

Student Name
Professor Name
Course
Date

Investigating the Influence of Wire Material on Resistance and Efficiency in Simple Electrical Circuits

1. Introduction and Rationale

Research Question

How does using various wire materials in simple circuits impact resistance and efficiency?

Reason for investigation

My deep fascination with this subject emerged from personal curiosity and hands-on experience. Regular interactions with a diverse range of electrical devices naturally led me to notice how the choice of wire materials profoundly influences the performance and effectiveness of these devices. This comment sparked my curiosity and propelled me to comprehensively explore the intricate interactions between various wire types and electrical circuits. As a result, I embarked on a research journey to investigate the impact of different wire materials on basic electrical circuits, seeking to unveil disparities in resistance and efficiency.

Modern technology heavily relies on electrical circuits, which act as conduits for energy flow, powering an array of systems and equipment. The efficacy of these circuits, crucial in applications spanning from electronics to power transmission, hinges upon the electrical properties of the materials employed within them. Resistance, a fundamental attribute of materials, plays a pivotal role in determining how effectively a circuit operates by either facilitating or impeding the smooth flow of electric current (Wilfred et al.60). This study delves into the resistance and efficiency of straightforward electrical circuits concerning various wire materials, such as copper, aluminum, and nichrome. For electrical systems and devices to be designed as efficiently as possible, it is essential to have a thorough grasp of the interactions between wire material, resistance, and efficiency.

Theoretical Background

A wire's resistance can be linked to several things, the most important of which is its composition. Several elements contribute to a wire's resistance, including its length and cross-sectional area. However, the composition of the wire plays a pivotal role. Different materials exhibit distinct electrical resistivities, representing their inherent resistance to the passage of electric current. For example, copper is preferred in applications demanding high conductivity thanks to its well-known reputation for low resistivity.

In contrast, while less conductive, aluminum is valued for its lightness and low cost(Wu et al. 123). However, due to its strong resistance, nichrome is frequently used in applications such as heating components. According to Ohm's Law, the choice of wire material directly affects the voltage-current relationship in a circuit. This, as a result, affects resistance.

In electrical circuits, efficiency refers to a circuit's ability to convert electrical energy into meaningful work or output while minimizing energy losses. It quantifies how well a circuit can fulfill its intended job while conserving energy. The following formula is used to calculate efficiency, which is commonly stated as a percentage:

$$\text{Efficiency (\%)} = (\text{Useful Output Energy} / \text{Total Input Energy}) \times 100\%$$

Efficiency is important in electrical engineering and design because it indicates how well a circuit can perform its intended goal while consuming the least energy. Circuits in practical applications are designed to be as efficient as feasible to save energy expenses, extend component lifespan, and limit environmental consequences.

Resistance can be influenced by the wire material used, as materials with higher resistivity have more resistance than materials with lower resistivity. This variation in resistance can affect efficiency since higher resistance can result in more energy losses in the form of heat. Hence, the choice of material can also tremendously impact efficiency.

2. Planing

The Hypothesis of the Investigation

The wire material used in a simple electrical circuit is predicted to impact resistance and efficiency considerably. Wires constructed of greater resistivity materials, such as nichrome, are predicted to have higher resistance and lower circuit efficiency, whereas wires made of lower resistivity materials, such as copper, are expected to have lower resistance and higher circuit efficiency (ENDO et al.137). This hypothesis is based on the fundamental concept that higher-resistivity materials obstruct the flow of electrical current more than lower-resistivity materials.

Variables:

Independent Variable:

The independent variable will be the wire material selection, which will be modified by picking different materials such as copper, aluminum, nichrome, and three others (a total of six materials).

Dependent Variables:

Resistance and efficiency will be the dependent variables. Resistance will be measured with an ohmmeter, and efficiency will be calculated as a % by measuring input and output power.

