltage, current, and resistance is important to know the working scheme of an electric power and energy flow in an electric circuit.

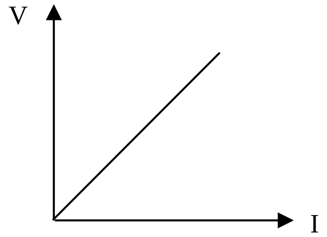
The difference in how to calculate total resistance in series and parallel circuits is very important to understand. In a series circuit, the total resistance is calculated by summing the resistance of each resistor, which causes the total resistance to increase as the number of resistors increases

$$R_{total} = R_1 + R_2 + R_3 \qquad \dots (1)$$

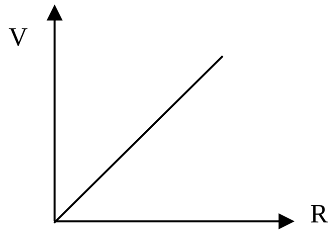
This increase in total resistance causes the current flowing in the circuit to be smaller for the same voltage. While in a parallel circuit, the total resistance is calculated using the formula

$$R_{total} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \qquad \dots (2)$$

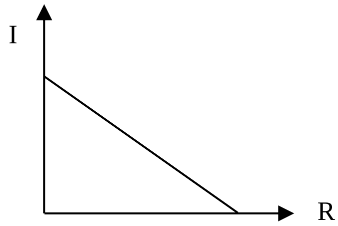
As a result, the total resistance in a parallel circuit is always smaller than the resistor with the smallest resistance in the circuit. This causes the current flowing in the parallel circuit to be greater than the series circuit at the same voltage.



Graph 1. Graph of the relationship between (V) and (I) in a series circuit.

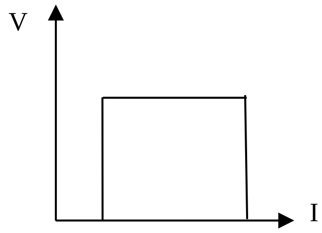


Graph 2. Graph of the relationship between (V) and (R) in a series circuit.

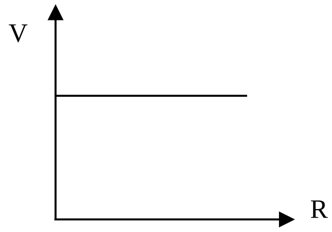


Graph 3. Graph of the relationship between (I) and (R) in a series circuit.

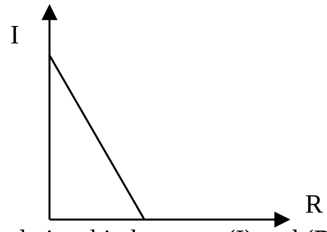
A graph depicting the interaction between voltage (V), current (I), and resistance (R) shows a clear pattern of how these three variables interact in a circuit. The graph of the relationship between voltage and current (V & I) will form a straight line indicating a linear relationship according to ohm's law. In a series circuit, the current remains the same at every point, so an increase in voltage will result in a linear increase in current. The graph of voltage against resistance (V & R) with a current that remains constant also shows a straight line, indicating that a voltage will increase as the resistance increases. Meanwhile, the graph showing the relationship between current and resistance (I & R) has illustrated an inversely proportional relationship, where the current becomes smaller which is known by the level of resistance at the same voltage. This has shown regarding current and resistance that resistance has worked as an obstacle to the flow of current in electricity by using the science of applying ohm's law.



Graph 4. Graph of the relationship between (V) and (I) in parallel circuits.



Graph 5. Graph of the relationship between (V) and (R) in parallel circuits.



Grafik 6. Graph of the relationship between (I) and (R) in parallel circuits.

Ohm's law describes the linear relationship between voltage (V) and current (I), where an increase in voltage causes a proportional increase in current if the resistance (R) is fixed. In a series circuit, the current at all points remains the same. The relationship between voltage and resistance (V & R) at a fixed current is also linear; voltage increases as resistance increases. In contrast, the relationship between current and resistance (I & R) shows an inverse relationship: when the voltage is fixed, an increase in resistance decreases the current, as the resistance inhibits the flow of current.

