Paths of Resistance
Measuring Voltage and Current in Simple, Series, and Parallel Circuits

This activity will allow you to use batteries, resistances, wires, and meters to measure current and voltage in simple, series, and parallel circuits. You will use your measurements and Ohm's law to verify the resistance in these circuits.

PURPOSE
Given the materials listed below, connect circuits in such a way that the light bulbs light in some circumstances, but not in others.

MATERIALS
- 3 resistors ranging from 5 Ω to 25 Ω
- 10 alligator-clip wires
- 4 size "D" batteries in battery holders
- 1 ammeter or current probe
- 1 voltmeter or voltage probe

Safety Alert
1. If a wire or resistor begins getting hot, especially if you smell something burning, disconnect the batteries immediately.
2. If you are using meters which have a needle (analog), and you see the needle jumping to the end of the scale or deflecting backward, disconnect the batteries immediately.

PROCEDURE
PART I: SINGLE RESISTOR CIRCUIT
1. Measure and record the voltage across each battery, and list your values in the spaces on your student answer page. Be sure to write the unit of voltage for each battery.

2. Connect one resistor to one battery in a simple circuit as shown in Figure 1 below. Be sure to connect the ammeter in series with the resistor, and the voltmeter in parallel with the resistor.

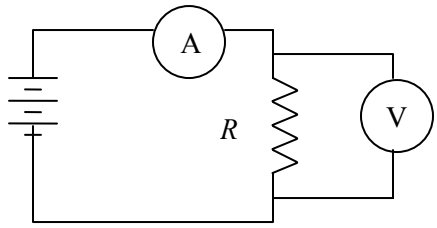

Figure 1

3. Measure and record the current and voltage in Data Table 1 on your student answer page. Using Ohm's law, calculate a value for the resistance. Show your work in the Analysis section of your answer page. This calculated value for the resistance will be referred to as the *measured value* since it is determined from two measured quantities. Your resistors may have the *actual value* of the resistance printed on them.

4. Repeat steps 2 and 3 by measuring the voltage and current produced by 2, 3, and 4 batteries, and record your measurements in Data Table 1.

PART II: THREE RESISTORS IN SERIES CIRCUIT

1. Connect one battery and three resistors in a series circuit as shown in Figure 2 below.

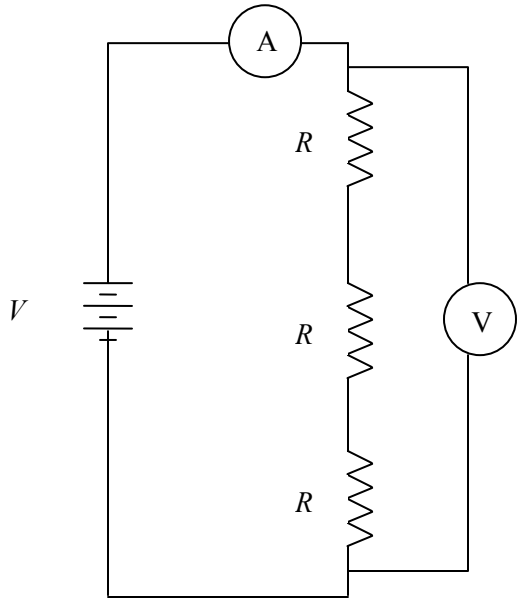

Figure 2

2. Measure and record the total current and total voltage in the Data Table 2 on your student answer page. Using Ohm's law, calculate a value for the total resistance in the circuit. Show all of your work in the Analysis section on your student answer page and record your answer in Data Table 2.

3. Repeat steps 1 and 2 by measuring the voltage and current produced by 2, 3, and 4 batteries, and record your measurements in Data Table 2.

4. Place the voltmeter in the circuit so that it will measure only the voltage across the largest resistor. Label the values of your resistors on the circuit on Part II of your answer page, and draw the voltmeter correctly connected to the largest resistor.

