Ohm's Law
(Power Output)

Equipment List

Qty	Items	Part Numbers
1	PASCO 750 Interface	
1	AC/DC Electronics Lab	EM-8656
2	Banana Plug Patch Cord	SE-9750 or SE-9751
1	10 Ω(Brown Black Black), 100 Ω (Brown Black Brown), 1 lightbulb	

Introduction

The purpose of this activity is to confirm the relationship of current, voltage, and resistance in an electric circuit. You will also explore what happens to the resistance of a light bulb's filament as it changes temperature. Use the *DataStudio* software to measure the current through resistors and the filament of a light bulb as the voltage across the resistors and the filament of the light bulb is changed.

Background

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. 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. Since the current is inversely proportional to the resistance, as the resistance increases, the current decreases.

A resistor is 'Ohmic' if as voltage across the resistor is increased, a graph of voltage versus current shows a straight line (indicating a constant resistance). The slope of the line is the value of the resistance. A resistor is 'non-Ohmic' if the graph of voltage versus current is not a straight line. For example, if resistance changes as voltage changes, the graph of voltage versus current might show a curve with a changing slope.

For a certain resistor, the value of its resistance does not change appreciably. However, for a light bulb, the resistance of the filament will change as it heats up and cools down. At high AC frequencies, the filament doesn't 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. As a consequence, the resistance of the filament changes dramatically and the resulting change in current through the filament is interesting to watch.

In the first part of this activity, investigate the relationship between current and voltage in simple ten-ohm (Ω) and one-hundred ohm resistors. In the second part, investigate the relationship between current and voltage in the filament of a small light bulb.

Prediction

What happens to the current in a circuit with a constant resistance as the voltage goes up? What happens to the resistance of the filament in a light bulb as the filament heats up?


SAFETY REMINDER

- Follow directions for using the equipment.

**THINK SAFETY
ACT SAFELY
BE SAFE!**

Setup

1.   Set up the PASCO 750 Interface and the computer and start *DataStudio*.

2.   Connect banana plug patch cords into the 'OUTPUT' ports on the interface.

3.   Create new experiment and set the signal output to a Triangle Wave with 3V and 60Hz with a sample rate of 5000Hz. Open <u>Scope</u> display with Output Voltage vs. output Current.

- The file opens with a Signal Generator window and a Scope display of voltage. The Scope display will show the voltage *across* the resistor from the 'Output' of the interface and the output current from the interface *through* the resistor.

- The Signal Generator is set to produce a triangle wave at 60 Hz. It is set to 'Auto' so it will automatically start or stop the signal when you start or stop measuring data. *DataStudio* will record the 'Output Voltage' and the 'Output Current'.

4.   Place a ten-ohm (Ω) resistor in the pair of component springs nearest to the banana jacks at the lower right corner of the AC/DC Electronics Lab Board.

5.   Connect banana plug patch cords from the 'OUTPUT' ports of the interface to the banana jacks on the right side of the AC/DC Electronics Lab circuit board.

10 Ω RESISTOR (BROWN, BLACK, BLACK)
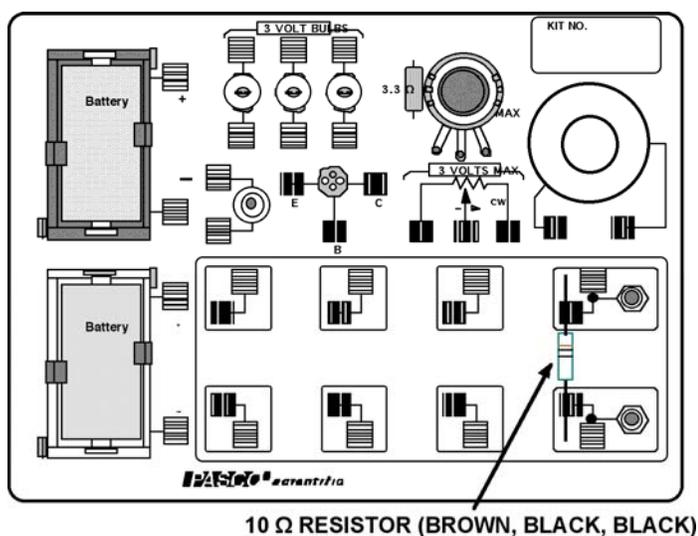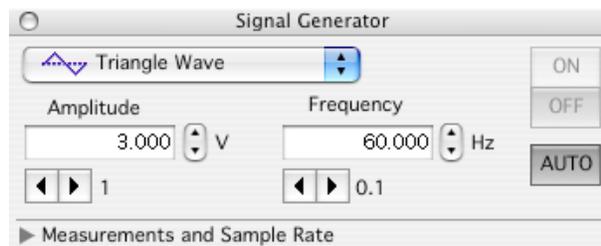
Procedure 1

