Factors Affecting Resistance Lab Report

Bryan Deng

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Contents

1 Design

1.1 Materials

- paper
- graphite pencil
- multimeter
- ruler

1.2 Purpose

To determine how length and width (cross-sectional area) affect the resistance of a ”wire”.

1.3 Procedure

1. Using the ruler and pencil, draw out 4 lines of the following dimensions:
   (a) length: $5\text{cm} \pm 0.05\text{cm}$, width: $0.5\text{cm} \pm 0.05\text{cm}$
   (b) length: $5\text{cm} \pm 0.05\text{cm}$, width: $2\text{cm} \pm 0.05\text{cm}$
   (c) length: $10\text{cm} \pm 0.05\text{cm}$, width: $0.5\text{cm} \pm 0.05\text{cm}$
   (d) length: $10\text{cm} \pm 0.05\text{cm}$, width: $2\text{cm} \pm 0.05\text{cm}$
2. Ensure that each line is completely and thoroughly filled in with graphite.
3. For each line, measure the resistance by putting the tips of the multimeter on opposite ends, along the length of the line.
4. Record data for each line in a table.

1.4 Diagrams

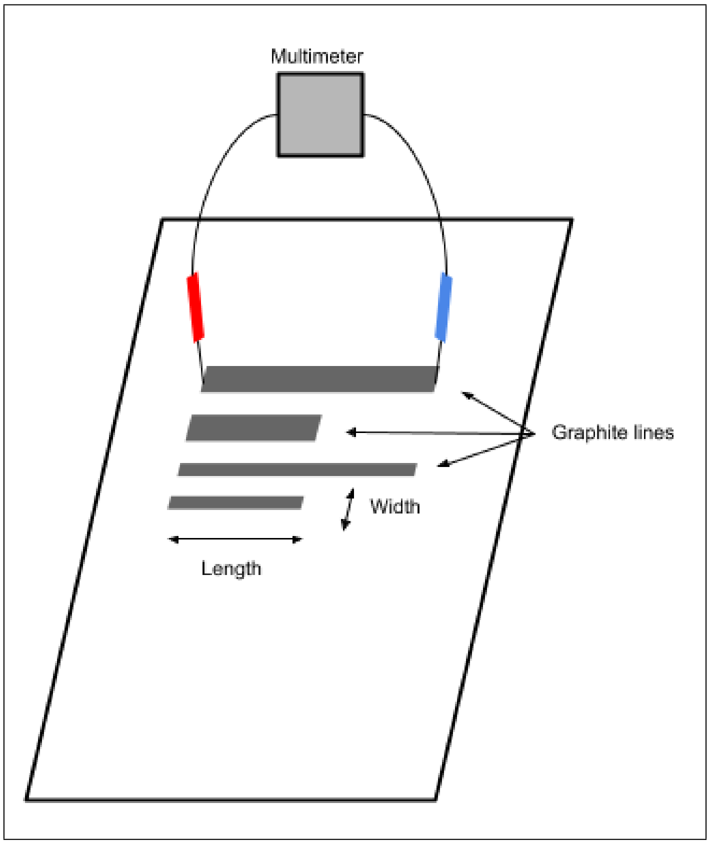

Figure 1: Diagram of lines and multimeter setup

2 Qualitative Observations

- The ends of the multimeter were not held completely still during each trial, so there was a constant fluctuation in the resistance readings.

3 Data Tables

Table 1: How width affects resistance, measured on 5cm long line

Width	**Resistance**
$0.5\text{cm} \pm 0.05\text{cm}$	$0.280\text{M}\Omega \pm 0.005\text{M}\Omega$
$2\text{cm} \pm 0.05\text{cm}$	$0.032\text{M}\Omega \pm 0.005\text{M}\Omega$

Table 2: How length affects resistance, measured on 0.5cm wide line

Length	**Resistance**
$5\text{cm} \pm 0.05\text{cm}$	$0.280\text{M}\Omega \pm 0.005\text{M}\Omega$
$10\text{cm} \pm 0.05\text{cm}$	$0.303\text{M}\Omega \pm 0.005\text{M}\Omega$

Table 3: Calculated slopes between factors that affect resistance and resistance

Variable	**Calculated Value**
Slope of resistance over width	$m_w = (-0.17 \pm 0.02)\frac{\text{M}\Omega}{\text{cm}}$
Slope of resistance over length	$m_l = (0.005 \pm 0.002)\frac{\text{M}\Omega}{\text{cm}}$

