Name **Period** **Date**

Ohm's Law: Series and Parallel Circuits

Guided Inquiry (GI)

Problem Statement

Design an experiment to graphically show the equivalent resistance of three resistors in series and in parallel.

- Set up circuits with three 330 Ω resistors in series, then in parallel.
- Vary the voltage and measure circuit voltage and current.
- Graph the results to find the total resistance of the circuit.

Materials and Equipment

For each student or group:

- Data collection system
- Voltage/Current sensor
- AC/DC Electronics Laboratory
- Patch cord, 4 mm banana plugs (4)
- Resistor (3), 330 Ω
- Alligator Clip Adapter (4)
- Wire lead (5)
- Variable DC power supply , 10 V

Background

Ohm's law tells us that the voltage drop across an electrical resistor is equal to the current multiplied by the resistance. If the voltage is held constant, and you double the resistance, then the current will be half its original value. Likewise, cutting the resistance in half will double the current.

Ohm's law applies to entire circuits or to smaller parts of a circuit, so we can isolate various components of a circuit, measure the voltage and current, and find the effective resistance of the object. Doing this for an unknown group of resistors can quickly yield their total resistance (or "equivalent resistance"). Varying voltage for a fixed set of resistors (whether they are in series or parallel) will lead to different currents, so accurate measurement of voltage and current will provide data that quickly determines this equivalent resistance. Equivalent resistances can be calculated for resistors in series by simply adding their resistances:

$$R_{total} = R_1 + R_2 + R_3 + \ldots \tag{1}$$

The equivalent resistance of resistors in parallel can be calculated using this equation:

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots \tag{2}$$

Voltage sensors, voltmeters, current sensors, and ammeters must be used properly or they can affect the circuit's behavior. Voltmeters and voltage sensors have a very high internal resistance, and should be hooked up in parallel with the device they measure. Ammeters and current sensors must be put in series with the circuit they measure, and are assumed to have very little internal resistance so as to not affect the circuit's current. Power supplies also have some internal resistance, but we assume this is very small compared to other resistors in the circuit. This explains why power supply settings usually drop slightly when the switch is closed.

Using Your Data Collection System

You may be using the following technical procedures in this activity. Your teacher will provide you with a copy of the instructions for these operations. If you are not familiar with a procedure, locate that operation in the list below. Use the tech tip number (identified by the number following the symbol: "�") to find the corresponding instructions.

- Connecting a sensor to the data collection system �(2.1)
- Putting the data collection system into manual sampling mode without manually entered data �(5.2.2)
- Changing the number of digits with which a variable is displayed �(5.4)
- Starting a manually sampled data set �(6.3.1)
- Recording a manually sampled data point �(6.3.2)
- Stopping a manually sampled data set �(6.3.3)
- Adjusting the scale of a graph �(7.1.2)
- Displaying multiple runs in a graph �(7.1.3)
- Displaying data in a table �(7.2.1)
- Applying a curve fit �(9.5)
- Saving your experiment �(11.1)

Safety

Add these important safety precautions to your normal laboratory procedures.

- Operate the power supply at low voltages only: **10 VDC or less**. More than 10 VDC may cause damage to the sensor or provide too much current for the 330 Ω resistors.
- Be sure the circuits are properly constructed. Follow your teacher’s instructions on how to avoid short circuits and overloading.
- Use only 330 Ω resistors in this experiment. Using smaller resistors may result in high current which could destroy a resistor, cause a resistor to become a fire hazard, or overheat a resistor

creating a burn hazard. Using larger resistors will cause a current too small to be detected by the sensor.

♦ Use the push button switch on the AC/DC electronics bread board to prevent overheating of the resistors from constant current flow during data collection. This will also help avoid electrical damage to the resistors.

Design and Conduct the Experiment

Write a brief outline of the procedure you will use to collect data. Identify the steps in sequence and the points at which each piece of equipment will be used. Be sure you include methods to find the equivalent resistance of both the resistors in series and the resistors in parallel.

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1. What electrical quantities could you measure to find the total resistance of 3 resistors in a circuit?

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2. How would you vary these quantities for a given circuit so as to plot a graph that shows the total resistance (or "equivalent resistance") of a circuit?

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3. Draw a schematic (circuit diagram) for your series circuit, and clearly show where you will connect the voltage and current sensors to gather data.

