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Laboratory Report

Experimental Determination of Resistivity in Metal Wires

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TABLE OF CONTENTS

ABSTRACT

In this experiment aimed to determine the **electrical resistivity** of **six** different **metallic wires** (Figure 1) —**four brass** wires of varying diameters, one **copper** wire, and one **aluminum** wire—by measuring the **voltage** across different **lengths** of wire under **constant current**. A **resistivity apparatus** (Figure 2), power supply, two multimeters, and a digital caliper were used to set up and conduct the measurements. **Voltage versus length** graphs were plotted to find the **slope**, which was used alongside the measured diameter and applied current to calculate the resistivity of each wire. The experimental values were then compared to manufacturer-provided standards. Results demonstrated good agreement, with error percentages ranging from 1% to 20%. The experiment validated **Ohm's law** and **the linear relationship between voltage and length** for uniform conductors while highlighting the impact of measurement precision and material characteristics on resistivity.

FIGURE 1. *Replacement wire set, consisting of four brass wires and one each copper and aluminum.*

FIGURE 2. *Resistivity apparatus setup used to measure voltage across a section of wire, with adjustable sliding contact and terminals.*

THEORETICAL BACKGROUND

Electrical **resistivity** is a property of a **material** that describes **how strongly it resists the flow of electric current**. Denoted by the **Greek letter** ρ **(rho)**, resistivity depends on the material's nature and internal structure. Metals like copper and aluminium have low resistivity, making them good conductors, while insulators like rubber have very high resistivity.

RELATION BETWEEN RESISTANCE AND RESISTIVITY

The **resistance R of a uniform conductor (like a wire)** is directly related to its resistivity and the dimensions of the conductor:

$$R = \rho \frac{L}{A}$$

where:

- R is the resistance (in ohms, Ω)
- ρ is the resistivity (in $\Omega \cdot m$)
- L is the length of the conductor (in meters)
- A is the cross-sectional area (in square meters)

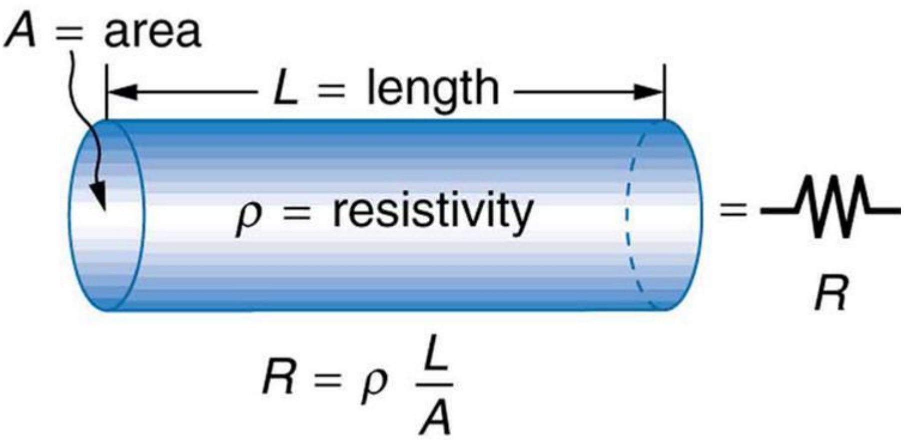


FIGURE 3. *Graphical representation of the relationship between resistivity (ρ), resistance (R), length (L), and cross-sectional area (A) for a uniform wire.*

This formula shows that **resistance increases** with **length** and **decreases** with greater **thickness (area)**.

OHM'S LAW

Ohm's Law states that the **voltage V** across a resistor is proportional to the **current I** flowing through it:

$$V = IR$$

Combining Ohm's Law with the formula for resistance, we get:

$$V = I\rho \frac{L}{A}$$

This equation implies that, for a **given wire carrying constant current**, the **voltage** across it will **increase linearly with length**. That is:

$$V \propto L$$

FINDING RESISTIVITY EXPERIMENTALLY

By measuring **the voltage across known lengths** of a wire carrying **constant current**, a graph of **V vs. L** can be plotted. Since the relationship is **linear**, the **slope** of the line corresponds to:

$$slope = \frac{I\rho}{A}$$

Rearranging this gives the formula to find resistivity:

$$\rho = slope \cdot \frac{A}{I}$$

To apply this, the following quantities must be measured:

- The **current** I, held **constant**
- The **slope** of the **linear** fit of **voltage *(y-axis)* vs. length *(x-axis)* data**
- The **cross-sectional area** A of the wire

CALCULATING CROSS-SECTIONAL AREA

Since wires are typically cylindrical, their cross-sectional area is calculated using:

$$A = \pi \left(\frac{d}{2}\right)^2$$

Where d is the wire's **diameter** in **meters**. The diameter can be measured using a **digital caliper** for accuracy.

