

Ohm's Law

Safety and Equipment

- Computer with PASCO Capstone, PASCO 850 Universal Interface
- 2 Double banana Cable, 2 Alligator Wires
- Multimeter with probes
- Rheostat
- Ruler
- 6 V Lantern Battery



Figure 1: (a) cables with alligator clips and (b) cables with banana plugs.

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. It has two fixed terminals connected to the ends of the wire (bottom terminals in the figure), and one terminal connected to the slider (top terminal in the figure). Choose one of the fixed terminals, and use the same fixed terminal for the entire lab. Always measure the slider position from the end with the fixed terminal that you're using.
2. Set the initial slider position to 4 cm.
3. Set the Multimeter up as an ***Ohmmeter***.
 - Set the main switch to the " Ω " setting.
 - Connect the red wire to the multifunction socket (with " Ω ") and the black wire to "COM".
4. Connect one wire of the Multimeter to your fixed terminal of the rheostat ("Current in") and the other wire to the terminal on the slider ("Current out"). Use alligator clips if necessary. See Figure 2.

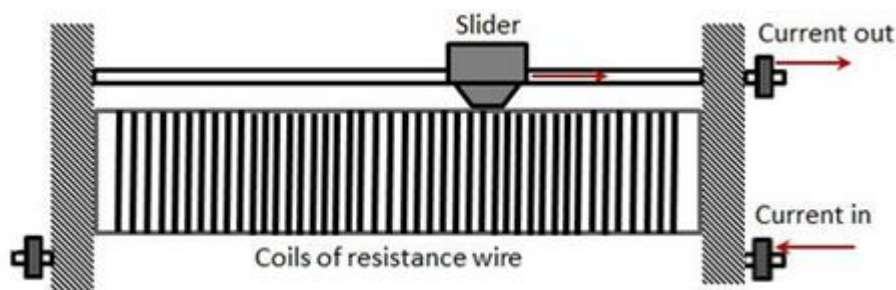


Figure 2. Diagram of the rheostat and its terminals.

5. Take a reading of the resistance from the Ohmmeter display. Record the reading in Table 1 (see part 2).
6. Set the slider 4 cm further away and repeat the measurement. Repeat this until the slider reaches the end of the rheostat.
7. 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.
8. **Disconnect the wires before proceeding to the next Part.**

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.

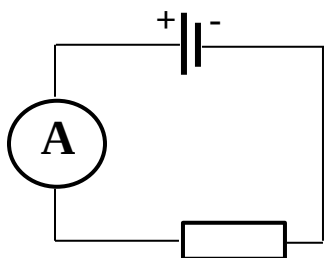


Figure 3. Schematic set up of a circuit with an ammeter. The rheostat is represented by the box.

1. Connect red/black banana wires to the corresponding terminals of the PASCO Interface.
2. Set the Multimeter up as an **Ammeter**.
 - Set the main switch to “A” (not “ μ A” or “mA”).
 - Connect the red wire (from the PASCO interface) to the socket labeled “10 A”.
 - Connect a black wire (not the one going to the PASCO interface) to the “COM”.
3. Connect the two black wires to the rheostat, using alligator clips if necessary. Use the same rheostat terminals that you used in Part #1.
 - One black wire comes directly to the PASCO interface.
 - The other black wire comes from the multimeter.
4. Open the file “DC Power Supply Set Up” from PhysLab.tamucc.edu, and make sure the PASCO interface is on.
5. Set the slider to 4 cm. Set the power supply voltage to 0.3 V.
6. Start the power supply (Press Record in Capstone). Take a reading of the Ammeter and compare it to Output Current (A). Are they similar? If not, you didn’t connect circuit right.
7. Record the current from the multimeter in Table 1.
8. Repeat the measurement for each slider position.
9. Press Stop in Capstone and disconnect the wires before proceeding.

Position (cm)	4	8	12	16	20	24(?)
Resistance (Ω)						
Current (A)						

Table 1. Rheostat resistance (Part #1) and current (Part #2) through the rheostat at different positions of the slider. When measuring current, the power supply voltage was _____.

10. Make scatter plot Current vs. Resistance; fit it into a power function $y = mx^{-1}$
11. 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.

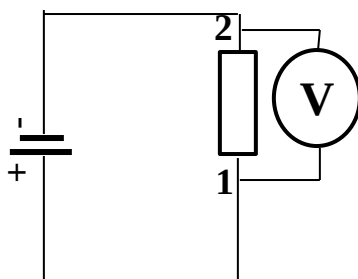


Figure 4. Schematic set up of the circuit with a voltmeter

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 rheostat slider to 16 cm.
2. Connect red/black banana wires to the corresponding terminals of the PASCO Interface.
3. Connect the red/black wires directly to the rheostat terminals, using alligator clips if necessary.
4. Set the Multimeter up as a Voltmeter.
 - Set the meter knob to DC Voltage (V $\overline{\text{---}}$).
 - Connect a second red wire to the multifunction socket (with "V").
 - Connect a second black wire to the "COM" socket.
5. Connect the red/black wires from the Voltmeter to the rheostat. The banana terminals "stack".
6. Set the DC Voltage to 0.2 V and press Record in Capstone.
7. Record the voltage from the voltmeter (it should be close to the Capstone setting) and record the current from Capstone display in Table 2.
8. Adjust the voltage of the power supply upward by 0.2 V, 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.

9. 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.
10. Verify whether the slope of the graph equals the resistance of the rheostat at set position of the slider (refer to Table 1 or re-measure the resistance). Calculate % difference between the slope and the resistance of the rheostat.

Slope of V vs. I graph (V/A)	
Measured Resistance of rheostat (Ω)	
% Difference	

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

11. Comment on how the experimental data supports the Ohm's Law. Include this statement in the abstract.
12. Make sure to press Stop in Capstone and disconnect all wires before proceeding.

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

Every power supply has an **internal resistance** (R_{int}). 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 ($\mathcal{E}$). 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

$$\mathcal{E} = V_{\text{terminal}} + IR_{\text{int}}$$

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. A large value like 16 cm is recommended.
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.

Requirements for the Report:

The report must contain a **Header** at the top (Title of Lab, Authors, and Date)

Abstract Section must contain the following in paragraph form:

- Brief Introduction that includes objectives and basic theory of the lab. Include:
 - The definition of Voltage, Current, and Resistance.
 - What is a difference in the way each of the above quantities is measured by a Multimeter?
 - According to Ohm's Law, what is the relationship between the three quantities above?
- Methodology describing broadly what was done, using what tools, and what was measured/recorded.
- Data Summary including quantities worked into sentences.
 - Explain how and why *resistance* changes as the rheostat slider moves away from the beginning of the coil.
 - Explain how and why *current* changes as the rheostat slider moves away from the beginning of the coil. Incorporate Current vs Resistance graph into your discussion. Analyze the graph and interpret its trendline (include equations using physics variables). How does the trend relate to Ohm's Law?
 - Comment on the relationship between voltage and current. Utilize Voltage vs Current graph to support your discussion. Does the slope of the graph match the measured resistance of the rheostat? Does the data support Ohm's Law?
 - Explain how you calculated the internal resistance of the battery. Include your measured values in your explanation. What is the difference between emf and terminal voltage?
- The lab manual contains questions and/or imperatives throughout that will guide you with the conclusions. **Always incorporate the questions and/or imperatives from the lab manual.**
- Sources of Error and a ballpark estimate of their contribution. DO NOT use "human error". That term is too vague to be meaningful.

Data Section must contain the following:

[Each table and graph should be labeled and descriptively captioned]

- 4 Tables
- 2 Graphs (each graph will use a different type of trendline)