4 Plots

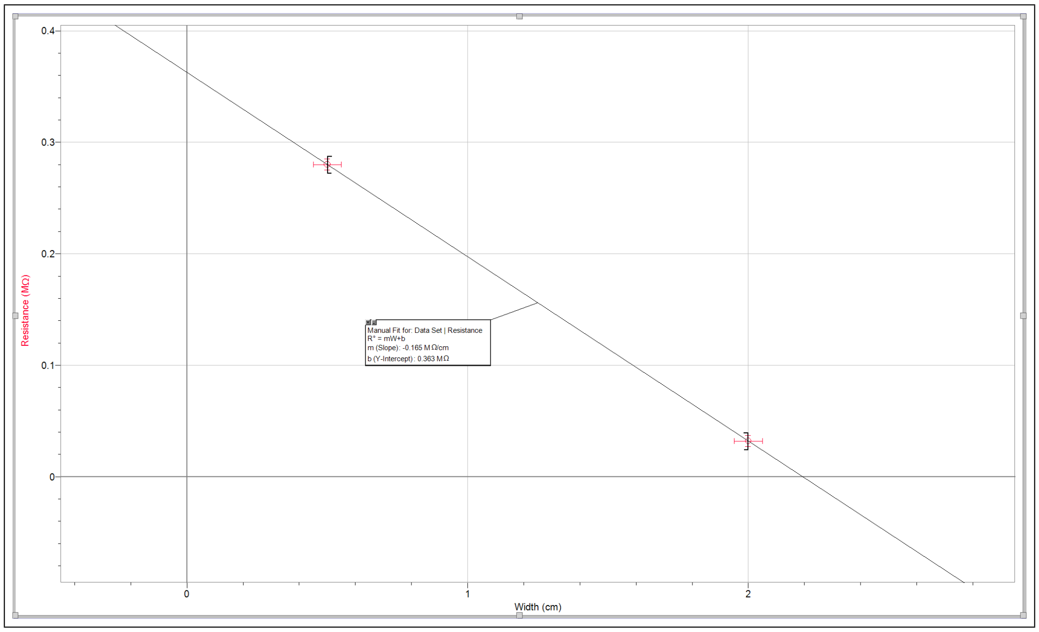

Figure 2: How width affects resistance, measured on 5cm $\pm$ 0.05cm long line

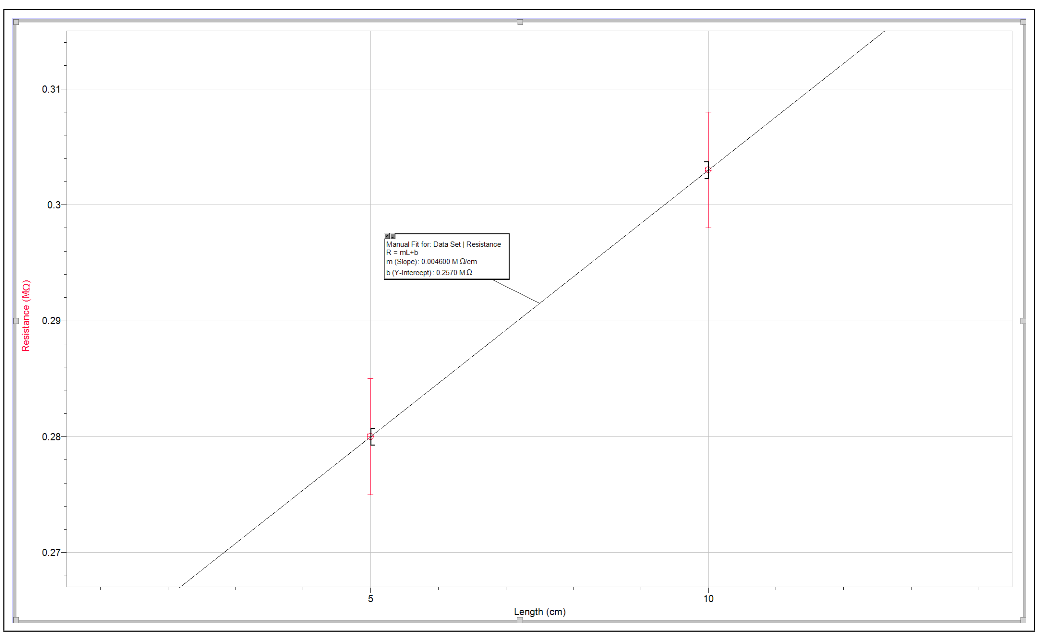

Figure 3: How length affects resistance, measured on 0.5cm $\pm$ 0.05cm wide line