PROCEDURE

APPARATUS

To perform this experiment on resistivity, you'll need the following equipment:

1. **Six metallic wires** – Four brass wires (each with a different thickness), one copper wire, and one aluminum wire (Figure 1).
2. **Resistivity apparatus** – This device holds the wire in place and lets you measure voltage across specific lengths (Figure 2).
3. **Power supply** – To send a constant current through the wire (Figure 4).
4. **Two multimeters** – One is used to measure current, the other to measure voltage across the wire (Figure 5).
5. **Digital caliper** – Used to measure the wire's diameter accurately (Figure 6).
6. **Connector wires** – To link the power supply, multimeters, and resistivity apparatus together (Figure 6).

FIGURE 4. *Adjustable DC power supply, used to fine-tune the current flowing through the wire.*

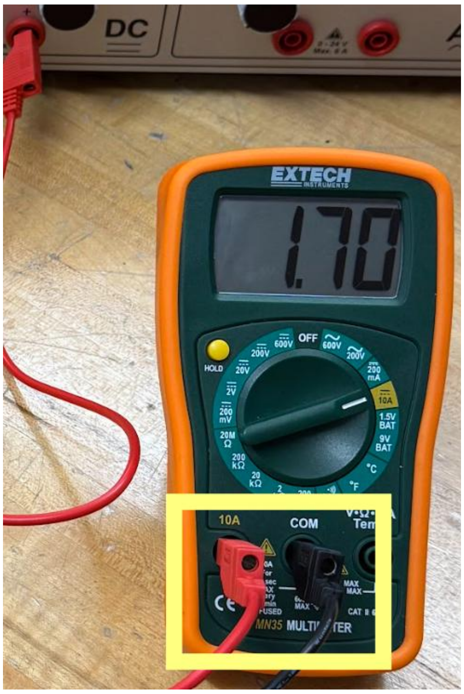
FIGURE 5. *Versatile digital multimeter, switched between voltage and current modes during testing.*

FIGURE 6. *Digital caliper used to measure wire diameters with high precision—down to a fraction of a millimeter.*

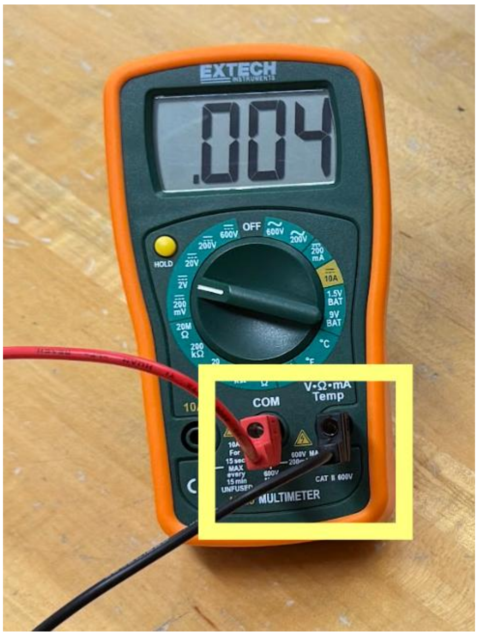
FIGURE 7. *Simple banana-to-banana connector wires used to complete the circuit between components.*

SETUP AND EXPERIMENTAL PROCEDURE

1. Set up your multimeters correctly
   - **Current multimeter**: Plug the **red** wire into the **10A port (first hole)** and the **black** wire into **COM (second hole).** This multimeter will measure the current flowing through the circuit.