Measure voltage and current for resistors

1. Begin measuring data. Click 'Start' in *DataStudio*.

2. Observe the Scope display of Voltage and Current. Adjust the vertical axis or the horizontal axis if necessary.

3. Use the 'Scope's built-in analysis tools to determine the voltage and current for the ten-ohm resistor.

4. In *DataStudio*, click the 'Smart Tool'. Move the 'Smart Tool' so it shows the coordinates of a point on the trace of voltage versus current.

- **Result**: The 'X-Y' coordinates are voltage and current. The 'X' coordinate is the current through the resistor and the 'Y' coordinate is the voltage across the resistor.

5. Divide the voltage ('Y' coordinate) by the current ('X' coordinate) to calculate the resistance. Record the calculated resistance in the Lab Report section.

6. Click 'Stop' to end data measurement.

7. Replace the ten-ohm resistor with a 100-ohm resistor and repeat the procedure.

8. Record the calculated resistance in the Lab Report.
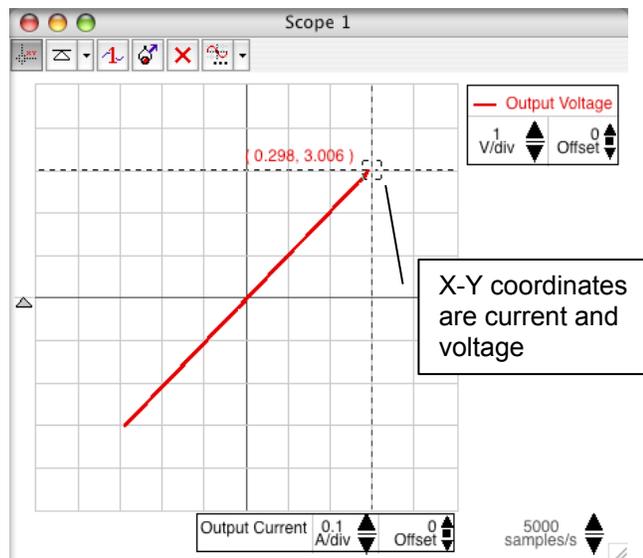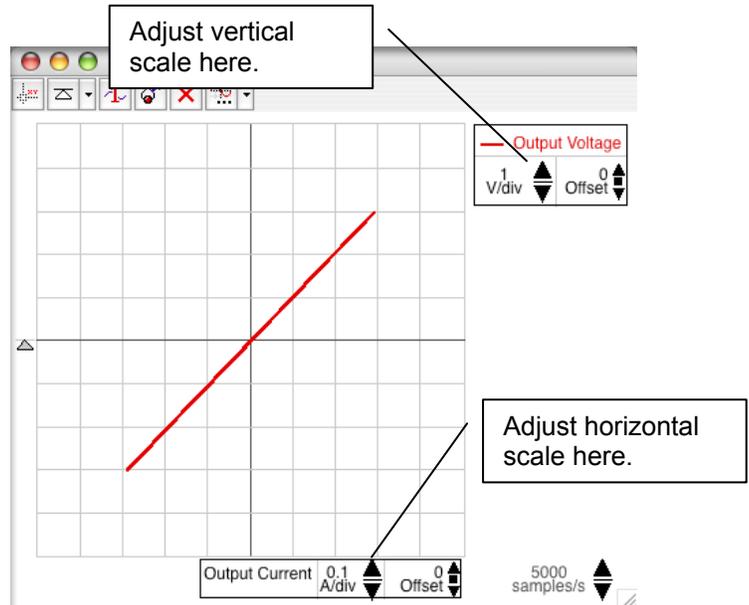
Procedure 2

Measure voltage and current for a light-bulb filament

1. After you record your data for the resistors, click 'Stop' to end data measurement.

2. Remove the 100-ohm resistor from the AC/DC Electronics Lab board.

3. Use two of the 10" wire leads to connect between the component springs near the banana jacks and the component springs above and below **3 VOLT BULB "C"**.

