RVCC Physics – Online Lab
Experiment: Ohm’s Law and Resistance

Objectives:

The objective of this activity is to investigate the relationship between current, voltage, and resistance in Ohmic and Non-Ohmic materials, and to verify Ohm's law using simulation software and real data obtained from resistance circuits. We will also explore the relationship between resistance and resistivity using simulation software.

Equipment:

- Scientific Calculator
- Real Voltage vs Current Data
- Computer with MS Excel (see instructions posted on Canvas for downloading/using)
- PhET Ohm’s Law Simulation
- PhET Resistance in a Wire Simulation

Theory

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

$$\boxed{\boldsymbol{I = \frac{V}{R} \quad \Rightarrow \quad V = IR}}$$

  Where:
  - $\boldsymbol{I}$ = current (A or Ampere)
  - $\boldsymbol{V}$ = voltage or potential difference (V or Volt)
  - $\boldsymbol{R}$ = resistance (Ω or Ohm)

- Ohm's law states that the current is directly proportional to voltage and inversely proportional to resistance. In other words, as the voltage increases, so does the current. The proportionality constant is the value of the resistance. The current is inversely proportional to the resistance. As the resistance increases, the current decreases.

- A material is **Ohmic** if it obeys Ohm's law and has a constant resistance for a wide range of voltages and currents. A graph of voltage versus current yields a straight line, indicating a constant resistance. The slope of the line is equal to the value of the resistance of the material.

- A material is **Non-Ohmic** if the graph of voltage versus current is not a straight line, indicating a resistance that changes as voltage or current change. The graph of voltage versus current yield a curve with a changing slope or resistance.

- For a typical resistor, the value of its resistance does not change appreciably. However, for a **lightbulb**, the resistance of the filament will change as it heats up and cools down.

- At high AC frequencies, the filament does not have time to cool down, so it remains at a nearly constant temperature and the resistance stays relatively constant. At low AC frequencies (e.g., less than one Hertz), the filament has time to change temperature.

- Resistivity is the measurement of how much a specific material resists the flow of an electrical charge. The resistance is directly proportional to its length, and inversely proportional to its cross-sectional area. The formula relating resistance to resistivity is given below.

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

Where:
- $\boldsymbol{R}$ = resistance (Ω)
- $\boldsymbol{\rho}$ = resistivity (Ω·m)
- $\boldsymbol{L}$ = length (m)
- $\boldsymbol{A}$ = cross-sectional area (m^2)

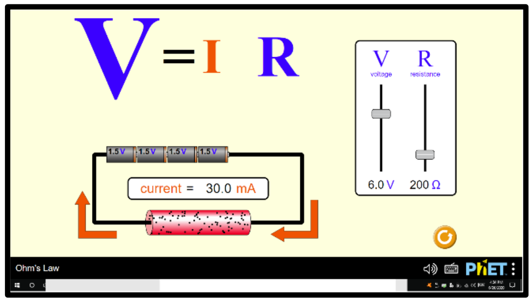
- In parts A and B of this activity, we will be simulating the relationship between current, voltage, and resistance. In parts B and C of this activity, we will investigate the relationship between current, voltage, and resistance across simple resistors, from real world data. In part D, we will investigate the relationship between current, voltage, and resistance across the filament of a small lightbulb. In part E of this activity, we will be simulating the relationship between resistance, resistivity, length, and area.

- Percentage error calculation is used to compare an experimental (measured) value to a theoretical or accepted value. The equation used to calculate a percentage error is:

$$\%\ \text{Error} = \frac{|Theoretical - Measured|}{Theoretical} \times 100\%$$

- Percentage difference calculation is used to compare two experimental (measured) values he equation used to calculate a percentage difference is:

$$\%\ \text{Diff} = \frac{|Measured1 - Measured2|}{Average} \times 100\%$$



<u>Part A – Resistance with *R* = *Constant* (*V* vs *I*):</u>

- In this part of the activity, we will explore the relationship between voltage and current with a constant resistance using the below PhET Ohm's Law Simulation:

  https://phet.colorado.edu/en/simulation/ohms-law

  ➢ Using the simulation slider controls, set approximately: "voltage (*V*)" ~ **1.00 V** and "resistance (*R*)" ~ **10.00 Ω**.