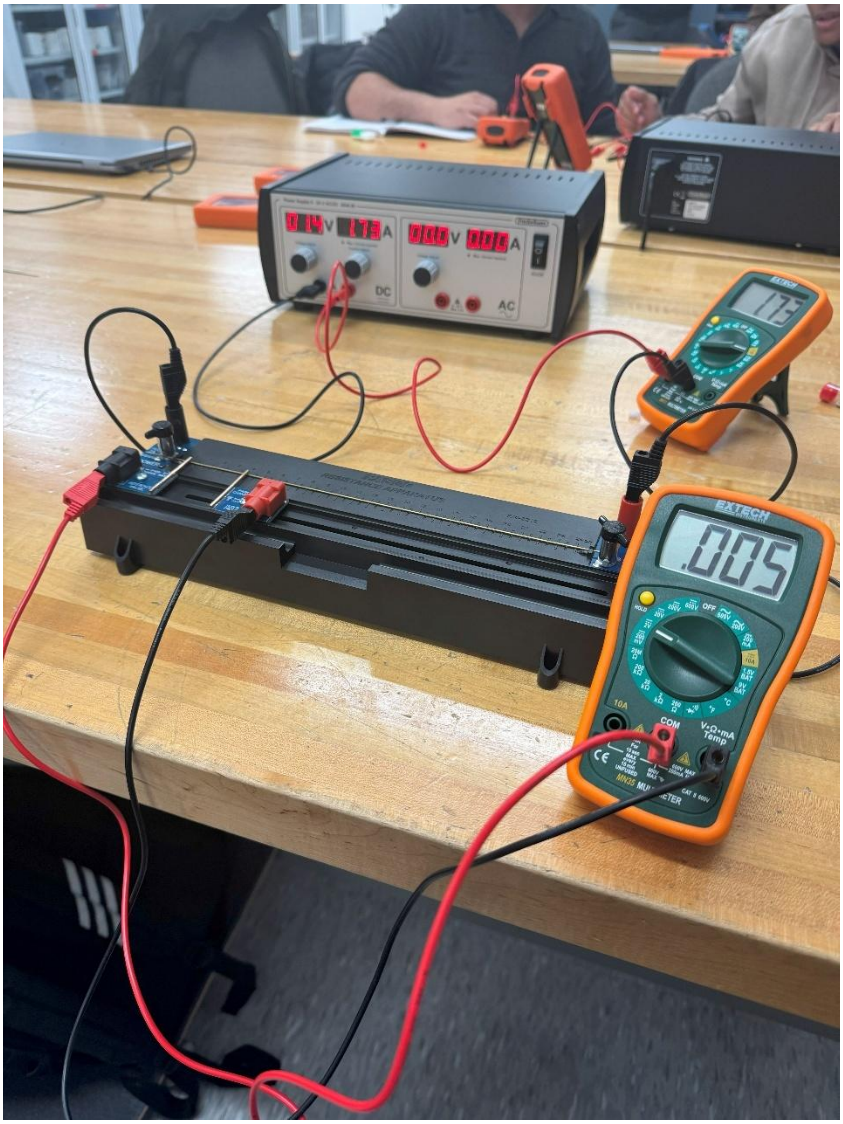
   - **Voltage multimeter**: Plug the **red** wire into the **V-Ω-mA port (third hole)** and the **black** wire into **COM (second hole)**. This one will measure the voltage drop across a section of wire.



2. Connect the circuit
   - Use a red wire to connect the positive terminal of the power supply to the 10A input on the current multimeter.

- Take a black wire and connect it from the COM output of the current multimeter to the right input port of the resistivity apparatus.

- Connect another black wire from the left side of the resistivity apparatus to the negative terminal of the power supply. Now, you have a full loop where current can flow through the wire.



3. Add the voltage probes
    - Attach the red and **black** wires from the voltage multimeter to the **reference and slider** probes on the **resistivity apparatus**. These probes will allow you to select different wire lengths for voltage readings.

4. Insert and identify the wire
    - Take one of the wires (start with brass), measure its diameter using the digital caliper, and write it down. Be sure to note the material (brass, copper, or aluminum) and its color (brass is yellow, copper is red, aluminum is shiny silver).

5. Insert the wire into the resistivity apparatus
    - Insert the wire securely between the terminal screws. Make sure it is stretched straight, and the connections are tight.

6. Set the voltage and current
    - Turn on the power supply. **Slowly** adjust the voltage and current dials **together** until the current displayed on the current multimeter is close to 1.7 A.

    - ⚠️ Important: Do not exceed 1.8 A. Higher currents may damage the apparatus or overheat the wire.

7. Take voltage measurements
    - Using the reference and slider probes, measure the voltage drop across wire sections of 0.04 m, 0.06 m, 0.08 m, 0.10 m, 0.12 m, and 0.14 m.

    - Write down the voltage readings from the **voltage multimeter** for each length. The **current should stay** the same throughout **all six points**.

8. Repeat for each wire
    - After finishing all 6 points, turn off the power supply, remove the current wire, and repeat steps 4–7 for the next wire.
    - Don't forget to measure and record the diameter each time before inserting the wire.