5. Using four batteries, measure the voltage and current through the largest resistor. Record your measurement in Data Table 2. Use Ohm's law to calculate a value for the resistance of the largest resistor in the circuit.

6. Repeat steps 4 and 5 for the other two resistors in the series circuit.

PART III: THREE RESISTORS IN PARALLEL CIRCUIT

1. Connect one battery and three resistors in a parallel circuit as shown in Figure 3 below.

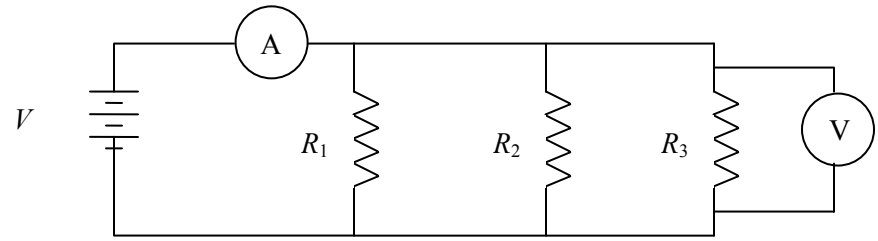

Figure 3

2. Measure the total current and total voltage and record your values in Data Table 3 on your student answer page. Use Ohm's law to calculate a value for the total resistance in the circuit. Show all of your work in the Analysis section on your student answer page and record your answer in Data Table 3.

3. Repeat steps 1 and 2 by measuring the voltage and current produced by 2, 3, and 4 batteries, and record your measurements in Data Table 3.

4. Place the ammeter in the circuit so that it will measure only the current through the largest resistor. Label the values of your resistors on the circuit on Part III of your answer page, and draw the ammeter connected to the largest resistor.

5. Using four batteries, measure the voltage and current through the largest resistor and record your measurement in Data Table 3. Use Ohm's law to calculate a value for the resistance of the largest resistor in the circuit. Show all of your work in the Analysis section on your student answer page and record your answer in Data Table 3.

6. Repeat steps 4 and 5 for the other two resistors in the parallel circuit.

PART IV: THREE RESISTORS IN COMBINATION CIRCUIT

1. Connect three batteries and three resistors in the combination series and parallel circuit shown in Figure 4 below.

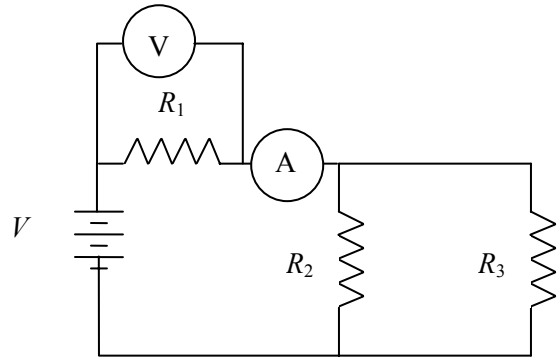

Figure 4

2. Using the known value for each resistor and the rules for determining total resistance in series and parallel, calculate the theoretical total resistance of your circuit. Show your work in the Analysis section and record your answer in Data Table 4 on your student answer page.

3. Place the voltmeter across the batteries while the circuit is connected to measure the total effective voltage in the circuit. Record this voltage in Data Table 4.

4. Use the voltmeter to measure the voltage across each individual resistor, and record each voltage in Data Table 4.

5. Place the ammeter in the circuit so that it will measure the current through resistor R_1, and record this current in Data Table 4.

6. Use the ammeter to measure the current of each individual resistor. Record each current in Data Table 4.

7. Using Ohm's law, calculate a value for the resistance of each resistor in the circuit. Show all of your work in the Analysis section on your student answer page and record your answer in Data Table 4.