Control Variables:

The control variables for this exploration are outlined in the table below:

Variable	Method of Control
Wire Length	Maintained a constant wire length for all materials tested by measuring and cutting wires to the same length.
Voltage	Used a stable power supply (battery or DC source) with a constant voltage setting, verifying and maintaining the voltage level throughout the experiment.
Temperature	Experimented in a controlled environment with a stable temperature to minimize temperature-related effects on resistance, avoiding exposure to extreme temperatures.

Wire Thickness (Gauge)	Used wires with the same gauge (diameter) for all materials to ensure consistent wire thickness.
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Table 1: Control Variables

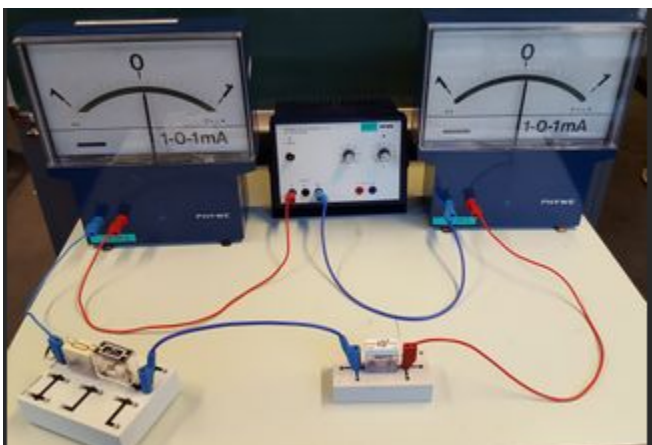
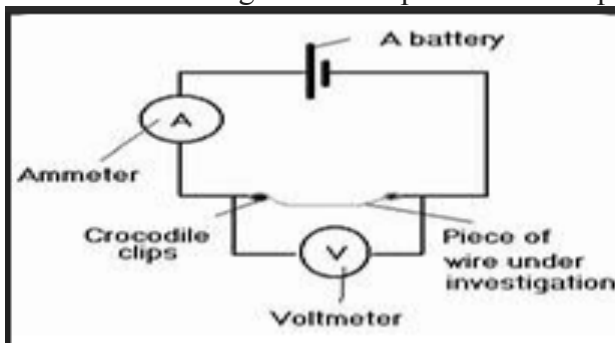
Materials and apparatus:

Below is a concise list of the Materials used in the exploration to collect the necessary data:

1. Various wire materials
2. A power source
3. Ammeter
4. Voltmeter
5. Crocodile clips
6. Connecting wires
7. Stopwatch
8. Wire cutter
9. Ruler
10. Multimeter

Experimental Setup:

Below are the images of the experimental setup:





Figures 1: Images of the experimental setup

Procedures:

1. Select a wire material to begin with.
2. Measure and cut the wire into two segments.
3. Connect one end of a wire segment to the positive terminal of the power source.
4. Connect the other end to the ammeter with crocodile clips.
5. Connect the voltmeter in parallel to the wire segment and measure voltage.
6. Note the initial current and voltage readings.
7. Activate the power source and record the time for the ammeter reading to stabilize.
8. Record the final current and voltage readings.
9. Record the input and output power of wire material.
10. Calculate the resistance of each wire segment using Ohm's law.
11. Calculate the efficiency of the wire using the efficiency formulae.
12. Repeat steps 4-9 twice with each wire segment of the same material.
13. Repeat the experiment using different wire materials while maintaining the same length variations.
14. Analyze the data by plotting resistance values for each wire material with the type of the wire.
15. Analyze the efficiency data and conclude how wire material impacts resistance and efficiency in simple electrical circuits.