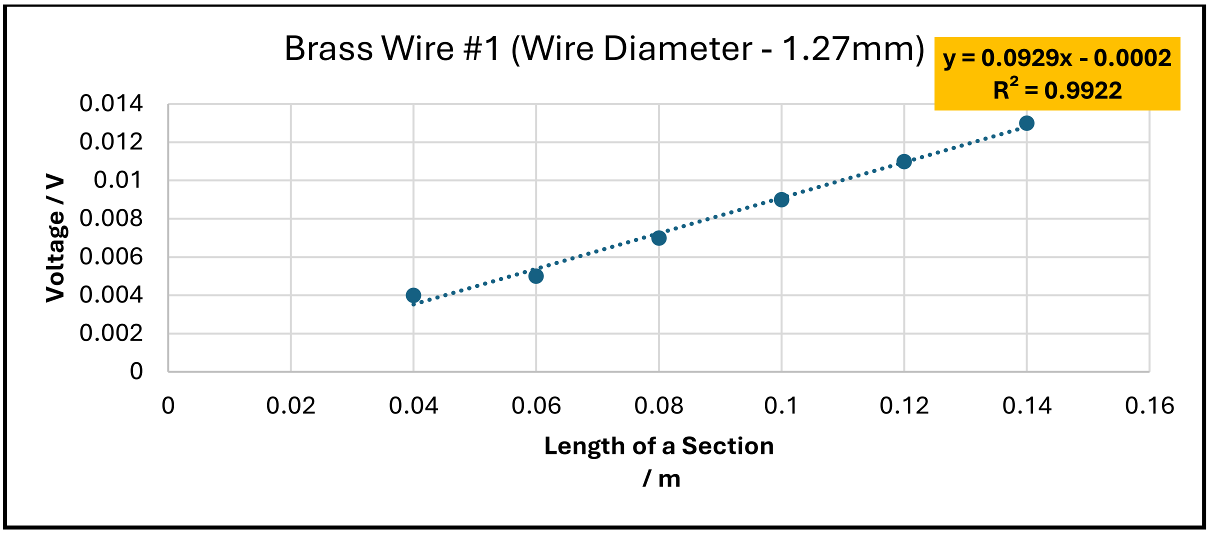
DATA & ANALYSIS

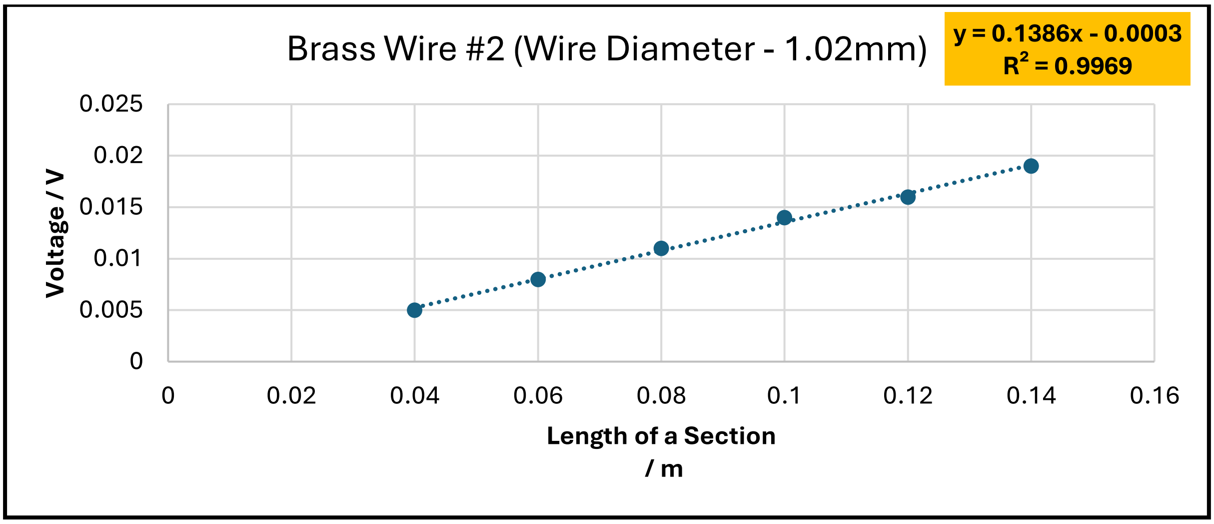
The experimental data collected is summarized in the following tables:

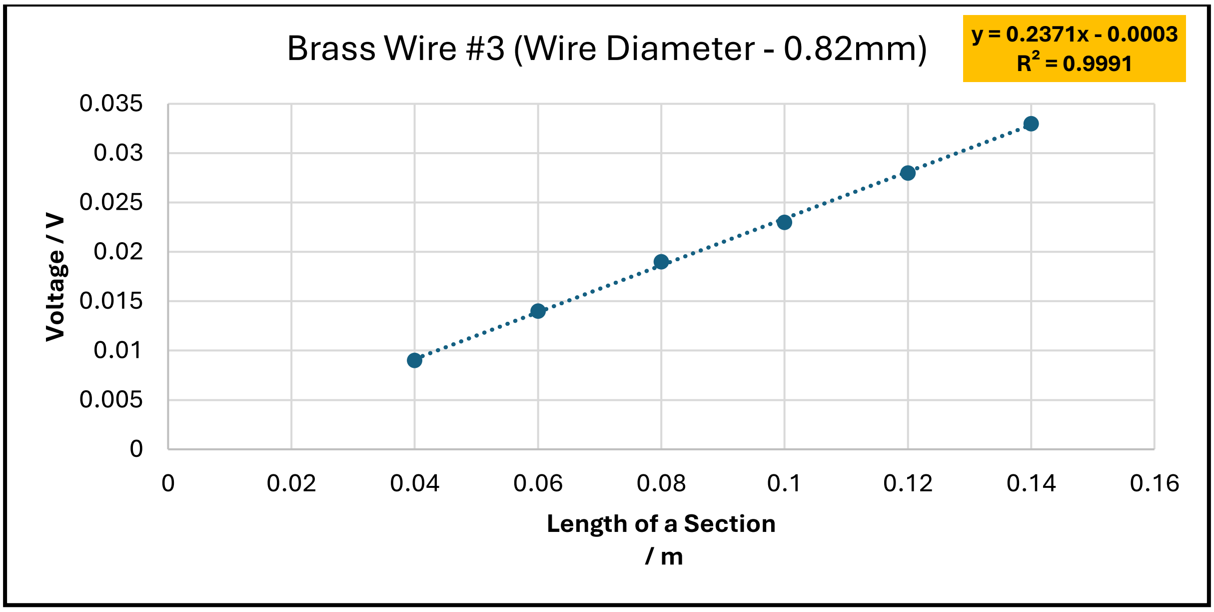
Brass Wire #1 (Wire Diameter - 1.27mm)				Brass Wire #2 (Wire Diameter - 1.02mm)			
Data Point	***Length of a Section / m***	***Voltage / V***	***Applied Current / A***	***Data Point***	***Length of a Section / m***	***Voltage / V***	***Applied Current / A***
1	0.04	0.004	1.7	***1***	0.04	0.005	1.7
2	0.06	0.005	1.7	***2***	0.06	0.008	1.7
3	0.08	0.007	1.7	***3***	0.08	0.011	1.7
4	0.1	0.009	1.7	***4***	0.1	0.014	1.7
5	0.12	0.011	1.7	***5***	0.12	0.016	1.7
6	0.14	0.013	1.7	***6***	0.14	0.019	1.7
Brass Wire #3 (Wire Diameter - 0.82mm)				**Brass Wire #4 (Wire Diameter - 0.50mm)**			
Data Point	***Length of a Section / m***	***Voltage / V***	***Applied Current / A***	***Data Point***	***Length of a Section / m***	***Voltage / V***	***Applied Current / A***
1	0.04	0.009	1.66	***1***	0.04	0.014	1.7
2	0.06	0.014	1.66	***2***	0.06	0.038	1.7
3	0.08	0.019	1.66	***3***	0.08	0.051	1.7
4	0.1	0.023	1.66	***4***	0.1	0.064	1.7
5	0.12	0.028	1.66	***5***	0.12	0.077	1.7
6	0.14	0.033	1.66	***6***	0.14	0.09	1.7
Copper Wire (Wire Diameter - 1.016mm)				**Aluminum Wire (Wire Diameter - 1.016mm)**			
Data Point	***Length of a Section / m***	***Voltage / V***	***Applied Current / A***	***Data Point***	***Length of a Section / m***	***Voltage / V***	***Applied Current / A***
1	0.04	0.001	1.7	***1***	0.04	0.004	1.7
2	0.06	0.002	1.7	***2***	0.06	0.007	1.7
3	0.08	0.003	1.7	***3***	0.08	0.009	1.7
4	0.1	0.003	1.7	***4***	0.1	0.011	1.7
5	0.12	0.004	1.7	***5***	0.12	0.014	1.7
6	0.14	0.005	1.7	***6***	0.14	0.016	1.7