Name _____

Period _____

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DATA AND OBSERVATIONS

PART I: SINGLE RESISTOR CIRCUIT

Battery 1 voltage: _____ Battery 3 voltage: _____

Battery 2 voltage: _____ Battery 4 voltage: _____

Data Table 1				
# of Batteries	**Voltage V (volts)**	**Current I (amps)**	**Measured Resistance R_M (ohms)**	**Actual Resistance R_A (ohms)**
1				
2				
3				
4				

PART II: THREE RESISTORS IN SERIES CIRCUIT

Data Table 2				
# of Batteries	**Voltage V (volts)**	**Current I (amps)**	**Measured Resistance R_M (ohms)**	**Actual Resistance R_A (ohms)**
1				
2				
3				
4	$V_T =$	$I_T =$		
4	$V_1 =$	$I_1 =$		
4	$V_2 =$	$I_2 =$		
4	$V_3 =$	$I_3 =$		

PART III: THREE RESISTORS IN PARALLEL CIRCUIT

Data Table 3				
# of Batteries	**Voltage V (volts)**	**Current I (amps)**	**Measured Resistance R_M (ohms)**	**Actual Resistance R_M (ohms)**
1				
2				
3				
4	$V_T =$	$I_T =$		
4	$V_1 =$	$I_1 =$		
4	$V_2 =$	$I_2 =$		
4	$V_3 =$	$I_3 =$		

PART IV: THREE RESISTORS IN COMBINATION CIRCUIT

Voltage across the batteries = _____

Data Table 4				
Resistor	**Voltage V (volts)**	**Current I (amps)**	**Measured Resistance R_M (ohms)**	**Actual Resistance R_A (ohms)**
R_1				
R_2				
R_3				

ANALYSIS

Equations and constants: Remember to report the answers to all calculations to the proper number of significant figures. The *actual value* of the resistance is the value obtained by using the resistance printed on the resistor(s), and the *measured value* of the resistance will be the ratio of the measured voltage to the measured current.

$$R = \frac{V}{I}$$

$$R_T = R_1 + R_2 + R_3$$

$$\frac{1}{R_1} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\% \text{ Error} = \left| \frac{\text{Actual value} - \text{Measured value}}{\text{Actual value}} \right| \times 100$$

PART I: SINGLE RESISTOR CIRCUIT

1. In the space below, show your calculation for finding the resistance of the resistor using Ohm's law.

2. Using the four values you calculated for the resistance, find the average resistance for the resistor. Show your work in the space below, and be sure to include the proper number of significant digits.

3. Using your measured value for the resistance and its actual value, find the percent error for the resistance. Show your work in the space below, and be sure to include the proper number of significant digits.

PART II: THREE RESISTORS IN SERIES CIRCUIT

1. Using the four values you calculated for the total measured resistance in series, find the average total resistance. Show your work in the space below, and be sure to include the proper number of significant digits.

2. Show your work below for the actual total resistance in the circuit, that is, the sum of the actual values of each resistor in series.

3. Using your measured value for the total resistance and its actual value, find the percent error for the total resistance in series. Show your work in the space below, and be sure to include the proper number of significant digits.

4. When you placed the voltmeter across each resistor, you measured the voltage and current through each resistor and found a measured value for each. Show your work below for the percent error between the measured value of each resistor and its actual value.

   Resistor 1:

   Resistor 2:

   Resistor 3:

PART III: THREE RESISTORS IN PARALLEL CIRCUIT

1. Using the four values you calculated for the total measured resistance in series, find the average total resistance. Show your work in the space below, and be sure to include the proper number of significant digits.

2. Using the actual value for the resistors and the equation for finding the total resistance in parallel, show your work below for the actual total resistance in the circuit.

3. Using your measured value for the total resistance and its actual value, find the percent error for the total resistance in series. Show your work in the space below, and be sure to include the proper number of significant digits.

4. When you placed the ammeter in series with each resistor, you measured the voltage and current through each resistor and found a measured value for each. Show your work below for the percent error between the measured value of each resistor and its actual value.

   Resistor 1:

   Resistor 2:

   Resistor 3:

PART IV: THREE RESISTORS IN COMBINATION CIRCUIT

1. Using the known value for each resistor and the rules for determining total resistance in series and parallel, calculate the theoretical total resistance of your circuit.

