PHY 112L Activity 3

Ohm's Law

Name: ____________________________ ID #:__________________________

Section: ___________________________ Date: _________________________

Lab Partners: ____ TA initials: ________

Objectives

1. Illustrate the validity of Ohm's Law
2. Verify the theoretical formulas for equivalent resistance of series and parallel circuits
3. Find the resistivity of carbon (lab report)

Materials & Resources

1. Computer with DataStudio and Pasco interface
2. Bench power supply, multimeter, and Resistance module
3. Clear ruler and digital calipers
4. Graphite

Introduction

Ohm's law, proposed by Georg Simon Ohm, is a fundamental rule for analyzing circuits that involve voltage, current, and resistance; it is given by:

$$V = IR$$

where V is voltage, I is current, and R is resistance, with units of volts (V), amps (A), and ohms (Ω), respectively. This simple relation allows you to find any of these three quantities, provided that you know, or can measure, the other two. Note: it also shows that the resistance R is proportional to the voltage *dropped* or lost by the circuit at R, but is inversely proportional to the current I that flows through R. Then, as I increases through R, so does V (the voltage dropped by R).

However, circuits often (almost always, in fact) contain many different resistors, as well as other types of circuit elements. So, if Ohm's Law is going to be of any practical use, we must be able to apply it to more complicated circuits. Fortunately, multiple configurations of resistors can be treated as an equivalent single resistor so that Ohm's can also be applied in those cases. Consider the still rather simple case of just two resistors connected in a circuit. What is the equivalent resistance? This depends on the way in which they are connected. If they are connected in series, then R_{ES} is given by:

$$R_{ES} = R_1 + R_2$$

This is because the current through both resistors is equal; therefore, only the voltage differs according to the value of each resistor. If they are connected in parallel, then V is the same, but I may be different, for each R_n. Then R_{EP} is:

$$R_{EP} = \frac{R_1 R_2}{R_1 + R_2}$$

Resistors are not the only objects that have resistance. In fact, all materials have some resistance. To find a material's resistance, we need to know the material-dependent value called resistivity (ρ), the length (l), and cross-sectional area (A). The relationship between resistance (in Ω) and resistivity (Ω·m) is given by:

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

To apply this knowledge in a practical setting, such as today's lab, you must know how to measure resistance. To do so, connect the red lead to the V-Ω port of the multimeter and the black lead to the COM port. Then turn the multimeter knob to the position labeled Ω. The leads are then connected to the resistor as shown in Figure 1.

1. *Testing Ohm's Law*

<u>Procedure</u>:

1) Connect the multimeter to R_S in the resistance module as shown in Figure 1. *Note that this is the type of connection, called parallel, that is needed to measure the resistance of any combination of resistors.*

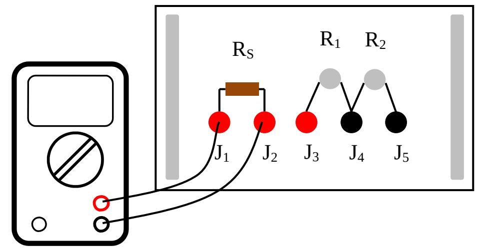

Figure 1

2) Set the multimeter to resistance mode, with symbol Ω, record the value for $\boldsymbol{R_S}$ below, and then disconnect the multimeter.

$\boldsymbol{R_S}$: ___________ (   )

3) Connect the voltage supply and multimeter to the resistance module as shown in Figure 2, and then set the multimeter to measure DC current.

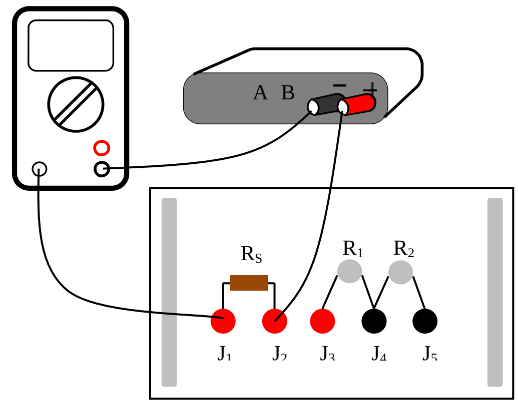

Figure 2

4) Click on the voltage output channel (Figure 3), select DC Voltage in the Signal Generator, set the Amplitude to 1.0V, then click "auto" and "on" when you are ready to begin the measurement.
5) Record the current measurement on the multimeter in the table below.
6) Then click "off," increase the Amplitude to the next voltage in the table, click "on" again and record the current in the table below.
7) Repeat step 6 until you have a current value for each voltage in the table. *Note: Convert your readings before entering them into the table if needed.*

Current (A)	Voltage (V)
	1 V
	2 V
	3 V
	4 V
	5 V

Figure 3

8) In DataStudio, click File, then New Project, and select "Enter Data."
9) Enter your results for current ***I*** above into the "X" column of the new "Data" table and your results for ***V*** above into the "Y" column of the new "Data" table.
10) A graph of this data should appear as you enter data into the table, then select "Linear Fit" from the "Fit" menu as shown in Figure 4.
11) Record your values for "m (slope)" as ***R*** and "Mean Squared Error" as Δ***R*** from the box that appears on the graph in the form below, and then print this graph.