4. Change the Amplitude and Frequency of the output AC waveform. Click the Signal Generator window to make it active.

5. Change the Amplitude value to '2.500 V'.

6. Change the Frequency value to '0.300'.

7. Adjust the sweep speed in the Scope display to 50 samples/second. In the Scope display, click the 'down' arrow next to 'samples/s'.

8. Start measuring data. Observe the Scope display of voltage versus current for the light bulb filament. Adjust the vertical and horizontal scales if necessary.

9. Wait a few seconds and then stop measuring data.

10. Use the built-in analysis tools in the Scope display to find the coordinates at several points on the trace of voltage versus current. Calculate the ratio of voltage to current at each point.

11. Make a sketch of the Scope display screen for voltage and current of the light bulb filament in the Lab Report section.
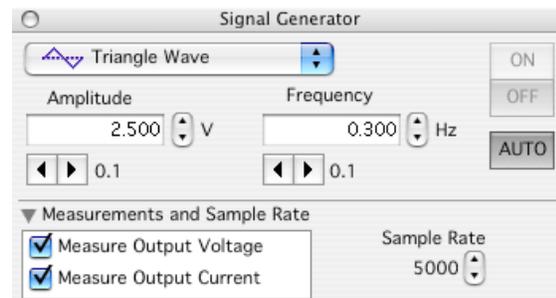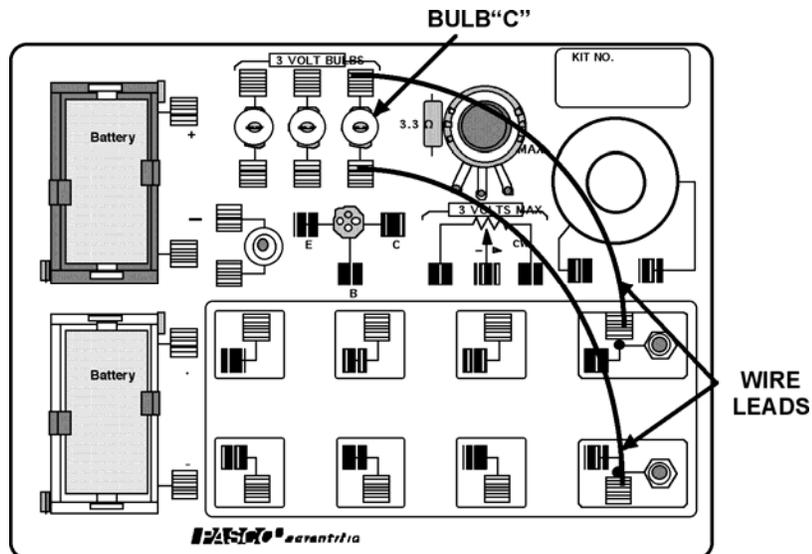
Lab Report: Ohm's Law

Name: _____

Prediction

What happens to the current in a circuit with a constant resistance as the voltage goes up? What happens to the resistance of the filament in a light bulb as the filament heats up?

Data

<div align="center">

resistance (ten-ohm resistor) = _____ volt/amp

resistance (100 Ω) = _____ volt/amp

</div>

Make a sketch of the Scope display screen for voltage and current for the light bulb filament.

Analysis

Questions

1. How does the ratio of voltage and current from the Scope display compare to the resistance of the resistors?

2. Does each resistor appear to have a constant resistance?

3. Does the light bulb filament appear to have a constant resistance (constant ratio of voltage to current)? Why or why not?

4.   For a circuit with a constant resistance, what happens to the current as the voltage increases?

5.   For a circuit with a constant resistance, what kind of relationship (e.g., inverse, linear) does the current have to the voltage?

Resistors in Series and Parallel Circuits
(Voltage Sensor, Current Sensor)

Equipment List

Qty	Items	Part Numbers
1	Voltage Sensor	CI-6503
1	Current Sensor	CI-6556
1	AC/DC Electronics Lab	EM-8656
1	1000 Ω	
2	100 Ω	

Introduction

The purpose of this activity is to confirm that when resistors are added in series to a circuit, they have a total resistance that equals the *sum* of their individual resistances, and that when resistors area added in parallel to a circuit, they have a total resistance that is *less* than the individual resistances. Use a voltage sensor, a current sensor, and the *DataStudio* software to measure the voltage across parts of the series and parallel circuits and a current sensor to measure the current through the circuits.