- Record the "current (*I*)" measurement in the table below. (Note: 1 mA = 1×10^{-3} A).

- Increase the "voltage (*V*)" by increments of ~**1.00 V**. Record the "current (*I*)" measurement for each trial in the below table. Repeat until you reach a maximum value of ***V*** = **8.00 V**.

- Using MS Excel program (see instructions posted on Canvas for downloading/using Excel), plot ***Voltage* versus *Current*** by entering your ***I*** (x-axis) and ***V*** (y-axis) into an Excel spreadsheet. Then, determine the slope by fitting a straight line (linear fit) to the data in the Excel graph. Record the slope in the below table.

- Repeat the above procedure using the "resistance (*R*)" set to ~ **100.00 Ω**.

- Save your two Excel graphs showing the data points, linear fit, and slope to include in the graphs section of your lab report.

<u>Part B – Resistance with *V* = *Constant* (*I* vs *1/R*):</u>

- In this part of the activity, we will explore the relationship between current and resistance with a constant voltage using the same PhET Ohm's Law Simulation:

  https://phet.colorado.edu/en/simulation/ohms-law

  ➢ Using the simulation slider controls, set approximately: "voltage (*V*)" ~ **1.00 V** and "resistance (*R*)" ~ **20.00 Ω**.

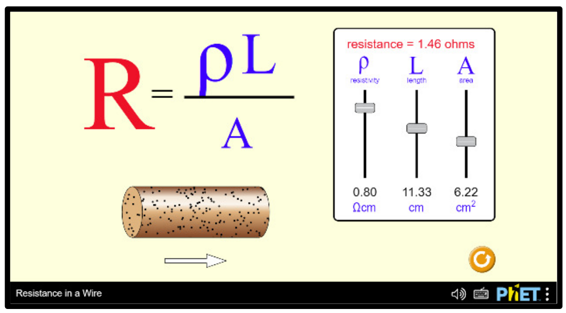
- Record the "current (*I*)" measurement in the table below. (Note: 1 mA = 1×10^{-3} A).

- Increase the "resistance (***R***)" by increments of **~10.00 Ω**. Record the "current (***I***)" measurement for each trial in the below table. Repeat until you reach a maximum value of ***R* = 90.00 Ω**.

- Calculate the *Inverse Resistance* (1/***R***) for all trials and record values in the below table.

- Using MS Excel program (see instructions posted on Canvas for downloading/using Excel), plot ***Current* versus *Inverse Resistance*** by entering your $\frac{1}{R}$ (x-axis) and ***I*** (y-axis) into an Excel spreadsheet. Then determine the slope by fitting a straight line (linear fit) to the data in the Excel graph. Record the slope in the below table.

- Save your Excel graph showing the data points, linear fit, and slope to include in the graphs section of your lab report.



Part C – Resistivity with *A* = *Constant* (*R* vs *L*):

- In this part of the activity, we will explore the relationship of resistance and length with a constant resistivity and area using the below PhET Resistance in a Wire Simulation:

  https://phet.colorado.edu/en/simulation/resistance-in-a-wire

  - Using the simulation slider controls, set approximately: "resistivity (*ρ*)" ~ **0.50 Ω·cm**, "length (*L*)" ~ **4.00 cm**, and "area (*A*)" ~ **7.50 cm^2**.

- Record the "resistance (***R***)" measurement in the below table.

- Increase the "length (***L***)" by increments of **~4.00 cm**. Record the "resistance (***R***)" measurement for each trial in the below table. Repeat until you reach a maximum value of ***L* = 20.00 cm**.

- Using MS Excel program (see instructions posted on Canvas for downloading/using Excel), plot ***Resistance* versus *Length*** by entering your ***L*** (x-axis) and ***R*** (y-axis) into an Excel spreadsheet. Then determine the slope by fitting a straight line (linear fit) to the data in the Excel graph. Record the slope in the below table.

- Save your Excel graph showing the data points, linear fit, and slope to include in the graphs section of your lab report.

Part D – Resistivity with *L = Constant* (*R* vs *1/A*):

- In this part of the activity, we will explore the relationship of resistance and length with a constant resistivity and area using the below PhET Resistance in a Wire Simulation:

  https://phet.colorado.edu/en/simulation/resistance-in-a-wire

  - Using the simulation slider controls, set approximately: "resistivity (ρ)" ~ **0.50 Ω·cm**, "length (***L***)" ~ **10.00 cm**, and "area (***A***)" ~ **3.00 cm^2**.

