

# Ohm's Law

## Experiment PH04\_Todd

Part A: *Ohmic Resistors*

Part B: *Non-Ohmic Resistors*

### OBJECTIVE

- To investigate the relationship between current  $I$ , resistance  $R$  and voltage  $V$  in Ohmic and non-Ohmic materials.

### EQUIPMENT NEEDED

**Computer:** Personal Computer with the Pasco Scientific *DataStudio*<sup>TM</sup> Program installed.

**Interface Unit:** Pasco Scientific *Science Workshop*<sup>TM</sup> (Model 500, 700 or 750.)

**Power Amplifier:** Pasco<sup>TM</sup> Power Amplifier II (CI-6552A)

**Experiment Software File(s):** PH04a\_Ohmic Resistors.ds / PH04b\_Non Ohmic Resistors.ds

### **Experiment Apparatus:**

Pasco<sup>TM</sup> RLC Circuit Network (CI-6512)

Wire Lead, Stackable, Banana-Banana (2) (1 red, 1 black)

Wire Lead, Banana-Banana (2) (1 red, 1 black)

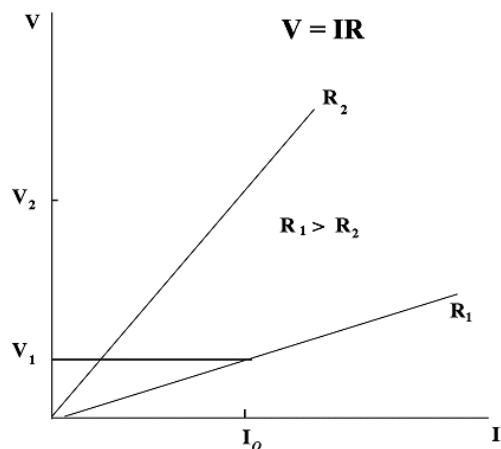
### THEORY

The mathematical relationship between voltage, current, and resistance is expressed by **Ohm's Law**:

$$V = IR \quad \text{or} \quad I = \frac{V}{R} \quad \text{or} \quad R = \frac{V}{I} \quad (1)$$

where  $V$  is the voltage,  $I$  is the current, and  $R$  is the resistance.

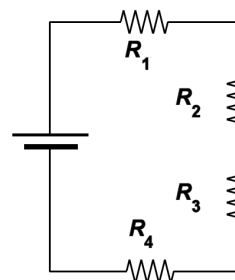
For the typical resistor, the value of its resistance does not change appreciably. However, in a light bulb the filament resistance changes as it heats up and cools down. At high AC (alternating current) frequencies, the filament doesn't have time to cool down, so it remains at a nearly constant temperature and the resistance stays relatively constant. At low AC frequencies (i.e., less than one Hertz (Hz)), the filament has the time to change temperature. So the resistance of the filament changes dramatically and the resulting change in current through the filament is interesting to watch.



If the voltage across an “Ohmic” resistor is increased, a graph of voltage  $V$  versus current  $I$  shows a straight line (indicating a constant resistance). **The slope of the line is the value of the resistance.** However, if the resistance *changes* (that is, if the resistor is “non-Ohmic”), the graph of voltage versus current will not be a straight line. Instead, it will show a curve with a changing slope.

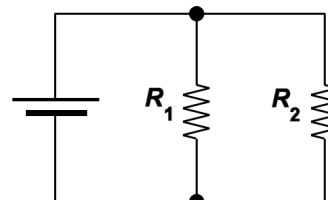
### Resistance in Series Circuit Configurations

$$R_{equiv} = R_1 + R_2 + R_3 + \dots + R_N \quad (2)$$



### Resistance in Parallel Circuit Configurations

$$\frac{1}{R_{equiv}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots + \frac{1}{R_N} \quad (3)$$



