Experiment: Ohm’s Law

Introduction: In this experiment you will examine the voltage-current characteristics for the following circuit elements: two resistors, a light bulb, and a light emitting diode. You will determine whether the relation between an applied voltage across the element (V) and the current that flows through the element (I) is a linear or nonlinear one.

The resistance R of a circuit element is the ratio of the measured voltage to the measured current at a given value of the voltage.

\[ R = \frac{V}{I} \]

In general, the resistance is a function of the applied voltage, but when the voltage vs. current curve is linear, this ratio is a constant, and one can talk about THE resistance of the element, \( R = \frac{V}{I} \). Any circuit element that has a linear relation is said to obey Ohm’s law. Copper wire and wire of most other metallic conductors and manufactured resistors are examples of elements that obey Ohm’s law with high accuracy, but in general Ohm’s law is only approximately obeyed at best and there are many important devices that do NOT obey Ohm’s law.

Current: Electric currents are flows of electric charge (PSE Chapter 27). Common currents range from mega-amperes in lightning to tens of amps in household wiring to nano-amperes in your nerves. The idea that current, I, is the rate of change of charge, Q, in time can be described mathematically by the relation

\[ I = \frac{dQ}{dt} \]

The unit of current is the ampere [A]. 1 amp = 1 coulomb/sec.

Power Supplies: Voltage sources are commonly referred to as power supplies. The rate of doing work is called power. A power supply with an output voltage \( \Delta V \) that supplies a current I has a power output

\[ P = \Delta V \, I \]

The unit of power is the watt, [W]=[V][A]; 1 watt = (1 volt)(1 amp).

Electrical Circuits: Electrical circuits connect power supplies through wires called ‘leads’ to ‘loads’ such as resistors, motors, heaters, or lamps.

Circuit elements can be connected in many ways, the most common of which are in parallel or in series. Elements are in parallel when they are connected across the same voltage difference (see Figure 1). When the elements are connected one after another, so that the current passes through each element without any branches, the elements are in series (see Figure 2).
These connections can be represented as \textit{pictorial} diagrams that show wires and components roughly as they appear, or as \textit{schematic} diagrams that use conventional symbols, somewhat like road or subway maps.

One can have \textit{closed} circuits, through which current flows, \textit{open} circuits in which there are no currents, and \textit{short} circuits when, usually by accident, wires touch causing most of the current to flow through the short, bypassing the load.

In electrical circuits, a point (or some common lead) is chosen as the \textit{ground}. This point is assigned an arbitrary voltage, usually zero, and the voltage $V$ at any other point in the circuit is defined as the voltage difference between that point and ground.

**Resistance:** When a voltage difference is applied to a circuit element, a current flows through it. The amount of the current is a function of the voltage. The current-versus-voltage relationship ($I-V$ curve) is an empirical property of the element.

**Experiment 1: Graphing the Voltage, Current and Power for a Resistor**

**Computer Setup:** Connect the 750 Interface to your computer, turn on the Interface, and then turn your computer on.

**Data Studio File:** Download the Data Studio file “Ohm’s Law.ds” from the “Current Assignment” webpage and save on your desktop. If there is already a file by this name on your desktop, save over it, as it may not be set up properly. Open it by double clicking on it. Your file has a Signal Generator Display, and three Graph Displays which are already set up to display Output Current versus Output Voltage and Voltage versus Time and Current versus Time.

**Signal Generator:**

1. In the Signal Generator dialog we have chosen “Triangle Wave Function”.
2. The Amplitude has been adjusted to 2.0 V, the Frequency to 1.0 Hz, and the sampling rate to 1000 Hz
3. We chose the output data that you will record by clicking the plus button (+) beside Measurements and Sample Rate on the Signal Generator dialog and clicking the appropriate Measure Output Voltage and Measure Output Current buttons.
AC/DC Electronics Lab circuit board

1. Connect the banana plug patch cords from the ‘OUTPUT’ ports of the 750 Interface to the banana jacks on the lower right corner of the AC/DC Electronics Lab circuit board (see locations D and E in Figure 1 of the “Simple Circuits Experiment” write-up).

2. Place a 10 ohm (Ω) resistor in the pair of springs nearest to the banana jacks at the lower right corner. (The 10 Ω resistor is solid brown).

Graph:

Here’s how to set up the Output Current vs Output Voltage graph if you ever need to (it should already be set up for you here). Drag the Grab the Output Current in the Data Window and drag it into the Graph icon. Then drag the Output Voltage in the display window into the Graph window and drop it on the time horizontal axis.