- Record the "resistance (***R***)" measurement in the below table.

- Increase the "area (***A***)" by increments of **~3.00 cm^2**. Record the "resistance (***R***)" measurement for each trial in the below table. Repeat until you reach a maximum value of ***A* = 15.00 cm^2**.

- Calculate the *Inverse Area* (1/***A***) for all trials and record values in the below table.

- Using MS Excel program (see instructions posted on Canvas for downloading/using Excel), plot ***Resistance* versus *Inverse Area*** by entering your $\frac{1}{A}$ (x-axis) and ***R*** (y-axis) into an Excel spreadsheet. Then determine the slope by fitting a straight line (linear fit) to the data in the Excel graph. Record the slope in the below table.

- Save your Excel graph showing the data points, linear fit, and slope to include in the graphs section of your lab report.

Part E – Ohmic and Non-Ohmic Materials:

- In this part of the activity, we will explore the resistance of ohmic and non-ohmic materials using real data using resistance circuits. The data was recorded using the following procedure:
  - A voltage source supplied a ramping voltage to ohmic *resistors* (10.00 Ω and 33.00 Ω) and a non-ohmic *lightbulb*.
  - Computer software was used to collect and display the *Current* versus *Voltage*.
  - The slope of the *Current* versus *Voltage* graph is the experimental resistance (R_{Exp}).

- The graphs in the data section show the results from this procedure. The red line is the data from the **10.00 Ω resistor**. The pink line is the data from the **33.00 Ω resistor**. And the green line is the data from the **lightbulb**.

- Compare the experimental and accepted values of the *resistors* by calculating the % error, and compare the resistance of the *lightbulb* while it was cold (low voltage) to the resistance while it was hot (high voltage) by calculating the % difference.

- Determine if each device is Ohmic or Non-Ohmic and record your results in the below table.

<u>**Analysis:**</u>

- **Part A – Resistance with *R* = *Constant* (*V* vs *I*):**

  1. For both standard resistors, compare the experimental (slope) values of the resistances R_{Exp} to the accepted (given) values R_{Acc} by calculating the % error. Record results in the below given tables.

  2. How do the above values compare, and what factors do think may cause there to be a difference between them? Discuss in your lab repot.

  3. Do the results agree with Ohm's law? Explain in your lab report.

- **Part B – Resistance with *V* = *Constant* (*I* vs *1/R*):**

  1. Compare the experimental (slope) value of the supplied voltage V_{Exp} to the accepted (given) value V_{Acc} by calculating the % error. Record results in the below tables.

  2. How do the above values compare, and what factors do think may cause there to be a difference between them? Discuss in your lab repot.

  3. Do the results agree with Ohm's law? Explain in your lab report.

- **Part C – Resistivity with *A* = *Constant* (*R* vs *L*):**

  1. From the slope of $\boldsymbol{R}$ **vs** $\boldsymbol{L}$ calculate the experimental value of the resistivity from $\boldsymbol{\rho_{Exp}} = (\boldsymbol{Slope})(\boldsymbol{Area})$. Compare the experimental value sensitivity to the accepted (given) value $\boldsymbol{\rho_{Acc}}$ by calculating the %Error. Record results in the below tables.

  2. How do the above values compare, and what factors do think may cause there to be a difference between them? Discuss in your lab repot.

  3. Do the results agree with the relationship between resistance to resistivity? Explain in your lab report.

  4. Derive in the theory section the above equation used to determine experimental resistivity $\boldsymbol{\rho_{Exp}}$ from the slope**.**

- **Part D – Resistivity with *L = Constant* (*R* vs *1/A*):**

  1. From the slope of $\boldsymbol{R}$ **vs** ***1/A*** calculate the experimental value of the resistivity from $\boldsymbol{\rho_{Exp}} = \boldsymbol{Slope/Length}$. Compare the experimental value sensitivity to the accepted (given) value $\boldsymbol{\rho_{Acc}}$ by calculating the % error. Record results in the below tables.

  2. How do the above values compare, and what factors do think may cause there to be a difference between them? Discuss in your lab repot.