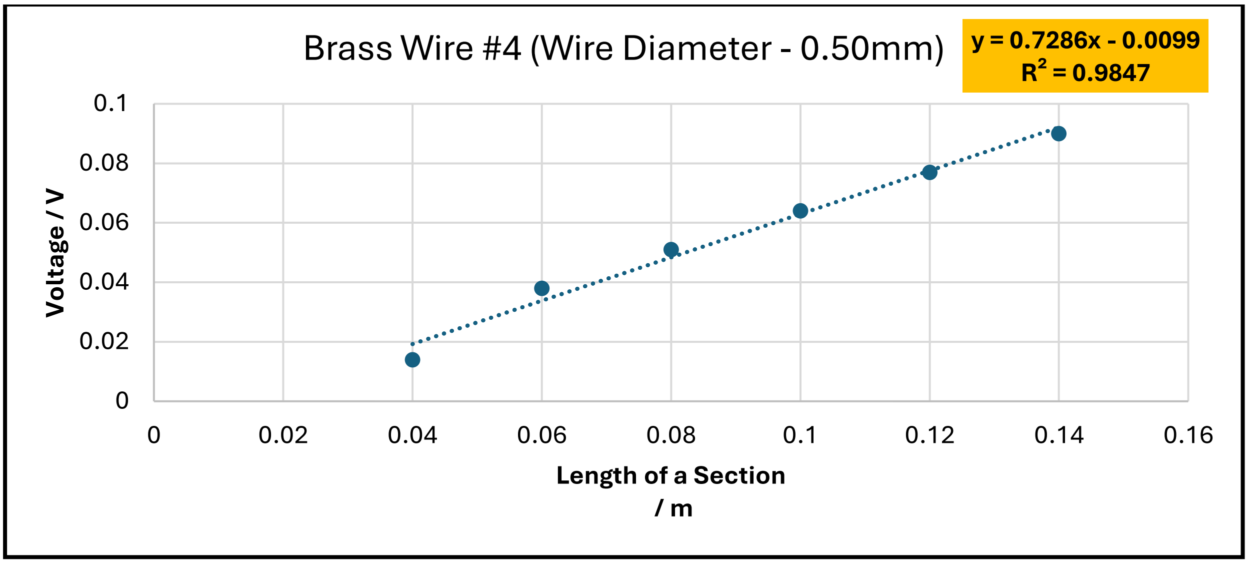
TABLE 1. *Experimental voltage readings taken along multiple lengths of brass, copper, and aluminum wires at steady current levels. Data supports resistivity calculations based on the linear relationship between voltage and length.*

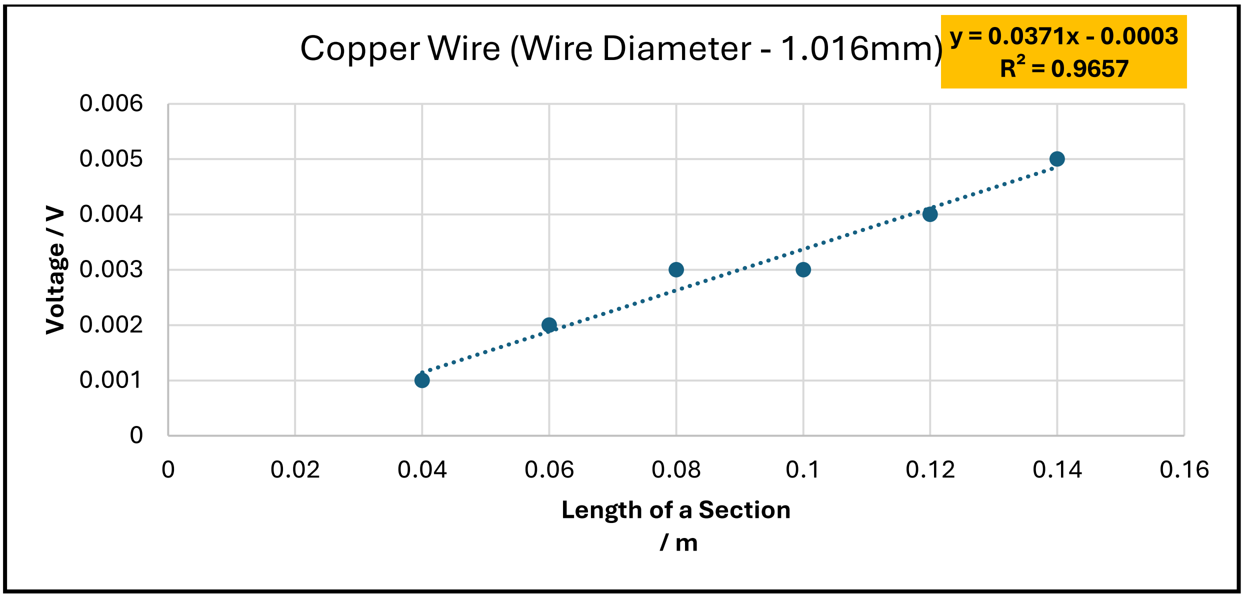
To analyse how voltage changes with wire length and determine resistivity for each material, voltage measurements were plotted against corresponding wire lengths. The graphs below represent these relationships for six different wires, each graph showing a clear linear trend. The slope of each line was obtained from the best-fit equation and used in the resistivity formula to calculate experimental values. Comparing these slopes gives insight into how factors like material type and wire diameter influence electrical resistance. Each graph is labelled with the wire material and diameter for clarity.