Safety Procedure And Environmental Considerations

Below are the safety procedures and environmental considerations to keep in mind while experimenting with wire materials' influence on resistance and efficiency in simple electrical circuits:

1. *Safety Gear:* Always wear suitable safety equipment, such as safety goggles to protect your eyes, gloves to guard your hands, and a lab coat to cover your clothing.
2. *Power Supply:* Ensure the power supply is turned off and unplugged when setting up the circuit or adjusting it to avoid electric shock.
3. *Insulation Tape:* Use electrical insulation to cover exposed wires and connections to prevent short circuits and reduce the risk of electrical hazards.
4. *Avoid Wet Conditions:* To prevent electrical short circuits and shocks, keep the experiment area dry and free from water or conductive fluids.

5. *Waste Disposal*: Properly dispose of waste materials, such as damaged wires or insulation, following local regulations and guidelines.

3. Data collected and Processing

Raw data:

In this investigation, data collection and Processing played a pivotal role in comprehending the electrical characteristics of various wire materials within simple circuits. Three trials of resistance, power input, and power output measurements were performed on each material. The resistance values of the wire to electric current were measured, and the power input and output were computed using voltage and current measurements. Subsequently, the data was averaged to derive representative values, reducing the impact of potential experimental variations. With these averaged values, efficiency was calculated to assess the circuit's ability to convert input electrical energy into useful output energy while minimizing losses. The meticulous data collection and processing procedures allowed for a thorough analysis of how different wire materials influence resistance and efficiency in electrical circuits.

Materials	Resistance (Ω)			Power Input (W)			Power Output (W)		
	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
Nichrome Wire	3.5	3.6	3.7	25.0	25.2	25.1	23	23.2	23.1
Iron Wire	2.0	2.2	2.1	21.0	21.0	21.3	19.5	19.6	19.8
Aluminum Wire	0.3	0.4	0.3	20.5	20.6	20.5	18.5	18.7	18.5
Copper Wire	0.2	0.3	0.2	20.0	20.1	20.3	18	18.0	18.2
Silver wire	0.1	0.2	0.1	18.0	18.3	18.2	16.5	16.6	16.7

Table 2: Raw data collected

Qualitative Data Analysis

1. An observation that was noticed was that as the length of the wire increased, the resistance also increased.
2. Certain wire materials resulted in more efficient circuits compared to others.

Processed Data

The averages were calculated as follows using the following example:

Average = Sum of trials / 3

$$\text{Average resistance of Nichrome wire} = \frac{3.5 + 3.6 + 3.7}{3} = 3.60$$

Materials	Resistance (Ω)	Power Input (W)	Power Output (W)
Nichrome Wire	3.60	25.10	23.10
Iron Wire	2.10	21.10	19.63
Aluminum Wire	0.30	20.50	18.60

Copper Wire	0.20	20.10	18.10
Silver wire	0.10	18.20	16.60

Table 3: Average values

The efficiency was computed as follows using the outlined example after the determination of the averages:

$$\text{Efficiency}\% = \frac{\text{Output power}}{\text{input power}}$$

$$\text{Nichrome wire efficiency} = \frac{23.10}{25.10}\% = 92.03$$

Materials	Resistance (Ω)\mp0.01	Efficiency(%)\mp0.01
Nichrome Wire	3.60	92.03
Iron Wire	2.10	93.03
Aluminum Wire	0.30	90.73
Copper Wire	0.20	90.05
Silver wire	0.10	91.21

Table 4: Processed Data

Percentage uncertainty

I calculated the percentage uncertainty as follows, which enabled me to determine the accuracy of my data:

$$\text{Percentage Uncertainty} = \frac{\text{Absolute Uncertainty}}{\text{Measured Value}} \times 100$$

For instance,

$$\text{Nichrome wire percentage uncertainty} = \frac{0.01}{3.60} \times 100 = 0.27$$

Materials	Uncertainty Resistance (Ω)%	U n c e r t a i n t y Efficiency(%)
Nichrome Wire	0.27	0.01
Iron Wire	0.48	0.01
Aluminum Wire	3.33	0.01
Copper Wire	5.00	0.01
Silver wire	10.00	0.01

Table 5: Percentage Uncertainty

The calculated percentage uncertainty is small, which indicates that there was accuracy in data collection. The introduced error bars in the charts are also small, indicating precision in data collection.