The comparison between voltage and current in series and parallel circuit configurations is in line with the basic principle of Ohm's Law. In a series circuit, the current flowing across the components is the same, while the total voltage is the sum of the voltages across each resistor. Therefore, the more resistors connected in a series circuit, the greater the voltage required to maintain the same current. Conversely, in a parallel circuit, the voltage applied to each resistor is the same, but the current flowing through each resistor will vary depending on the resistance value. The total current in a parallel circuit is the sum of the currents in each branch. This shows that in a parallel circuit, the total current generated is greater than in a series circuit at the same voltage, making the parallel configuration more efficient in current distribution.

An analysis of the relevant graphs and formulas in series and parallel circuits shows how voltage, current, and resistance affect each other. In a series circuit, the voltage versus current (V & I) graph shows that the voltage increases as the current increases if the resistance remains constant, showing a linear relationship. Conversely, the current to resistance graph (I & R) shows that the current decreases significantly as the resistance increases at constant voltage. This proves that resistance has a great influence on the current that can flow in the circuit. In a parallel circuit, although the voltage remains the same in each branch, the current will be different depending on the resistance in each branch.

The results of previous research and current research are consistent in efforts to improve understanding of physics concepts, especially in dynamic electricity material, where previous research identified relevant conceptual understanding questions [30], while the current study provides experimental verification of the basic concept of Ohm's law which can strengthen students' understanding through the application of theory to real practice. The results of previous studies and the current study have parallels in exploring the behavior of series and parallel circuits, where the previous study used Proteus 8 Professional software and a manual approach to compare circuit analysis [31], while current research focuses on experimental verification of Ohm's law through actual measurements and comparison with theoretical values, both of which contribute to a deeper understanding of the basic characteristics of electrical circuits.

As a result of the experiments, it can be tentatively concluded that the circuit configuration, both series and parallel, greatly affects the total resistance, voltage, and current flow. In series circuits, the total resistance increases as the number of resistors increases, which results in a reduced current for a fixed voltage. While in a parallel circuit, the total resistance will decrease as the branches increase, allowing more current to flow. Ohm's law is the main principle in explaining the relationship between voltage, current and resistance in these two circuit configurations. Overall, the experimental results show that parallel circuits are more efficient in distributing current, while series circuits serve to limit the current due to their increased total resistance.

This study provides a new contribution to the understanding of the application of Ohm's Law to series and parallel circuits, by directly measuring the current and resistance in both types of circuits using a digital multimeter and an ohmmeter. One of the main findings is the comparison of the current flowing in series and parallel circuits at various voltages, which shows significant differences in the distribution of current and voltage between the two circuit configurations. This study also confirms the validity of Ohm's Law in a practical setting by comparing experimental results with theoretical calculations, which provides further evidence that the law remains valid in different circuit configurations.

The implications of this study are an increased practical understanding of the application of Ohm's Law in series and parallel circuits, which can be used to design electrical circuits with better efficiency in various electronic applications. This study also provides insights for the teaching of electronics and physics, by providing experimental data that can be used to enrich students' understanding. However, this study has several limitations, such as the use of fixed-value resistors and only testing two types of circuits, which may not cover the full range of components or more complex circuit configurations. Recommendations for further research are to explore the influence of other components such as capacitors and inductors, as well as to conduct experiments on more complex circuits or with various resistor values to obtain more diverse and comprehensive results.

4. CONCLUSION

Resistors are important components in electrical circuits that serve to limit electric current. The main characteristics of a resistor include its resistance value measured in ohms, which indicates how much it resists the flow of current. This resistance is usually indicated by a color bracelet on the resistor, where each color represents a specific number that allows us to calculate its resistance value. Ohm's Law, expressed by the formula $V = I \times R$, explains the relationship between voltage (V), current strength (I), and resistance (R). In an electrical circuit, the greater the resistance used, the smaller the current strength that flows if the voltage remains constant. Conversely, if the resistance is fixed and the voltage increases, the current strength will also increase. When comparing series and parallel circuits, there is a significant difference in the behavior of voltage and current. In a series circuit, the total voltage is shared among the resistors, while the current strength is the same throughout the circuit. Whereas, in a parallel circuit, the voltage in each branch shows the same value, but the total current strength is the sum of the currents flowing in each branch. In conclusion, an understanding of the characteristics and uses of resistors, the resistance values indicated by color bands, and the application of Ohm's law are essential in designing and analyzing electrical circuits. In addition, the difference in behavior between series and parallel circuits in terms of voltage and current provides a deep insight into how these components work together in an electrical system..

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