5 Analysis

5.1 Slope of Resistance Over Width

$$
\begin{aligned}
m_w &= \frac{\Delta y}{\Delta x} \\
&= \frac{y_1 - y_2}{x_1 - x_2} \\
&= \frac{(0.280 \pm 0.005)\mathrm{M\Omega} - (0.032 \pm 0.005)\mathrm{M\Omega}}{(0.5 \pm 0.05)\mathrm{cm} - (2 \pm 0.05)\mathrm{cm}} \\
&= \frac{(0.280 - 0.032)\mathrm{M\Omega} \pm (0.005 + 0.005)\mathrm{M\Omega}}{(0.5 - 2)\mathrm{cm} \pm (0.05 - 0.05)\mathrm{cm}} \\
&= \frac{(0.248 \pm 0.01)\mathrm{M\Omega}}{(-1.5 \pm 0.1)\mathrm{cm}} \\
&= \left(\left(\frac{0.248}{-1.5}\right) \pm \left(\left|\frac{0.01}{0.248}\right| + \left|\frac{0.1}{-1.5}\right|\right) \times 100\%\right) \frac{\mathrm{M\Omega}}{\mathrm{cm}} \\
&= (-0.165 \pm 10.699\%) \frac{\mathrm{M\Omega}}{\mathrm{cm}}
\end{aligned}
$$

$$
\boxed{m_w = (-0.17 \pm 0.02) \frac{\mathrm{M\Omega}}{\mathrm{cm}}}
$$

5.2 Slope of Resistance Over Length

$$
\begin{aligned}
m_l &= \frac{\Delta y}{\Delta x} \\
&= \frac{y_1 - y_2}{x_1 - x_2} \\
&= \frac{(0.280 \pm 0.005)\text{M}\Omega - (0.303 \pm 0.005)\text{M}\Omega}{(5 \pm 0.05)\text{cm} - (10 \pm 0.05)\text{cm}} \\
&= \frac{(0.280 - 0.303)\text{M}\Omega \pm (0.005 + 0.005)\text{M}\Omega}{(5 - 10)\text{cm} \pm (0.05 - 0.05)\text{cm}} \\
&= \frac{(-0.023 \pm 0.01)\text{M}\Omega}{(-5 \pm 0.1)\text{cm}} \\
&= \left(\left(\frac{-0.023}{-5} \right) \pm \left(\left| \frac{0.01}{-0.023} \right| + \left| \frac{0.1}{-5} \right| \right) \times 100\% \right) \frac{\text{M}\Omega}{\text{cm}} \\
&= (0.005 \pm 45.478\%) \frac{\text{M}\Omega}{\text{cm}}
\end{aligned}
$$

$$
\boxed{m_l = (0.005 \pm 0.002) \frac{\text{M}\Omega}{\text{cm}}}
$$

6 Error Discussion

6.1 Random Errors

- It is impossible to completely fill in the lines with graphite, or maintain a consistent density of shading throughout the line, or across different lines. Therefore the resistance may fluctuate throughout the length of the line.

6.2 Methodological Errors

- Given the short time constraint, it was not possible to conduct further trials and generate a larger dataset. The smaller dataset is more prone to errors.
  - It is impossible to determine whether the relationship between each factor and resistance is linear or non-linear as there are only 2 data points per factor.
- Furthermore, only a single trial was conducted for each line. Although the measurements are accounted for by uncertainties, the entire dataset depends on this single trial. Therefore, if this one trial was off, it would not be possible to correct it by averaging it out with other values.

7 Conclusion

7.1 Width (Cross-sectional Area)

Based on the conclusion that the change in resistance over change in width is:

$$m_w = (-0.17 \pm 0.02)\frac{\mathrm{M\Omega}}{\mathrm{cm}}.$$

Resistance is negatively proportional to width, as $m_w < 0$. For every 1cm that width increases, resistance decreases by $(-0.17 \pm 0.02)\mathrm{M\Omega}$. Furthermore, because the experiment is based on a 2 dimensional plane, the width of the graphite line is equivalent to cross sectional area (A) in the third dimension. Therefore the experimental conclusion is:

$$R \propto -A$$

7.2 Length

Based on the conclusion that the change in resistance over the change in length is:

$$m_l = (0.005 \pm 0.002)\frac{\mathrm{M\Omega}}{\mathrm{cm}}.$$

Resistance is directly proportional to length, as $m_l > 0$. For every 1cm that length increases, resistance increases by $(0.005 \pm 0.002)\mathrm{M\Omega}$. Therefore the experimental conclusion is:

$$R \propto l$$

7.3 Comparison With Theory

Theoretically, $R \propto \frac{1}{A}$. This is in agreement with the experimental conclusion that as width increases, resistance decreases. However, the theoretical relationship is non-linear, as opposed to the linear relationship derived from the experimental data. This is due to the very small dataset of only 2 points, as aforementioned in error analysis.

As with length, theoretically, $R \propto l$. This is the same as what was derived through the experiment.