Background

In a series circuit, devices are connected in such a way that there is the same electric current, *I*, through each device. The voltage, *V*, supplied by the source is divided among the devices. Each device has a resistance , *R*, that is the ratio of the voltage across the device divided by the current through the device ($R = V/I$). Since each device shares a portion of the voltage, *V*, the following describes how the voltage, current, and individual resistances are related in a series circuit:
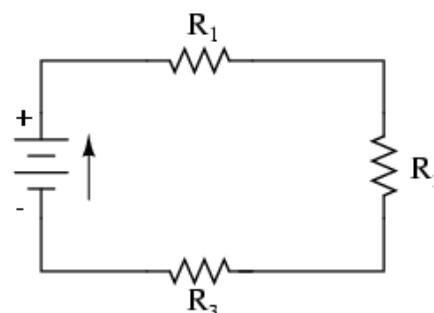
$$V = V_1 + V_2 + V_3 = IR_1 + IR_2 + IR_3 = I(R_1 + R_2 + R_3) = IR_{Total}$$

where R_{Total} is the sum of the individual resistances.

- Components in a series circuit share the same current: $I_{Total} = I_1 = I_2 = \ldots I_n$

- Total resistance in a series circuit is equal to the sum of the individual resistances: $R_{Total} = R_1 + R_2 + \ldots R_n$

- Total voltage in a series circuit is equal to the sum of the individual voltage drops: $V_{Total} = V_1 + V_2 + \ldots V_n$

In a parallel circuit, devices are connected in such a way that the same voltage is supplied across each device. When more than one device is connected in parallel to a voltage source, each receives current from the source as if the other device were not there. Therefore, two devices connected in parallel draw more current from the source than either device does by itself. The
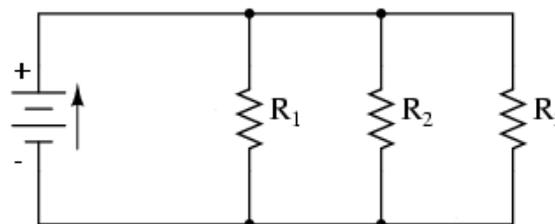
following describes how the voltage, current, and individual resistances are related in a parallel circuit:

$$I = I_1 + I_2 + I_3 = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) = V\left(\frac{1}{R_{Equivalent}}\right)$$

You can calculate the value of $R_{Equivalent}$ from the other individual resistances as follows:

$$R_{Equivalent} = \frac{1}{\dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3} + ...}$$

- Components in a parallel circuit share the same voltage: $V_{Total} = V_1 = V_2 = . . . V_n$

- Total resistance in a parallel circuit is less than any of the individual resistances: $R_{Total} = 1 / (1/R_1 + 1/R_2 + . . . 1/R_n)$

- Total current in a parallel circuit is equal to the sum of the individual branch currents: $I_{Total} = I_1 + I_2 + . . . I_n$.


SAFETY REMINDER

- Follow directions for using the equipment.

**THINK SAFETY
ACT SAFELY
BE SAFE!**

Setup

1. Set up the PASCO Interface and the computer and start *DataStudio*. Connect the Voltage Sensor and the Current Sensor into the interface.

2. Open *DataStudio* and plug in the voltage sensor in A, the current sensor into B and the power amplifier into C. Set the Power Amplifier to 3V DC Voltage.

- Open the Digits displays of voltage and current from ChA & ChB respectively. The voltage Digits display will show the voltage *across* whatever part of the circuit you select. The current Digits display will show the current *through* the circuit.

3. Connect a 100-ohm resistor (brown, black, brown) into the pair of spring clips near the lower left corner of the AC/DC Electronics Laboratory board.