Sampling Options:

Click on drag down menu labeled “Experiment” on the top tool bar. In the Experiment menu, click on the “Set Sampling Option” to open the Sampling Options dialog. Check that the Delay Choice is on “Time” and that the delay time is 0.5 seconds. Check that the Automatic Stop choice is Time with 5.0 seconds in the window. If these are not set in this manner, set them to these choices.

Data Recording:

Press Start to begin taking data. Once the data has been recorded, scale it to fit the graph screen by clicking on the first icon on the left at the top of the Graph Window, which is the “scale to fit” icon.

Data Analysis:

1. On your current vs. voltage graph, click the ‘Smart Tool’ icon on the bar in the Graph window. (The Smart Tool is the sixth icon from the left). The Smart Tool will appear at the origin. Left click on the Smart Tool with the mouse and drag to a point on the trace of current vs. voltage. The ‘Smart Tool’ shows the coordinates of your selected data point. The x-component is the voltage and the y-component is the current.

2. Use the coordinates of the point to determine the ratio of the measured voltage versus measured current. What is your value for the resistance?

3. Throughout the experiment, delete data runs after you have finished your analysis, by going the “Experiment” pull down menu on the top tool bar and choosing “Delete ALL Data Runs”.


Discussion Question:

What does your 1 Hz frequency setting on the Signal Generator Display mean in terms of the output voltage of the signal generator?

Experiment 2: Voltage-Current characteristics for a 100 ohm resistor.

Repeat Experiment 1 using a 100 ohm resistor. What is your value for the resistance?

Experiment 3: Voltage-Current characteristics for a small light bulb.

1. AC/DC Electronics Lab circuit board:
   - Disconnect the resistor from the board.
   - Use two 10” wire leads (white) to connect the springs near the banana jacks and the springs above and below the 3 VOLT BULB “C”.

3. Data Recording. Press Start to begin taking data. Observe the Graph Display of current vs. voltage. This data was taken at 1 Hz. Now go to the “Signal Generator” Dialogue box and change the “Frequency” from 1 Hz to 100 Hz. Remember to delete data runs after you have finished your analysis, by going the “Experiment” pull down menu on the top tool bar and choosing “Delete ALL Data Runs”. Now press start and see what the characteristics of the current vs voltage curve looks like. Can you find a frequency range where the characteristics of the current vs voltage curve change?

Discussion Question:

Can you explain your current vs voltage curves in terms of the resistance of the light bulb and the input frequency of the voltage source?

Experiment 4: Voltage-Current characteristics for a light emitting diode.

1. Disconnect the wires going to the small light bulb.
2. Place the red light emitting diode in the pair of springs nearest to the banana jacks at the lower right corner.
3. Use the 1 Hz frequency setting for the signal generator.
4. Data Recording: Press Start to begin taking data. Observe the Graph Display of current vs voltage curve.
5. Take out the diode and connect it the other way. Repeat step 4 above. How does the display change?
Discussion Question:

Observe the shape of the current vs. voltage curves for the diode. How do you explain the shape of the curve?

Experiment 5: Using the Scope for Voltage vs. Current

In this experiment you will use the Scope capabilities of the Data Studio to observe the voltage vs. current behavior of the two different light emitting diodes, one red and the other green.

Note: The graph and the scope cannot both operate simultaneously. Close the Graph windows and delete all data using the “Experiment” pull down menu in order to use the Scope.

Set Sampling Options:

Click on the pull down menu “Experiment” on the top tool bar, and click on the Set Sampling Options to open the Sampling Options dialog. Set the Automatic Stop choice to “None”.

Set Up Scope:

- In order to set up the vertical and horizontal axes of the scope, you must drag the Output Current icon from the Data Window (upper left on your screen) into the Display Window (lower left on your screen) and drop it on the Scope icon. A Scope Window will appear. Now drag the Output Voltage icon from the Data Window into the Scope Window and drop the icon on the 5 ms/div on the bottom center of the window. Your Scope Window should look like this:

![Scope Window](image)

- You can adjust the vertical and horizontal scales as needed by clicking the arrows on the V/div or A/div in the boxes that appear on the Scope Window.
Data Recording:

Make sure the red light emitting diode is still connected to the pair of springs nearest to the banana jacks at the lower right corner. Press Start to begin taking data. Observe the Scope Display of current vs. voltage. Make sure you adjust the scale for the current on the Scope as needed.

Now replace the red light emitting diode with the green light emitting diode.

Discussion Question:

For the red and green diodes, measure the value of the voltage when the current starts to flow through the diodes. Can you explain the significance of your measured values in terms of the photon energy of the emitted light? Do you think the red light has higher or lower photon energy than the green light?