  3. Do the results agree with the relationship between resistance to resistivity? Explain in your lab report.

  4. Derive in the theory section the above equation used to determine experimental resistivity $\boldsymbol{\rho_{Exp}}$ from the slope**.**

- **Part E – Ohmic and Non-Ohmic Materials:**

  1. For the two resistors, compare the experimental (slope) values of the resistances $\boldsymbol{R_{Exp}}$ to the accepted (given) values $\boldsymbol{R_{Acc}}$ by calculating the % error. Record results in the below tables.

  2. For the lightbulb, compare the cold resistance to the hot resistance by calculating the % difference. Record results in the below table.

  3. How do the above values compare, and what factors do think may cause there to be a difference between them? Discuss in your lab repot.

  4. Does each resistor you used have a constant resistance? Why or why not?

  5. Does the lightbulb filament have a constant resistance? Why or why not?

  6. What is the relationship between current and voltage in a simple resistor? Is it Ohmic or Non-Ohmic? Explain in your report.

  7. What is the relationship between current and voltage in the lightbulb? Is it Ohmic or Non-Ohmic? Explain in your report.

Lab Report:

- When writing the lab report, you must review and follow very carefully the Physics Lab Report instructions handout.

- In your lab report, include the Cover Page, Objectives, Theory, Equipment, Data, Graphs, Calculations, Conclusions, Sources of Error, and References.

- Remember to show all equations and calculations in detail and to round the results to the correct number significant figures and precision.

- In the conclusions section, be sure to summarize the final results, comment on the agreement or disagreement of the results with the theory or expectations and discuss what you personally learned from this experiment and your observations/comments.

- Submit your complete lab report electronically by the due date!

Physics - Online Lab: Ohm's Law and Resistance
Tables of Data and Results

- **Part A – Resistance with *R* = *Constant* (*V* vs *I*):**

Voltage *V* (V)	**Current *I* (A)**
1.00	
2.00	
3.00	
4.00	
5.00	
6.00	
7.00	
8.00	

- **Accepted (given)** $R_{Acc} = 10.0\ \Omega$
- **Experimental (slope)** $R_{Exp} =$
- $\%$ **Error =**

Voltage *V* (V)	**Current *I* (A)**
1.00	
2.00	
3.00	
4.00	
5.00	
6.00	
7.00	
8.00	

- **Accepted (given)** $R_{Acc} = 100.0\ \Omega$
- **Experimental (slope)** $R_{Exp} =$
- $\%$ **Error =**

(*Note*: 1 mA = 1 × 10^{-3} A)

- **Part B – Resistance with V = *Constant* (I vs $1/R$):**

<table>
<tr><th>Resistance R
(Ω)</th><th>Inverse Resistance 1/R
(Ω^{-1})</th><th>Current I
(A)</th></tr>
<tr><td>20.0</td><td></td><td></td></tr>
<tr><td>30.0</td><td></td><td></td></tr>
<tr><td>40.0</td><td></td><td></td></tr>
<tr><td>50.0</td><td></td><td></td></tr>
<tr><td>60.0</td><td></td><td></td></tr>
<tr><td>70.0</td><td></td><td></td></tr>
<tr><td>80.0</td><td></td><td></td></tr>
<tr><td>90.0</td><td></td><td></td></tr>
<tr><td colspan="3">• Accepted (given) $V_{Acc} = 1.00\ V$
• Experimental (slope) $V_{Exp} =$
• % Error =</td></tr>
</table>

(*Note*: 1 mA = 1 × 10^{-3} A)