4. Use wire leads to build up a circuit with the power amplifier, the pushbutton switch, the Current Sensor, and the 100-ohm resistor as shown.
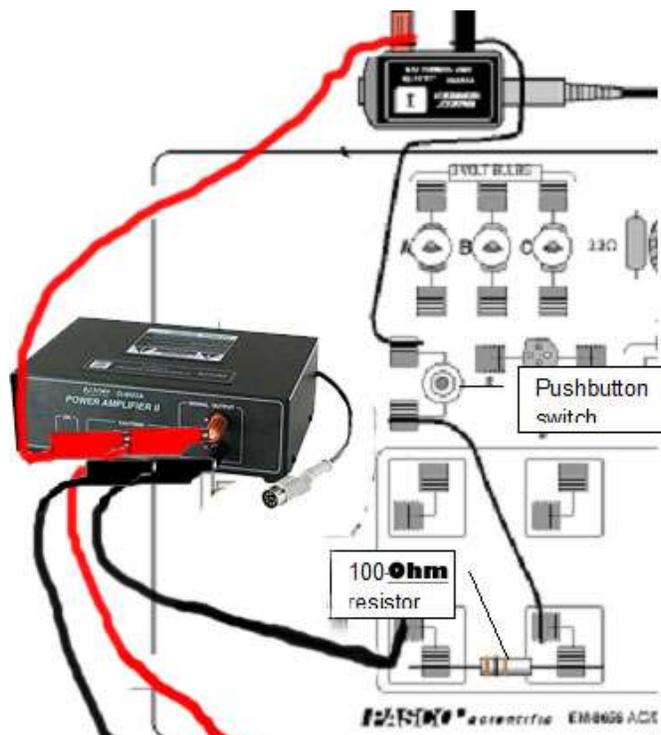
5.   Plug in the leads of the Voltage Sensor to the positive and negative terminals of the power amplifier as shown.

Note: The diagram is not to scale and doesn't show the connections to the PASCO interface.

Procedure 1: Resistors in Series

Measure voltage and current for resistors in series

Note: Data recording is easier if one person runs the computer and records data, a second person presses the pushbutton switch, and a third person handles the Voltage Sensor leads.
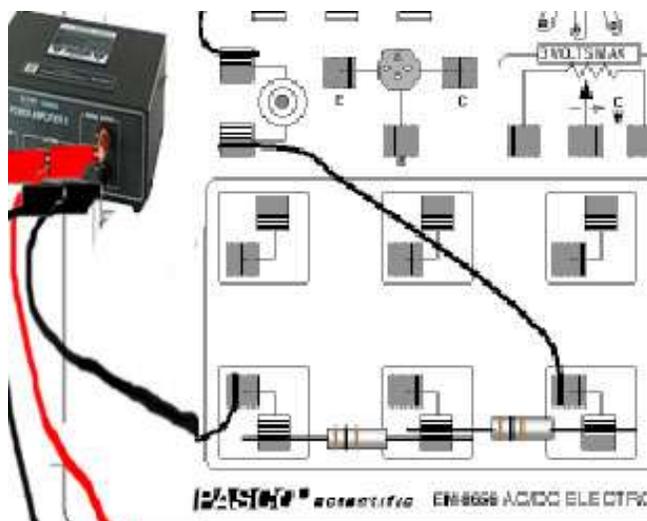
One 100-Ω Resistor

1.   Begin measuring data. Select 'Monitor' from the Experiment menu in *DataStudio*.

2.   Press and hold the pushbutton switch. Observe the Digits displays of Voltage and Current.

3.   Record the values of voltage *across* the voltage source and current *through* the circuit in the Lab Report section.

4.   Move the Voltage Sensor leads to the spring clips on either side of the first resistor and record the voltage *across* the resistor.

5.   Release the pushbutton switch.
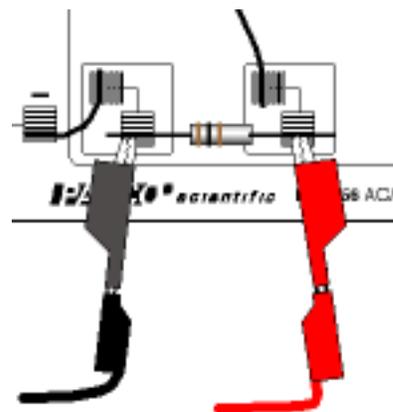
Two 100-Ω Resistors in Series

6.   Change the circuit to add a second 100-Ω resistor in series. Connect another 100-Ω resistor into the spring clips along the bottom part of the AC/DC Electronics Laboratory board as shown.

7.   Move the wire lead from the pushbutton switch holder to the spring clip to the right of the second 100-Ω resistor. Return the Voltage Sensor leads to the terminals of the battery holders.