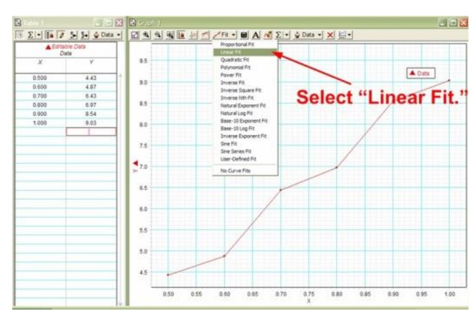

Figure 4

<u>Questions</u>: $\boldsymbol{R} \pm \Delta\boldsymbol{R}$ = _________________________ ± ___________ (
)

1) According to Ohm's Law, should the slope of the line from these measurements equal $\boldsymbol{R_S}$? Why or why not?

2) Does the value you obtained from the graph for ***R*** agree with the value you measured for $\boldsymbol{R_S}$ with the multimeter? Why or why not?

2. *Equivalent Resistance*

Procedure:

1) Connect the multimeter to R_1 as shown in Figure 5, set it to resistance mode, and then record the multimeter reading for R_1 below.

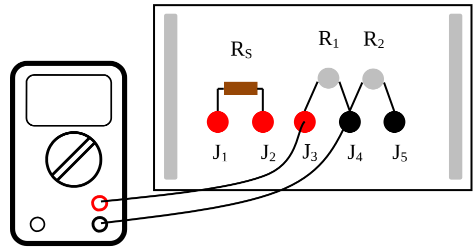

Figure 5

R_1: _______________ (   )

2) Connect the multimeter to R_2 by disconnecting the lead from J_3 and connecting it to J_5; record the multimeter reading for R_2 below.

R_2: _______________ (   )

3) Connect the multimeter <u>and</u> the voltage source to R_1 and R_2, with the resistors <u>*in series*</u>. These connections are almost identical to those of Figure 2 except that the leads to J_1 and J_2 should instead be connected to J_3 and J_5, respectively. Then set the multimeter to its DC current mode.
4) Configure DataStudio to output 2 V (as in part 1, step 4) and record the current through R_1 and R_2 in series in the table below.
5) Click "off" to turn off the DC voltage output.
6) Reconnect the voltage source and multimeter to R_1 and R_2, with the resistors <u>*in parallel*</u> as shown in Figure 6.
7) Click "on" to start the voltage output again, and record the current through R_1 and R_2 in parallel in the table below.
8) Calculate the test resistance for R_1 and R_2 in series (R_{TS}) <u>and</u> in parallel (R_{TP}) using Ohm's Law as shown in the table below and record your results. Then, using values measured above for R_1 and R_2 and the equivalent resistance equations given for series and parallel, calculate R_{ES} and R_{EP} and record your results in the table below.

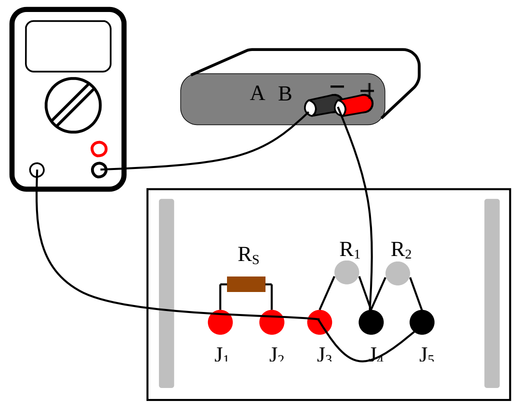

Figure 6

Note: the resistances R_{MM} *of these multimeters are {0.2, 2.0, 100.4}* Ω *in the {A, mA, μA} current modes.*

Connection	Voltage (V)	Current (A)	Test Resistance (Ω)	Equivalent Resistance (Ω)
Series	2 V		$R_{TS} = V/I - R_{MM} =$	$R_{ES} = R_1 + R_2 =$
Parallel	2 V		$R_{TP} = V/I - R_{MM} =$	$R_{EP} = (R_1R_2)/(R_1+R_2) =$