4. Data Presentation

Resistance

The data analysis was conducted using charts as follows

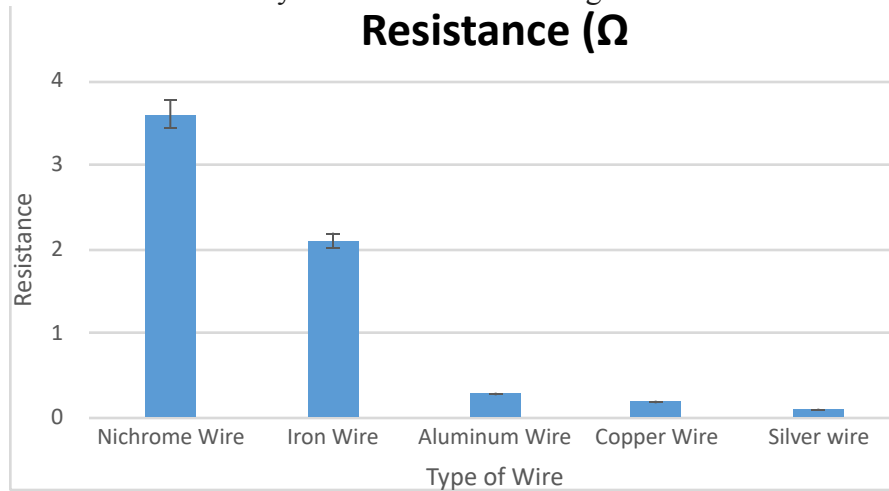


Figure 2: Resistance Chart

The bar chart depicting resistance values for various wire materials provides valuable insights into their electrical characteristics. Nichrome Wire and Iron Wire emerge as the high-resistance materials in this analysis, with resistance values of approximately 3.60 Ω and 2.10 Ω , respectively. These findings align with expectations, as materials with higher resistivity exhibit higher resistance. Conversely, Aluminum Wire and Copper Wire demonstrate moderate resistance, with values of about 0.30 Ω and 0.20 Ω , respectively. Silver Wire, with the lowest resistance of approximately 0.10 Ω , showcases its superior conductivity. This analysis reaffirms the well-established relationship between resistivity and resistance and underscores the importance of selecting wire materials that meet the specific requirements of electrical circuits. Therefore, the choice of wire material significantly impacts the resistance of a simple electrical circuit.