8.   Press and hold the pushbutton switch.

9.   Record the values of voltage *across* the voltage source and current *through* the circuit with two resistors in series.

10.   Move the Voltage Sensor leads so one is on the clip at the left of the first resistor and the other is on the clip at the right of the second resistor and record the voltage *across both resistors*.

11.   Release the pushbutton switch.

Three Resistors in Series

12.   Change the circuit to add a 1000-Ω resistor (brown, black, red) in series. Connect another 100-Ω resistor into

the spring clips along the bottom part of the AC/DC Electronics Laboratory board as shown.

13. Move the wire lead from the pushbutton switch holder to the spring clip to the right of the 1000-Ω resistor. Return the Voltage Sensor leads to the terminals of the battery holders

14. Press and hold the pushbutton switch.

15. Record the values of voltage *across* the voltage source and current *through* the circuit with three resistors in series.

16. Move the Voltage Sensor leads so one is on the clip at the left of the first resistor and the other is on the clip at the right of the third resistor and record the voltage *across all three resistors*.

17. Release the pushbutton switch.
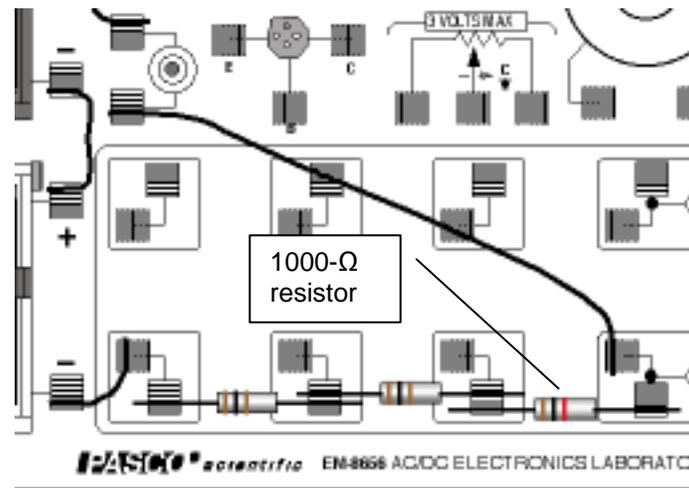
Procedure 2: Resistors in Parallel

Measure voltage and current for resistors in parallel

Two 100-Ω Resistors in Parallel

1.   Return the AC/DC Electronics Laboratory board to the way it was at the beginning of Procedure 1.

2.   Change the circuit so the two 100-Ω resistors are connected to the voltage source in parallel. Turn the first 100-Ω resistor bulb so it is 'parallel' to the battery holders and reconnect it to the pair of spring clips next to the battery holder as shown.

3.   Connect the second 100-Ω resistor to a set of spring clips to the right of the first resistor as shown. Add a wire lead from the spring clip above the first resistor to the spring clip above the second resistor as shown. Add a second wire lead from the spring clip below the first resistor to the spring clip below below the second resistor.

4.   Press and hold the pushbutton switch.

5.   Record the values of voltage *across* the voltage source and current *through* the circuit with two resistors in parallel.

6.   Move the Voltage Sensor leads to the spring clips on either end of the second resistor and record the voltage *across* the second resistor as before.

7.   Release the pushbutton switch.
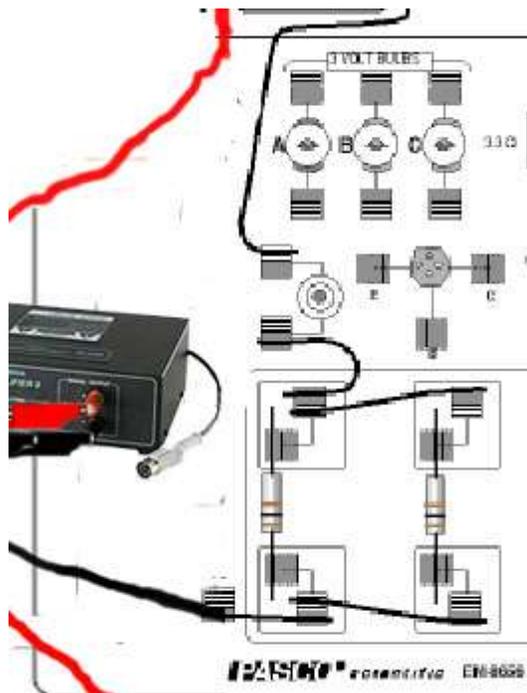
Three Resistors in Parallel

8.   Change the circuit to add the 1000-Ω resistor in parallel to the other resistors. Add a wire lead from the spring clip above the second resistor to the spring clip above the 1000-Ω resistor. Add a second wire lead from the spring clip below the second resistor to the spring clip below the 1000-Ω resistor.