4. **Draw a schematic for the parallel circuit and clearly show where you will connect the voltage and current sensors.**

5. **Each circuit can be simplified by finding the "equivalent" or total resistance of the circuit, from the perspective of the power supply. Draw the two circuits above (series and parallel circuits), but in a simplified fashion, showing all 3 resistors simplified as one equivalent resistor.**

6. **What is the underlying assumption about the internal resistance of a voltmeter that allows us to use it in this way with minimal impact to the rest of the circuit?**

7. **How would you hook up a current sensor to properly measure current? What assumption do we make about the current sensor when using it in the circuit?**

Relevant Equations

List the relevant equations you will use and show how you will use them in conjunction with your measured values to determine the equivalent resistance of each circuit (series and parallel).

Collect Data

Data Analysis

Present your data in the form of a graph and any other way you find useful to determine the equivalent resistance of each circuit (series and parallel).

Analysis Questions

1. Describe what your graphs look like. Which variables did you plot, what does the slope of each graph represent, and what values for the slope did you get for each graph you made?

2. **Calculate the theoretical resistance for each circuit, using the appropriate formulas and the stated value of the resistors (show formulas and all work).**

3. **Are your calculated theoretical values close to the experimental values from the graphs? Find the percent error for each circuit.**

4. **What would happen to the current through the power supply if you added more resistors to the series circuit?**

Increases ______ Decreases ______ Stays the same______

Explain your answer.

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5. **Would your answer to #4 be any different if you added additional resistors to the parallel circuit? Explain why or why not.**

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Synthesis Questions

Use available resources to help you answer the following questions.

1. **Suppose you had a parallel circuit with several identical light bulbs of equal resistance. If one bulb goes bad (or is disconnected), what happens to the brightness of the other bulbs?**

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2. **What happens to the brightness of other bulbs if a single bulb goes bad in a series circuit? Explain your answer.**

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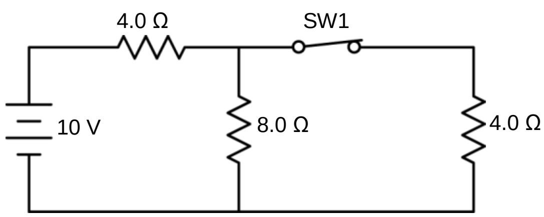
3. **The circuit shown here contains three light bulbs: two with identical resistance, and one with twice the resistance as the other bulbs. The circuit is powered by a 10 VDC power supply (assume that the power supply is ideal and has negligible internal resistance) and controlled by a switch *S*.**

When answering the following questions, be sure to show all of your work.



3a. **What is the equivalent resistance of the entire circuit?**

3b. **Find the current through the power supply.**

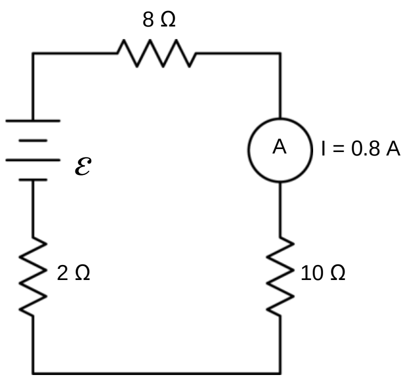
3c. **What is the voltage drop across Bulb A?**

3d. **Find the current through each bulb:**

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. **What is the voltage across the power supply in the circuit below?**



A. 1.6 V

B. 16.0 V

C. 8.8 V

D. 10.0 V

E. 5.0 V

2. **Consider the circuit from the previous question. If an additional 10 Ω resistor was placed in series with the first 10 Ω resistor, and the power supply voltage was set to 3 V, what would the new current throughout the circuit be?**

A. 5.0 A

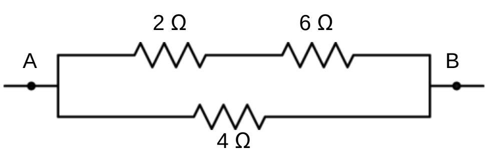
B. 0.15 A

C. 0.1 A

D. 0.01 A

E. 0.05 A

3. **In the circuit to the right, what is the electrical resistance of the part of the circuit shown between point A and point B?**



A. 2.5 Ω

B. 8 Ω

C. 4 Ω

D. 12 Ω

E. 2.7 Ω

4. Which statement below is TRUE about the current through the circuit in the previous question?

- **A.** Current is greater in the 2 Ω resistor than in the 4 Ω resistor.
- **B.** Current is greater at point B than at point A.
- **C.** Current is the same everywhere in the circuit.
- **D.** Current is greater in the 2 Ω resistor than in the 6 Ω resistor.
- **E.** Current is greater in the 4 Ω resistor than in the 6 Ω resistor.