Efficiency

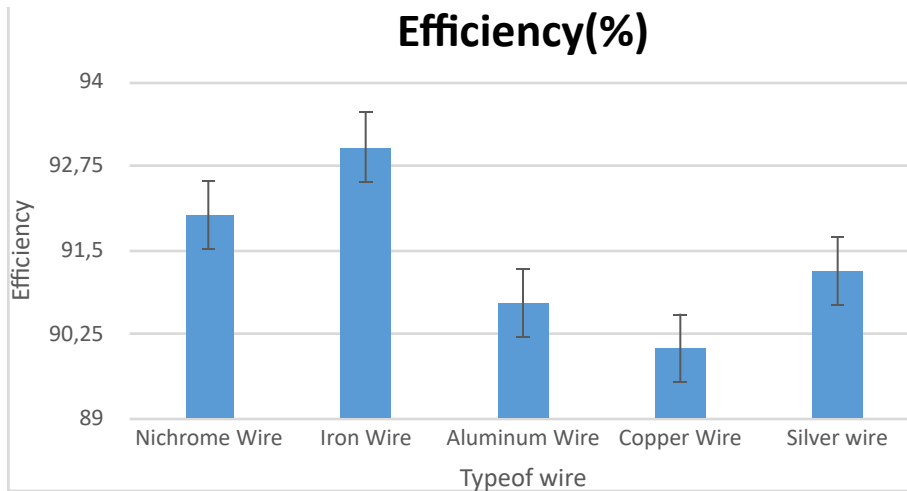


Figure 3: Efficiency Chart

From the chart, Iron Wire demonstrates the highest efficiency, approximately 93.03%, closely followed by Nichrome Wire, achieving around 92.03%. These results underscore the remarkable ability of these materials to effectively convert input electrical energy into useful output energy while minimizing losses, a critical attribute for energy-efficient circuits. Furthermore, Aluminum Wire and Silver Wire exhibit robust efficiency values, approximately 90.73%, and 91.21%, respectively, emphasizing their suitability for applications demanding efficient energy utilization. Copper Wire maintains commendable energy conversion capabilities with an efficiency of approximately 90.05%. Therefore, the choice of wire material undeniably significantly impacts the efficiency of a simple electrical circuit.

5. Conclusion and Evaluation:

Conclusion

In summary, this investigation unveiled the substantial impact of wire material selection on resistance and efficiency in simple electrical circuits. The analysis revealed a clear relationship between material resistivity and resistance, with high-resistivity materials exhibiting higher resistance values. Conversely, the choice of low-resistivity materials resulted in significantly lower resistance. Efficiency, on the other hand, showcased the nuanced interplay between material properties and energy conversion. While Iron and chrome led in efficiency, other materials like Aluminum, Copper, and Silver also displayed commendable energy conversion capabilities. These findings emphasize that engineers and designers must carefully consider the electrical characteristics of wire materials to optimize circuit performance. In conclusion, the choice of wire material has a profound and multifaceted impact on resistance and efficiency within simple electrical circuits, ultimately shaping their effectiveness and functionality.

Evaluation

Strengths	Impacts
Methodology	A systematic approach was used, ensuring precision in data collection and analysis.

Bar Chart	Bar charts were instrumental in visually presenting complex data, making trends and variations easily discernible to experts and non-experts.
Low Uncertainty Instruments	Instruments with low uncertainty levels improved measurement precision, providing more accurate resistance and efficiency values for each wire material. This increased the confidence in the investigation's conclusions.
Multiple Trials	Conducting experiments repeatedly with each wire material minimized the potential for outliers or experimental errors, enhancing the reliability and accuracy of the data.

*Table 6: Strengths
Limitations*

Below are the limitations of this exploration:

Error	Effect	Improvement
Limited Range of Wire Materials Tested	The investigation may not capture the full spectrum of wire material behavior due to a restricted selection of wire materials.	Expanding the range of wire materials tested would provide a more comprehensive analysis.
Limited Environmental Control (e.g., Temperature)	Environmental factors, such as temperature variations, could influence resistance and efficiency measurements.	Conducting experiments in a controlled environment can mitigate the impact of external factors on results.

Table 7: Random errors

Error	Effect	Improvement
Uncertainty in Instrumentation (e.g., Voltmeters and Ammeters)	Measurement instruments may have inherent uncertainties, introducing random errors into the data	Calibrating and using instruments with lower uncertainties can enhance measurement accuracy.

Single Wire Length and Diameter (Lack of Variability):	Wire length and diameter variations should have been considered, which could introduce random errors.	Testing wire materials with varying lengths and diameters would help assess the impact of these factors on resistance and efficiency.
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Table 8: Systematic errors

Extension

To extend this experiment, one considers exploring the impact of wire length variations on resistance and efficiency in electrical circuits. One can investigate how wire length affects their electrical properties by systematically altering the length of the wire materials while keeping other factors constant (Anitha et al. 435). This extension would offer valuable insights into the relationship between wire length and circuit performance, potentially leading to practical implications for designing circuits with optimized wire lengths for specific applications.

Works Cited

- Anitha, Nilavan, et al. "Corrosion resistance of orthodontic wire made of nickel-titanium alloy in artificial saliva in the presence of Kopiko candy." *Zaštita materijala* 63.4 (2022): 430-436.
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