- **Part C – Resistivity with A = *Constant* (R vs L):**

Length L (cm)	**Resistance R (Ω)**
4.00	
8.00	
12.00	
16.00	
20.00	

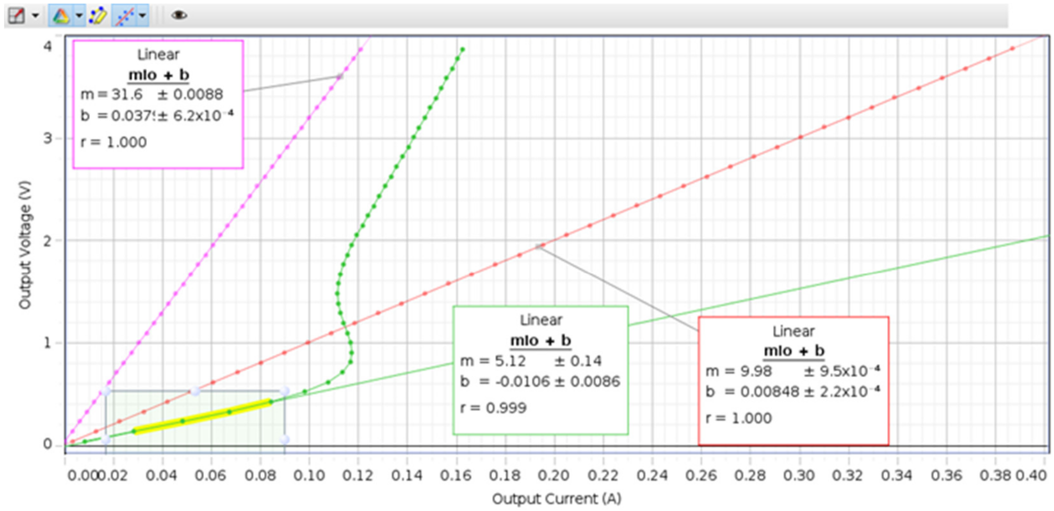
- **Accepted Resistivity $\rho_{Acc} = 0.50$ Ω·cm**
- **Area $A = 7.50$ cm^2**
- **Slope of R vs L =**
- **Experimental Resistivity ρ_{Exp} =**
- **% Error =**

- **<u>Part D – Resistivity with *L* = *Constant* (*R* vs *1/A*):</u>**

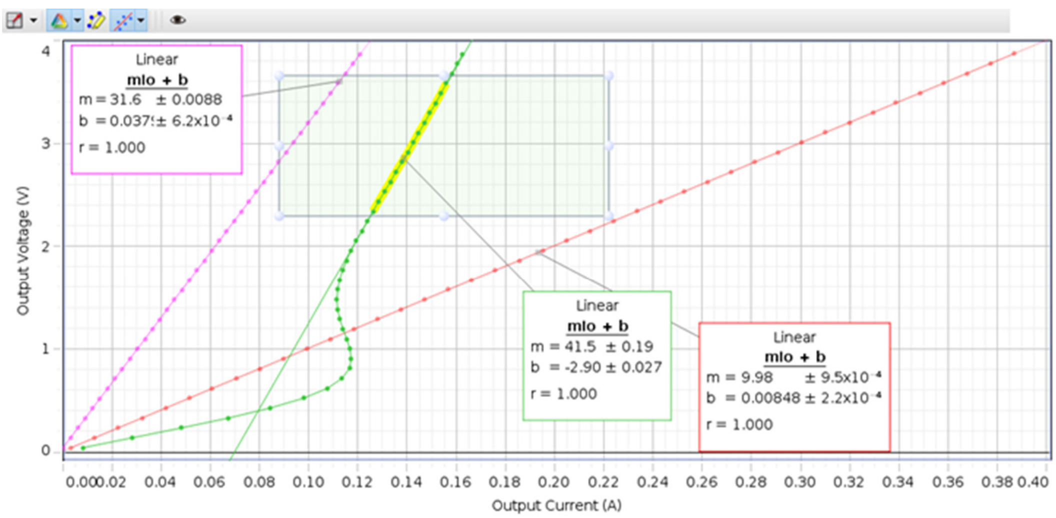
Area *A* (**cm^2**)	**Inverse Area 1/*A*** (**cm^{-2}**)	**Resistance *R*** (**Ω**)
3.00		
6.00		
9.00		
12.00		
15.00		

- **Accepted Resistivity $\rho_{Acc} = 0.50$ Ω·cm**
- **Length $L = 10.00$ cm**
- **Slope of *R* vs *1/A* =**
- **Experimental Resistivity $\rho_{Exp} =$**
- **% Error =**

- **Part E – Ohmic and Non-Ohmic Materials:**



Voltage vs Current



Voltage vs Current

Device	**Resistance R (Ω)**		**% Error/Difference**	**Ohmic?**
Resistor 1	$R_{Acc} = 10.0$	$R_{Exp} = 9.98$	% Error =	
Resistor 2	$R_{Acc} = 33.0$	$R_{Exp} = 31.6$	% Error =	
Lightbulb	$R_{Cold} = 5.12$	$R_{Hot} = 41.5$	% Diff =	