Ohm’s Law

Safety and Equipment
- Computer with PASCO Capstone, PASCO 850 Universal Interface
- Double banana/alligator Cable, 2 Alligator Wires
- PASCO Voltage Sensor Cable
- Multimeter with probes.
- Rheostat
- Ruler
- 6 V Lantern Battery

![Figure 1: (a) cables with alligator clips and (b) cables with banana plugs.](image)

Introduction

Georg Ohm discovered that when the voltage (potential difference) across a resistor changes, the current through the resistor changes. He expressed this as

\[ I = \frac{V}{R} \]

where \( I \) is current, \( V \) is voltage (potential difference), and \( R \) is resistance. According to Ohm’s Law, current is directly proportional to voltage (if the resistance is constant) and inversely proportional to resistance (if the voltage is constant). In other words, as the voltage increases, so should the current. The proportionality constant is the value of the resistance. Since the current is inversely proportional to the resistance, as the resistance increases, the current decreases.

A resistor is ‘Ohmic’ if its resistance is constant. This means that as the voltage across a resistor is increased, the current increases proportionally. A graph of voltage vs. current will show the function \( V = IR \) as a straight line. The slope of the line is the value of the resistance. A device is ‘non-Ohmic’ if the graph of voltage vs.
current is not a straight line. For example, if the resistance changes as voltage changes, the graph of voltage vs. current might show a curve with a changing slope. (Note: the "resistance" is \( \frac{V}{I} \), which is the slope of a line from a point on the graph to the origin. If the \( V \) vs. \( I \) graph is curved, the slope of that curve is not the resistance.)

**Objectives:**

- *To verify Ohm’s Law.*
- *To determine the internal resistance of a battery using Ohm’s Law.*

**Part #1 Measurement of Resistance**

The device designed to measure a Resistance is called an ohmmeter. The Ohmmeter can be a part of a Multimeter, a device designed to measure multiple quantities including a Resistance. **There should be no voltage across the resistor when its resistance is measured.** Measure the resistance prior to constructing a circuit. To measure the resistance, just connect the ends of the resistor to be measured to the terminals of the ohmmeter or touch the probes of the ohmmeter to the ends of the resistor.

1. A device with adjustable resistance is called a rheostat. Move the slider of the rheostat to the position 4 cm from the point where current enters the device. See Figure 2.
2. Set the Multimeter up as an Ohmmeter.
   - Set the main switch to the “\( \Omega \)” section starting with 200\( \Omega \)
   - Connect the red wire to the socket labeled “\( V/\Omega \)” and leave the black wire in the "COM"
3. Connect one wire of the Multimeter to the point where current enters and the other wire to the point where the current exits the rheostat. See Figure 2.

![Figure 2. Diagram of the rheostat and its terminals.](image)

4. Take a reading of the resistance from the Ohmmeter display. Record the reading in Table 1(see part 2)
5. Move the slider of the rheostat 4 cm further from that end and take another reading of the resistance. Repeat this until the slider reaches the end of the rheostat.
6. Comment on how and why the resistance changes as the slider of the rheostat moves further from the point of the current entrance. Include this statement in the abstract.
Part #2 Measurement of an Electric Current

The device designed to measure an Electric Current is called an **ammeter**. The Ammeter can be a part of a Multimeter, a device designed to measure multiple quantities including an Electric Current. To ensure that the same current passes through both the resistor and the ammeter, the ammeter is always inserted into the circuit next to the resistor by **disconnecting and reconnecting wires** as shown on Figure 3. The current flows from “+” terminal (higher potential) of the battery into the Ammeter, then it flows out of the Ammeter to enter the resistor. Therefore, the red terminal of the ammeter should be connected to a higher potential ("+" end of the battery) and black terminal of the ammeter should be connected to the resistor.

![Figure 3. Schematic set up of the circuit with an ammeter](image)

1. Open the file “DC Power Supply Set Up” from the Blackboard (Lab #2 folder)
2. Connect banana plugs to corresponding Red/Black terminals of the 850 Universal Interface
7. Set the Multimeter up as an **Ammeter**.
   - Set the main switch to the A section.
   - Connect the red wire to the socket labeled “A” and leave the black wire in the "COM"

3. Connect the red terminal of the Ammeter to the red alligator clip and the black terminal of the Ammeter to the “in” point of the rheostat; then connect the “out” point of the rheostat to the black alligator clip.
4. Move the slider of the rheostat to the first slider location that you used in Part 1.
5. Start the power supply (follow the instructions in the Capstone file).
6. Take a reading of the Ammeter and compare it to Output Current (A). Are they agreed? If not, you didn’t connect circuit right.
7. Move the slider of the rheostat to the next position that you used in Part 1 and take another reading of the current. Repeat for each of the slider positions.

