Ohm's Law
Spring 2024

Introduction

In this experiment, you will practice connecting simple circuits, measuring the *voltage across* and the *current through* an element of the circuit, and examine the current-voltage relation for a small bulb, a resistor, and an LED (light emitting diode). Before beginning this experiment, you should again read the "Using a Digital Multimeter" document from last week.

- Always connect your wires to the + and – terminals of the power supply ***after*** your circuit elements are connected; never leave bare wires hanging from the power supply.
- Never pull on the wire, only on the end connector.

Experiment

1. *Prepare the ammeter and voltmeter/ohmmeter:* You will be using two identical multimeters, one labeled as an *ammeter* (for measuring current), the other a *voltmeter* (for measuring voltage). It is important that you connect each meter correctly to the circuit, to prevent blowing a fuse in the meter or the power supply. Be sure to record all meter settings in your journal that are used during the experiment!

   a. An **ammeter** measures the *current through* the circuit, and gets inserted into the circuit just like any other circuit element (bulb, resistor, battery, etc.) Insert *one* wire into the "A" port of the ammeter and set the dial on the "DCA" (*Direct Current Amperage*) scale. This will remind you that the circuit needs to be opened to measure the current (the "free" wire from the opened circuit will be connected to the "COM" port).

   b. A **voltmeter** measures the *voltage across* a circuit element; insert *two* wires into the voltmeter, one in the "COM" port, the other in "V/Ω", and set the dial on the "DCV" (*Direct Current Voltage*) scale. This will remind you that the voltmeter is used to "touch" both sides of an element. The voltmeter should always be connected to the circuit *after* the ammeter.

   c. An **ohmmeter** measures the resistance of a circuit element. You will use the meter labeled 'V' since the wire connections are the same; the only difference is that the dial will be set on the "Ohm" scale.

2. *Direct measurement of resistance:*

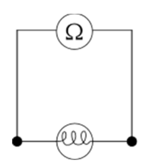


Figure 1: Measuring the resistance of a bulb.

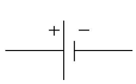
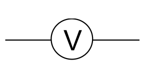
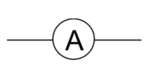
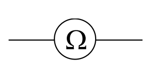
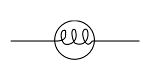
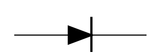
   a. Before connecting the circuit to the power supply, connect the ohmmeter across the small bulb (refer to "Using a Digital Multimeter", *page 3, Example 1*). Draw **Figure 1** in your journal, using the symbols used for a bulb and ohmmeter listed in **Table 1**.

   b. Measure and record the resistance of the bulb. Be sure to also record the meter setting that you used.

   c. You also have a resistor and an LED on your bench. Connect the ohmmeter to each circuit element, one at a time, again drawing **Figure 1** with the appropriate circuit element symbol for each and record the measured resistance and meter setting for each.

   *Note: Don't use the meter setting with the musical notes (♫). This is the **continuity** setting for the ohmmeter and will emit a tone for a closed circuit. It will give erroneous resistance measurements.*

TABLE 1: COMMONLY USED CIRCUIT SYMBOLS:

						
DC Voltage	**Voltmeter**	**Ammeter**	**Ohmmeter**	**Bulb**	**Resistor**	**LED**

3. *Assemble the circuit*: You will connect the bulb to the power supply, at first *without meters*, and then illuminate the bulb. Meters will then be connected, and measurements recorded.

   Turn the voltage knob on the DC power supply counterclockwise to zero and turn the power off with the switch each time you make a change to your circuit. **<u>Do not adjust the current knob</u>.**

   a. Sketch the circuit diagram (**Figure 2a**) in your journal, again noting that no meters are included.

   b. Assemble the circuit using two wires to connect the socket containing the small bulb to the + and – terminals of the power supply (*don't use the GND terminal*). Turn the power supply on and slowly turn the voltage knob clockwise until the voltage reads 6.0 *V* on the power supply. The bulb will slowly increase in brightness; if not, have your instructor check your circuit.

      The bulbs are rated at 7.5 volts. Do not exceed 6.0 volts in this step, as shown on the power supply's "voltage" meter, so that we can keep the bulb from accidentally blowing by applying too much voltage. We will use the full rated voltage later in step 3e when we calculate the power output of the bulb.

   c. *Connect the ammeter*: You will first connect the **ammeter** to measure the current through the bulb. **Turn the voltage off** by turning the power supply knob counterclockwise all the way and pressing the button. Disconnect the wire from the + terminal of the power supply (**Figure 2b**) and insert it in the "COM" port of the ammeter; the free end of the wire previously inserted in the "A" port of the ammeter is then connected to the power supply to complete the circuit. Set the ammeter to '2' DCA. (<u>Keep the power supply turned off!</u>)

   d. *Connect the voltmeter*: Next you will connect the **voltmeter** to measure the voltage across the bulb. Plug the red and black wires from the voltmeter into the connectors on both sides of the bulb as shown in **Figure 2b** – don't remove the wires connected to the bulb. Set the voltmeter to '200' DCV. (<u>The power supply is *still* off!</u>). Sketch this completed circuit in your journal.