2. Using the appropriate values for voltage and current from the measurements in the data table, find a value for the total resistance of your circuit.

3. Find the percent difference between the two values for the total resistance you calculated in Part IV.

CONCLUSION QUESTIONS

PART I: SINGLE RESISTOR CIRCUIT

1. Why is the ammeter always connected in series with the resistor(s) whose current it is trying to measure?

2. Why is the voltmeter always connected in parallel with the resistor(s) whose voltage it is trying to measure?

3. Was Ohm's law verified in this part of the experiment? Write a general statement comparing your measured and actual values of the resistance, and whether your data supports Ohm's law.

PART II: THREE RESISTORS IN SERIES CIRCUIT

1. Was Ohm's law verified in this part of the experiment? Write a general statement comparing your measured and actual values of the resistance, and whether your data supports Ohm's law.

2. Let V_1 be the voltage across Resistor 1, V_2 be the voltage across Resistor 2, and V_3 be the voltage across Resistor 3.What is the relationship between V_1, V_2, V_3, and the total voltage in the circuit? Write a general statement about the voltage across each resistance in a series circuit and the total voltage in the circuit.

PART III: THREE RESISTORS IN PARALLEL CIRCUIT

1. Was Ohm's law verified in this part of the experiment? Write a general statement comparing your measured and actual values of the resistance, and whether your data supports Ohm's law.

2. Let I_1 be the current through Resistor 1, I_2 be the current through Resistor 2, and I_3 be the current through Resistor 3.What is the relationship between I_1, I_2, I_3 , and the total current in the circuit? Write a general statement about the current through each resistance in a series circuit and the total current in the circuit.

3. Consider the identical light bulbs in the circuit shown in Figure 5 below.

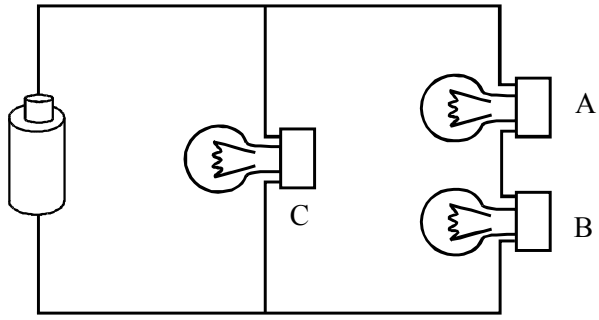


Figure 5

   a. Which bulb draws the most current, and therefore burns the brightest? Explain.

   b. Explain what will happen to bulbs B and C if bulb A is removed from its socket.

c. Explain what will happen to bulbs A and B if bulb C is removed from its socket.

4. A 5 Ω bulb, 10 Ω bulb, and a 15 Ω bulb are connected to a battery in series in a circuit.
   a. Which bulb will have the greatest voltage across it? Explain.

   b. Which bulb will have the greatest voltage across it if they are connected in parallel? Explain.

5. Can you think of any sources of error in this lab which may have caused your measured total resistance to be different than the actual values for the total resistance? Describe a reasonable source of error, and how the source would affect the value for the total resistance in (a) the series circuit, and (b) the parallel circuit.
   a. Series circuit

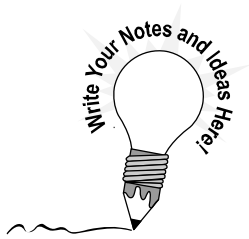
   b. Parallel circuit

PART IV: THREE RESISTORS IN COMBINATION CIRCUIT

1. What are some reasons the two values you determined for the total resistance are different?

2. According to your data, what is the relationship between the total effective voltage in the circuit and the individual voltages across R_1, R_2, and R_3? Explain your answer.

3. According to your data, what is the relationship between the current through R_1 and the current through each of the other resistors? Explain your answer.


Write Your Notes and Ideas Here!