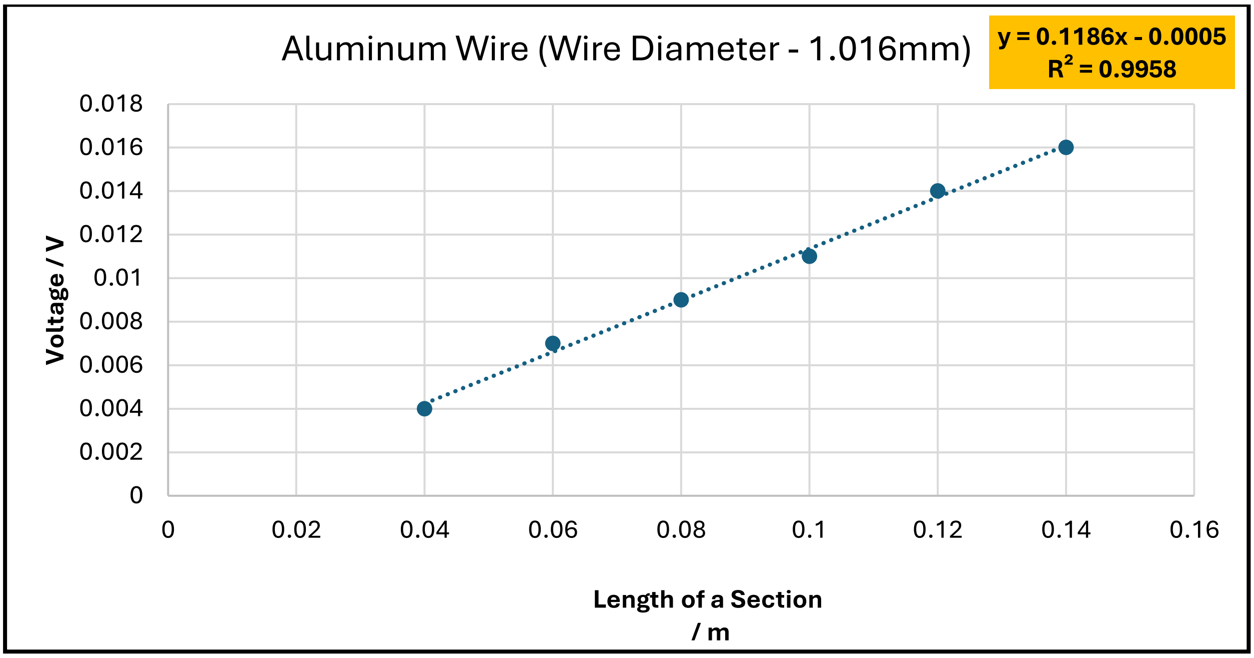







Brass Wire #4 (Wire Diameter - 0.50mm)
y = 0.7286x - 0.0099
R² = 0.9847
Voltage / V
0.1
0.08
0.06
0.04
0.02
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
Length of a Section / m


Copper Wire (Wire Diameter - 1.016mm)
y = 0.0371x - 0.0003
R² = 0.9657
Voltage / V
0.006
0.005
0.004
0.003
0.002
0.001
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
Length of a Section / m


Aluminum Wire (Wire Diameter - 1.016mm)
y = 0.1186x - 0.0005
R² = 0.9958
Voltage / V
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
Length of a Section / m