9) Calculate the percent difference for both the series and parallel measurements.

$$\%\ \text{difference (series)} = \frac{|R_{ES}-R_{TS}|}{\frac{1}{2}(R_{ES}+R_{TS})} \times 100 = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_\_\_\_\_\_ \%$$

$$\%\ \text{difference (parallel)} = \frac{|R_{EP}-R_{TP}|}{\frac{1}{2}(R_{EP}+R_{TP})} \times 100 = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_\_\_\_\_\_ \%$$

Questions:

1) What is the <u>experimental difference</u> between the methods used above for obtaining the test resistances R_{TS} and R_{TP} on the one hand and the equivalent resistances R_{ES} and R_{EP} on the other hand?

2) Is this <u>physically</u> consistent with the results you obtained above for ***series*** (R_{ES} and R_{TS}) and ***parallel*** (R_{EP} and R_{TP}) resistances? Briefly justify your answer below.

3. Resistivity of Graphite (Lab Report)

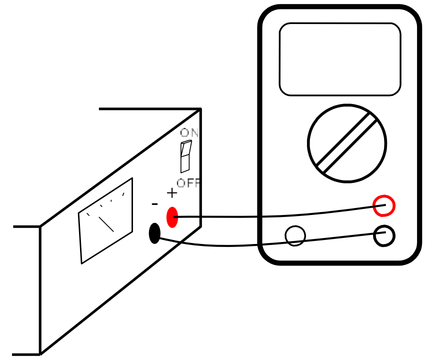

Figure 7

Procedure:

1) Verify that the power supply is turned off before making any connections.
2) Connect the multimeter to the power supply as shown in Figure 7, set the multimeter to measure DC voltage, turn on the power supply, and set the voltage to no more than 1.5 V. *CAUTION: Be sure the voltage is not more than 1.5 V; the graphite can become extremely hot if it is greater than 1.5 V.*
3) Record the precise voltage measurement below, turn off the power supply, and disconnect the multimeter. Then carefully measure the length and diameter of the pencil lead using a ruler and calipers; record these measurements below.
4) Connect the multimeter and the power supply to the *very ends* of the pencil lead, as shown in Figure 8, and set the multimeter to DC current mode.
5) Turn the power supply back on *without* adjusting the voltage setting and record the current reading from the multimeter below; turn off the power supply immediately after making this measurement. *Note: the current may fluctuate some; try your best to estimate the approximate value.*
6) Complete the calculations below. Remember to account for the resistance of the multimeter; use $R_L = V/I - R_{MM}$ for the resistance of the lead. The accepted value for the resistivity of carbon is approximately $\rho_a = 3.0 \times 10^{-5}\ \Omega\cdot$m.

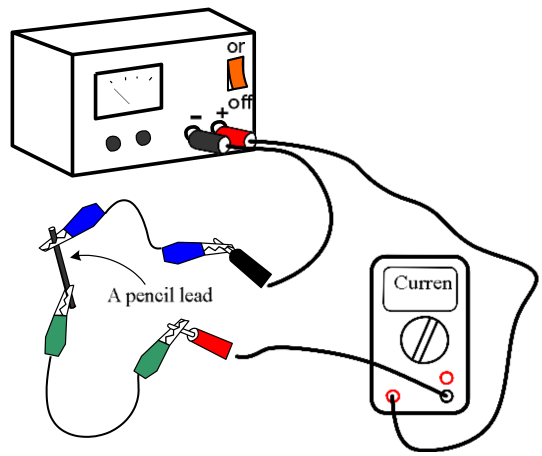

Figure 8

Measured Values:

Current I: _______________

Voltage V: ______________

Length l: _______________

Diameter d: _____________

Calculated Values:

Lead Resistance R_L: _____________

Lead Area A: ___________________

Resistivity ρ_e: ___________________

% error $= \frac{\text{measured - accepted}}{\text{accepted}} \times 100 = \frac{\rho_e - \rho_a}{\rho_a} \times 100 =$ _____________ %

Questions:

1) Account for your % error for ρ_e in terms of your measurements for length and diameter below.

2) Which of these measurements likely contributed the most error to your calculated value for ρ_e? Explain why below.

3) Imagine two circuits, each with its own battery. Both batteries supply the same voltage, but one circuit has only a single resistor, and the other has a complex configuration with multiple resistors. Under what condition will both batteries produce the same current through these circuits?

4) Imagine a circuit that consists of a wire connected across a 5V battery and that the wire has no resistance. What would the current through this wire be? Is this configuration possible? Why or why not?