## PROCEDURE

### Part A: Ohmic Resistors

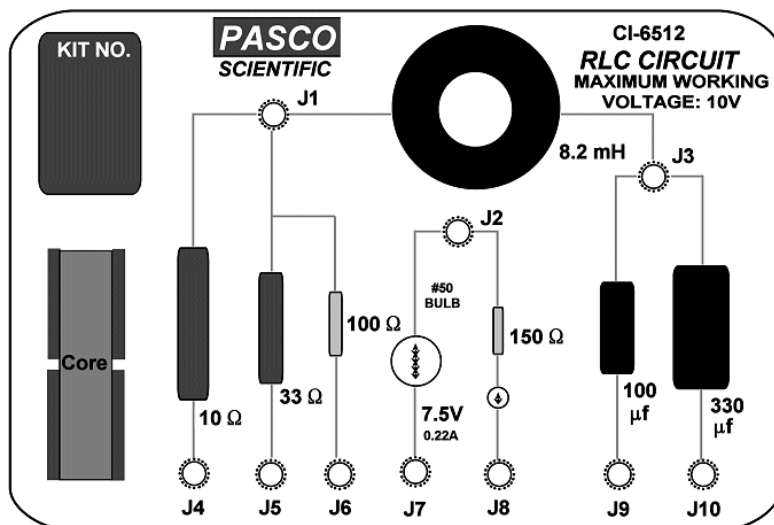
In this part of the experiment you will use a graph of voltage vs. current to confirm the resistance value of sample resistors on a circuit board.

#### • Computer Setup

1. Plug the Power Amplifier into **Analog Channel "A"**.
2. Open the experiment file `PH04a_Ohmic Resistors.ds`.
3. The default **Signal Generator** output is a **2.97 V Amplitude, Saw Tooth AC waveform** (triangle icon), at **60.00 Hz** with a sample rate of **4000 Hz**. It is set to **Auto** so it will start automatically when you click the  button and to stop automatically when you click the  button.
4. The Scope is set to show Output Voltage ( $V$ ) on the vertical axis at **1 V/div** and Current ( $A$ ) on the horizontal axis at **0.1 A/div**.

#### • Equipment Setup

1. The **Pasco RLC Circuit board (RLC)** contains hard-mounted electrical components for use in experiments and is configured by plugging test leads into the board. **RLC Jack points (J1 – J10)** are used to connect *banana plug* connector test leads to the board.

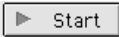



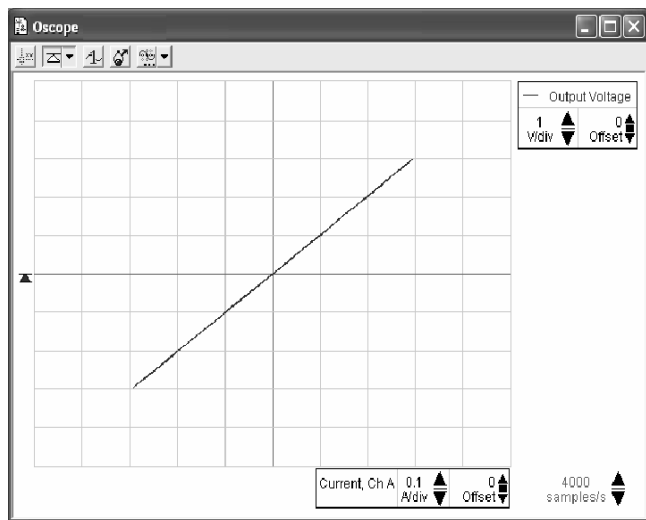
**NOTE: The RLC jack points are not directly numbered on the board; refer to the figure on the left.**

2. Using wire leads with *banana plugs* at opposite ends; connect one end of the *red* wire lead into the *red* connection jack on the Power Amplifier and connect the other end to RLC jack **J1**.

3. Connect one end of the *black* wire lead into the *black* connection jack on the Power Amplifier and connect the other end to RLC jack **J4**.