<table>
<thead>
<tr>
<th>Position (cm)</th>
<th>4</th>
<th>8</th>
<th>12</th>
<th>16</th>
<th>20</th>
<th>24(?)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistance (Ω)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current (A)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 1.** Rheostat resistance and current through the rheostat readings at different positions of the slider. The slider’s position should not vary between two parts.

8. Make scatter plot Current vs. Resistance; fit it into a power function $y = mx^{-1}$
9. Comment on how and why the current changes as the slider of the rheostat moves further from the point of the current entrance. Does the current decrease as the resistance gets larger? Is the relationship truly an inverse proportionality? Make a connection between the experimental observation of the trend in both, current and resistance, and Ohm’s Law. Include this statement in the abstract.

Part #3 Measuring Voltage and an I-V Curve.

The device designed to measure a Potential Difference or Voltage is called a voltmeter. The Voltmeter can be a part of a Multimeter, a device designed to measure multiple quantities including a potential difference. A Voltmeter is often built in to a DC Power Supply. To measure a potential difference between any two points in a circuit, the red terminal of the voltmeter is connected to a point at a higher potential and the black terminal to a point at a lower potential. On the Figure 4, point ① has higher potential than point ② (current always flows from higher potential to lower potential). Notice that the potential difference or voltage is measured across a battery or resistance.

![Figure 4](image)

**Figure 4.** Schematic set up of the circuit with a voltmeter

During this part, the rheostat slider doesn’t move. Instead, the power supply’s voltage will vary. The response of the current to the variations of the voltage is the “I-V Curve” for the rheostat.

1. Set the Multimeter up as a Voltmeter.
   - Set the main switch to the 20V setting of DC Voltage section (\(\text{V/Ω}\)).
   - Connect the red wire to the socket labeled “V/Ω” and leave the black wire in the "COM"

2. Connect the terminal of Voltmeter to respective ends of the rheostat (red to high potential and black to low potential).
3. Move the slider of the rheostat to the position of 16 cm.
4. Set the DC Voltage as low as 0.5 V.
5. Take a reading of the Voltage and the Output Current of the 850 Universal Interface.
6. Adjust the voltage of the power supply upward by 0.5V, and take readings of the Current and Voltage.

| Current (A) |   |   |   |   |
| Voltage (V) |   |   |   |   |

*Table 2.* Current through the rheostat measured at different voltages across the rheostat. The slider was at a Position of 16 cm during all measurements.
7. Make scatterplot Voltage vs. Current. (Make sure to plot Voltage values along the y-axis. This means we’re generating a “V-I Curve”, but this graph is easier to analyze.) The slope of the Voltage vs. Current graph should be equal to the resistance of the rheostat at current position of the slider.

8. Verify whether the slope of the graph equals the resistance of the rheostat at set position of the slider (refer to Table 1). Calculate % difference between the slope and the resistance of the rheostat.

<table>
<thead>
<tr>
<th>Slope of V vs. I graph (V/A)</th>
<th>Measured Resistance of rheostat (Ω)</th>
<th>% Difference</th>
</tr>
</thead>
</table>

Table 3. Comparison of the V-I graph of the rheostat to its resistance.

9. Comment on how the experimental data supports the Ohm’s Law. Include this statement in the abstract.

**Part #4. Determining the Internal Resistance of a Battery.**

Every power supply has an *internal resistance* (*r*). In a circuit, the current flows in closed loop. This means that it flows through power supply as well as through the rest of the circuit. The power supply itself adds some extra resistance to the circuit. The voltage measured across the terminals of the power supply before connecting anything is different from the voltage measured across the terminals after the circuit is complete. The maximum possible potential difference across the terminal of the power supply is called *emf* (ε). The voltage across the terminals of the power supply or terminal voltage equals emf of the battery when circuit is open and there is no current in the battery.

In the closed circuit, where there is current passing through the battery, the value of the terminal voltage is lower than the value of emf. The difference between terminal voltage of an open circuit and terminal voltage of a closed circuit comes from the internal resistance of the power supply that drops voltage as any resistance. The effect of the internal resistance on the circuit could be described by the Ohm’s Law for a complete circuit

\[
emf = V_{terminal} + Ir
\]

The greater the current in the circuit the greater the difference between emf and terminal voltage of a closed circuit.

1. Set the slider of the rheostat to a random position.
2. Set the Multimeter as a Voltmeter and measure emf of a battery (refer to Part #3).
3. Connect the battery to the rheostat and measure the terminal voltage of the battery.
4. Remove the Multimeter from the circuit.
5. Set the Multimeter as an Ammeter and correctly insert the Ammeter *into the circuit* (refer to Part #2).
6. Measure the current through the rheostat.
7. Determine the internal resistance of the battery from the Ohm’s Law for a complete circuit.
8. Design and label Table 4 to record the results. Include the numerical results in the abstract.