9.   Press and hold the pushbutton switch.

10. Record the values of voltage *across* the voltage source and current *through* the circuit with three resistors in parallel.
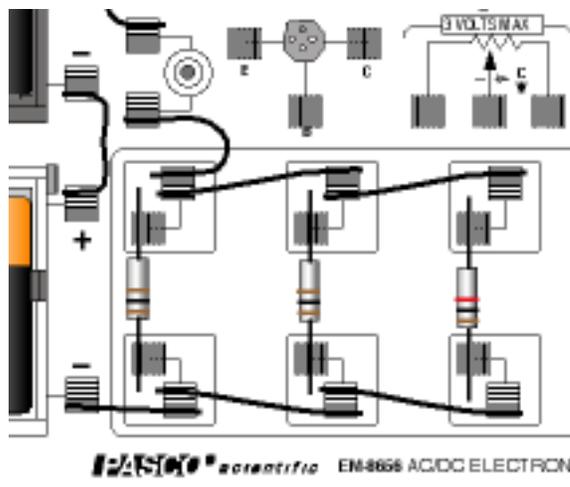
11. Move the Voltage Sensor leads to the spring clips at either end of the 1000-Ω resistor and record the voltage *across* the resistor as before.

12. Release the pushbutton switch. Click 'Stop' in *DataStudio*.

Lab Report: Resistors in Series and Parallel

Name: _____

Calculations

1. Based on the voltage across the voltage source and the resistance values of the resistors in the circuit, use Ohm's law (I=V/R) to calculate the theoretical current for each circuit.

2. Calculate the percent difference between the measured and calculated values of current for each circuit: $\%diff = \left| \dfrac{measured - calculated}{calculated} \right| \times 100\%$

Data

Procedure 1: Voltage and Current for Resistors in Series	
One 100-Ω Resistor	
Item	**Value**
Voltage across voltage source	V
Measured current through circuit:	A
Resistance of the circuit	Ω
Calculated current through circuit	A
Percent difference	%
Voltage across 100-Ω resistor[1]	V
Two 100-Ω Resistors in Series	
Item	**Value**
Voltage across voltage source	V
Measured current through circuit:	A
Resistance of the circuit	Ω
Calculated current through circuit	A
Percent difference	%
Voltage across 100-Ω resistor[1]	V
Voltage across 100-Ω resistor[2]	V
Voltage across both resistors	V
Three Resistors in Series	
Item	**Value**
Voltage across voltage source	V
Measured current through circuit:	A
Resistance of the circuit	Ω
Calculated current through circuit	A
Percent difference	%
Voltage across 100-Ω resistor[1]	V
Voltage across 100-Ω resistor[2]	V
Voltage across 1000-Ω resistor	V
Voltage across all resistors	V

Procedure 2: Voltage and Current for Resistors in Parallel	
Two 100-Ω Resistors in Parallel	
Item	**Value**
Voltage across voltage source	V
Measured current through circuit:	A
Resistance of the circuit	Ω
Calculated current through circuit:	A
Percent difference	%
Voltage across 100-Ω resistor[1]	V
Voltage across 100-Ω resistor[2]	V
Three Resistors in Parallel	
Item	**Value**
Voltage across voltage source	V
Measured current through circuit:	A
Resistance of the circuit	Ω
Calculated current through circuit:	A
Percent difference	%
Voltage across 100-Ω resistor[1]	V
Voltage across 100-Ω resistor[2]	V
Voltage across 1000-Ω resistor	V

Analysis

1. What happens to the *net current* through a series circuit as more resistors are added in series compared to the current through each individual resistor?

2. How did your calculated (theoretical) values for current through the resistors in series compare to the actual (measured) values for current?

3. What happens to the *current* through a parallel circuit as more resistors are added in parallel?

4. How did your calculated (theoretical) values for current through the resistors in parallel compare to the actual (measured) values for current?