● **Data Collection–Resistor (10 Ω)**

1. Turn on the Power Amplifier. Click the  button in the *DataStudio*<sup>TM</sup> program **main toolbar** to begin collecting data.
2. Observe the Voltage vs. Current display for approximately 10 seconds, and then click the  button in the *DataStudio*<sup>TM</sup> program **main toolbar** to end data collection.



• The figure on the left shows a typical output of the experiment. The vertical axis is the voltage  $V$ , while the horizontal one is the current  $I$ .

3. Turn off the power amplifier.

4. Click the  **Smart Tool** button on the **oscilloscope toolbar**. The cursor changes to a crosshair when you move it into the display area of the oscilloscope. The waveform's **voltage** and **current** values at the cursor's position are shown next to the crosshair.

The **y-coordinate** of the cross-hair is the **voltage**  $V$ .  
The **x-coordinate** of the cross-hair is the **current**  $I$ .

5. Use the  $x$  and  $y$  coordinates of a point on the trace of the Scope display to determine the slope. Record in

Data Table 1, the values of the  $x$  &  $y$  coordinates for the **10 Ω** resistor. Turn **off** the **Smart Tool** by re-clicking the Smart Tool button.

6. Determine the total resistance of the circuit by using the  $x$  and  $y$  coordinates to **find the slope of the graph**. Record the resulting value (in Ohms) as the **measured total resistance**, in Data Table 1. Show your work in the data section of your lab report.

$$\text{slope} = \frac{(y_2 - y_1)}{(x_2 - x_1)} = \frac{y_2}{x_2}$$

7. Calculate the **percent difference** between the values of the theoretical total resistance and the measured total resistance in the circuit. Record the result in Data Table 1. Show your work in the data section of your lab report.

$$\% \text{ difference} = \left| \frac{\text{theoretical total resistance} - \text{measured total resistance}}{\text{theoretical total resistance}} \right| \times 100$$

● **Data Collection–Resistor (100 Ω)**

1. Disconnect the *black* wire lead from RLC jack **J4** and connect it to RLC jack **J6**.
2. Repeat steps 1-8 just as you did for the **10 Ω resistor**. Record all necessary data in Data Table 1.

● **Data Collection–Resistors in Series (10 & 100 Ω)**

1. Disconnect the *red* wire lead from RLC jack **J1** and connect it to RLC jack **J4**.
2. Repeat steps 1-8 just as you did for the **10 Ω resistor**. Record all necessary data in Data Table 1.


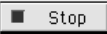
- Use Equation (3) and the “known” value of the resistors ( $R_1 = 10 \Omega$ ,  $R_2 = 100 \Omega$ ) to calculate the **theoretical total resistance** of the **series circuit**. Record the result in Data Table 1. Show your work in the data section of your lab report.
- Calculate the percent difference between the values of the theoretical total resistance and the measured total resistance in the **series circuit**. Record the result in Data Table 1. Show your work in the data section of your lab report.

### • Data Collection–Resistors in Parallel (10 & 100 $\Omega$ )

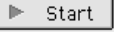

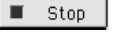
- Disconnect both of the wire leads from the RLC Circuit board. Using a wire lead with *stackable banana plugs* at opposite ends, plug one end into RLC jack **J4** and the other end into RLC jack **J6**. Plug the *red* wire lead coming from the Power Amplifier into RLC jack **J1**. Plug the *black* wire lead coming from the Power Amplifier into the top of the stackable wire lead in RLC jack **J6**.
- Repeat steps 1-8 just as you did for the **10  $\Omega$  resistor**. Record all necessary data in Data Table 1.
- Use Equation (4) the “known” value of the resistors ( $R_1 = 10 \Omega$  &  $R_2 = 100 \Omega$ ) to calculate the **theoretical total resistance** of the **parallel circuit**. Record the result in Data Table 1. Show your work in the data section of your lab report.
- Calculate the percent difference between the values of the theoretical total resistance and the measured total resistance in the **parallel circuit**. Record the result in Data Table 1. Show your work in the data section of your lab report.