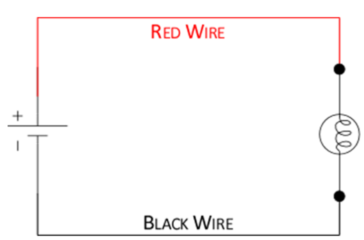


Figure 2a: Bulb circuit *without* meters

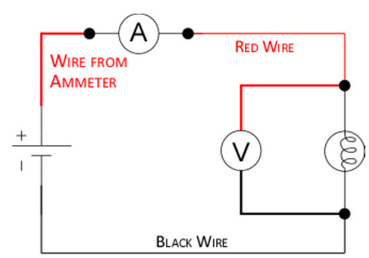


Figure 2b: Bulb circuit *with* meters

   e. *Measurements*: Turn on the power supply switch and raise the voltage *slowly* until the **voltmeter** reads 7.5 *V*. Record the voltage and current you measure at this voltage in your journal. *Don't forget the units!*

   f. *Calculating power output*: The power output of the bulb, in *Watts* (*W*) is the product of the voltage across the bulb (units: *V*) and the current through it (units: *A*): $\mathbf{P = I \cdot V}$. Calculate the power of the bulb and calculate the % difference with the published value (1.65 *W*).

4. *Ohm's Law*: Ohm's Law states that certain types of circuit elements exhibit a linear relationship between current and voltage: **V = I·R**. Elements that follow Ohm's law are called "*ohmic*", and they will produce a straight line *through the origin* when plotting I vs. V; the resistance of the element can be determined from the inverse-slope of the line. The resistance cannot be accurately determined this way if an element produces a non-linear graph, or the graph does not go through the origin. In that case, you will not need to apply a linear fit to non-linear Excel data.

Bulb:

a. Create a data table in your journal ***and*** in Excel to record measurements of V and I. *Put the voltage in the first column in Excel so that it will plot correctly.*

b. With the bulb still connected to the circuit (**Figure 2b**), adjust the power supply so that the reading on the voltmeter is 7.0 *V* (the maximum you will use). Measure and record the current on the ammeter in your journal and on Excel.

c. Decrease the voltage to 6.0 *V* (as read on the voltmeter) and measure the current on the ammeter. Continue to decrease voltage by 1.0 *V* increments and measure the current. After collecting the third data point, create your Excel graph of current as a function of voltage, and continue collecting data, decreasing by 1.0 *V* each time.

- You will create an Excel graph *as you collect your data*. Recall that in Excel you can start an x-y scatter plot after you have entered *three data points*.

d. Collect one additional current measurement when the voltage is 0.5 *V*, and then add an entry for {0,0}.

Resistor:

e. Turn the power supply voltage knob down to zero and turn the supply off. Remove the small bulb from the circuit. Attach the wires that were connected to the bulb to the connectors on the resistor. Change the ammeter setting to '20m' DCA, and the voltmeter to '200' DCV.

f. Your circuit now has the resistor connected in place of the bulb. Draw a new circuit diagram like **Figure 2b**, using the resistor symbol from *Table 1*.

g. Create a new data table in your journal ***and*** Excel. Turn on the power supply, and then measure and plot I vs. V on a new graph, increasing the voltage in 1.0 *V* increments until you reach the maximum of 10.0 *V*. Keep the current units in *mA*, and be sure to include {0,0} as a data point as before.

h. Turn the voltage knob on the power supply to zero and turn the supply off.

LED:

Note: A small resistor is attached to the LED to protect it from high currents. Our measurements will ignore this resistor, but you can add it to your circuit diagram as shown in ***Figure 3****.*

Figure 3: The LED is protected from high currents with a resistor.

i. Now replace the resistor with the small resistor-LED combination (**Figure 3**).

j. Draw a new circuit diagram like **Figure 2b**, using the LED symbol from *Table 1*.

k. Create a new data table in your journal ***and*** Excel. Turn on the power supply, and then measure and plot I vs. V on a new graph, increasing the voltage in 1.0 *V* increments until you reach the maximum of 10.0 *V*. Keep the current units in *mA*, and be sure to include {0,0} as a data point as before.

- *Increase the voltage slowly at first. You may notice some unusual behavior in the LED!*

l. Create a *third* graph of I vs. V for the LED, using the values measured on the multimeters (columns 2 and 3 of the table). Again, keep the current units in *mA*.

Analysis

a. Look at your three I vs. V graphs: which circuit element(s) are *ohmic*, that is, they behave as predicted by Ohm's Law (linear data *through the origin*)?

b. If you haven't yet done so, apply a liner fit to the graph(s) that follow Ohm's Law, and calculate the value of resistance from the *reciprocal* of the slope.

c. In your journal, briefly explain *why* the resistance is calculated from the reciprocal of the slope.

d. Move each graph to a new sheet in the spreadsheet (so it looks better when printed) and then print the graphs.

e. Be sure to record the units of your slope as well as the resistance! (*Hint: the slope units* ***are not*** $^1/_{k\Omega}$)

f. Calculate the % difference between the resistances calculated from the graph of the ohmic circuit element(s) to that measured using the ohmmeter in Step 2. How well do these values agree with each other?

Discussion

- Comment on the measured power output of the small bulb as compared to its expected value – this means you should have calculated the %difference!
- Summarize your resistance measurements and calculations for each of the three circuit elements. Which elements are *ohmic* (followed Ohm's Law), and which are not? Be sure to support your argument by discussing your graphs.
- Not all the circuit elements examined today are ohmic. For those elements that are not ohmic, what can you say about its resistance, as shown by its graph? (As you increase the voltage, is the resistance constant? Increasing? Decreasing?) Justify your answer.

PLEASE UNPLUG ALL THE WIRES FROM YOUR CIRCUIT,
AND TURN OFF THE POWER SUPPLY & MULTIMETERS