Analysis								
Wire Material	***Wire Diameter / mm***	***Wire Diameter / m***	***Cross-sectional Area of a wire / m^2***	***Obtained Slope***	***Applied Current / A***	***Experimental Resistivity / Ohm meters (Ω·m)***	***Manufacturer Provided Resistivity / Ohm meters (Ω·m)***	***Error %***
Brass #1	1.27	1.27E-03	1.27E-06	9.29E-02	1.7	6.92E-08	7.00E-08	1%
Brass #2	1.02	1.02E-03	8.17E-07	1.39E-01	1.7	6.66E-08	7.00E-08	5%
Brass #3	0.82	8.20E-04	5.28E-07	2.37E-01	1.66	7.54E-08	7.00E-08	8%
Brass #4	0.5	5.00E-04	1.96E-07	7.29E-01	1.7	8.41E-08	7.00E-08	20%
Copper	1.016	1.02E-03	8.11E-07	3.71E-02	1.7	1.77E-08	1.80E-08	2%
Aluminum	1.016	1.02E-03	8.11E-07	1.19E-01	1.7	5.65E-08	4.90E-08	15%

TABLE 2. *Comparison of experimental and manufacturer-provided resistivity values for six metallic wires. The table includes wire diameters, calculated cross-sectional areas, slope from voltage vs. length graphs, applied current, and percent error. Results show strong agreement for thicker wires, with increased deviations observed for thinner wires.*

CONCLUSION

This experiment successfully demonstrated how to determine the electrical resistivity of different metal wires by analyzing the **linear relationship** between **voltage and length under constant current**. Using **Ohm's Law** and the **resistivity formula**, we calculated experimental resistivity values for four brass wires of varying diameters, one copper wire, and one aluminum wire. By measuring the voltage across known lengths and maintaining steady current, we extracted **slopes from the voltage vs. length graphs**, then incorporated measured wire diameters to calculate **cross-sectional areas.**

Our experimental values showed strong alignment with manufacturer-provided resistivities, with **error percentages** ranging from as low as **1% for Brass #1 to as high as 20%** for the **thinnest brass** wire. These variations are likely due to difficulties in measuring voltage accurately across very thin wires, and minor inconsistencies in wire uniformity or contact resistance.

Overall, the experiment confirmed that resistivity is a **material-specific property.** Moreover, the experiment reinforced the **direct proportionality** of **voltage to length** for uniform conductors. The findings validate Ohm's Law and emphasize the importance of precise measurements when dealing with small voltages and dimensions in electrical experiments.

ACKNOWLEDGMENTS

I would like to acknowledge my lab partner Jonah Villafan and Jabir Rahman for their assistance in data collection. I also appreciate Dr. Ray D. Sameshima's guidance during the lab.

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FIGURES

Figure 1. *Replacement wires*. From PASCO Scientific. https://www.pasco.com/products/lab-apparatus/electricity-and-magnetism/circuits-and-components/replacement-wires-resistivity-apparatus

Figure 2. *Resistivity apparatus*. From PASCO Scientific. https://www.pasco.com/products/lab-apparatus/electricity-and-magnetism/circuits-and-components/resistivity-apparatus

Figure 3. *Graphical representation of the relationship between resistivity (ρ), resistance (R), length (L), and cross-sectional area (A) for a uniform wire.* https://d1yqpar94jqbqm.cloudfront.net/styles/media_full/s3/images/8a556384c665250773869401ee575b0ee71557fc.jpg?itok=K_DQacRg

Figure 6. *Digital caliper*. From Walmart. https://i5.walmartimages.com/seo/Visland-Electronic-Digital-Caliper-Plastic-Vernier-Caliper-Caliper-Measuring-Tool-Inch-Millimeter-Conversion-Extra-Large-LCD-Screen-0-6-Inch-0-150-mm_ddc81d59-bbc2-4b5b-a95a-56db2c844ff3.f8a3683fe1d0dbc92253e960972a50eb.jpeg?odnHeight=768&odnWidth=768&odnBg=FFFFFF

Figures 4, 5, 7. *Photos taken during lab performance*. Photographed by Jabir Rahman.

TABLES

Table 1. *Experimental voltage readings taken along multiple lengths of brass, copper, and aluminum wires at steady current levels*. By Zhasmin Tuiachieva.

Table 2. *Calculated resistivity values based on slopes, wire dimensions, and applied current*. By Zhasmin Tuiachieva.