## Part B: Non-Ohmic Light Bulb Filament

### • Computer Setup

- Open the PH04b\_Non Ohmic Resistors.ds experiment file.
- The default **Signal Generator** output is a **2.500 V Amplitude, triangle AC waveform**, at **0.300 Hz** with a **sample rate** of **4000 Hz**. It is set to **Auto** so it will start automatically when you click the  **Start** *button* and to stop automatically when you click the  **Stop** *button*.
- The default Scope settings show Output Voltage ( $V$ ) on the vertical axis at **1 V/div** and Current ( $A$ ) on the horizontal axis at **0.1 A/div**.

### • Equipment Setup

1. Connect the *red* wire lead coming from the Power Amplifier to RLC jack **J2**. Connect the *black* wire lead coming from the Power Amplifier to RLC jack **J7**. It is set to **Auto** so it will start automatically when you click the  **Start** *button* and to stop automatically when you click the  **Stop** *button*.
5. Observe the trace of the Voltage vs. Current display for approximately 10 seconds, then click the  **Stop** *button* in the *DataStudio*<sup>TM</sup> program **main toolbar** to end data collection. **Turn off the Power Amplifier**.

*Note:* Your oscilloscope display should look similar to that shown in the figure below. The display has the appearance of a **figure eight pattern** because in effect, the scope is tracing out the complete pattern of rising and falling resistance due to the non-Ohmic nature of the light bulb filament.



## ENDING THE EXPERIMENT

1. Close the PH04b\_Non Ohmic Resistors experiment file. **Do NOT save the file.**
2. Disassemble the equipment.
  - ▶ Disconnect the wire leads and voltage sensor from the RLC circuit board, power amplifier and interface.
  - ▶ Disconnect the power amplifier from the interface unit.
  - ▶ Return the wire leads and voltage sensor to the wire lead storage locker.
3. Complete analysis questions 1 through 4.

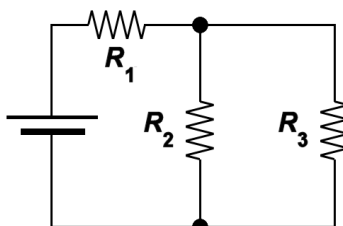
## DATA ATTACHMENTS

- ▶ Experiment PH04 Data Table 1.

## ANALYSIS QUESTIONS

### Part A: Ohmic Resistors

1. (5 pts). As shown in the schematic below, a circuit in a combination configuration consists of three resistors and a voltage source. If the value for all three resistors is  $500\ \Omega$ , and the power source produces  $24.0\ \text{V}$ , what is the current supplied by the power source to this circuit? Show your work.



2. (5 pts). In this experiment for the resistors in parallel circuit configuration, if we added to the circuit two additional parallel legs with each leg having a single  $50\ \Omega$  resistor, what would be the new **theoretical total resistance** of the circuit? Show your work.



**DATA TABLE – Experiment PH04**

Lab Instructor Signature/Date: \_\_\_\_\_

**Data Table: Ohm’s Law**  
**Fill in values to the right of labeled white boxes**

10 Ω Resistor		100 Ω Resistor	
“Known” Value $R_1$	10 Ω	“Known” Value $R_2$	100 Ω
$x$ & $y$ values		$x$ & $y$ values	
Theoretical total resistance	10 Ω	Theoretical total resistance	100 Ω
Measured total resistance	Ω	Measured total resistance	Ω
% difference	%	% difference	%
10 Ω & 100 Ω Resistors in Series		10 Ω & 100 Ω Resistors in Parallel	
“Known” Value $R_1$	10 Ω	“Known” Value $R_1$	10 Ω
“Known” Value $R_2$	100 Ω	“Known” Value $R_2$	100 Ω
$x$ & $y$ values		$x$ & $y$ values	
Theoretical total resistance	Ω	Theoretical total resistance	Ω
Measured total resistance	Ω	Measured total resistance	Ω
% difference	%	% difference	%