Ohm's Law
Spring 2020

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 a light emitting diode (LED). Before beginning this experiment, you should again read the "Using a Digital Multimeter" document you printed 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. *Setting up 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 power supply. Be sure to record all meter settings used during the experiment in your report!

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

   b. A **voltmeter** measures the *voltage across* an 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:*

   a. Before connecting the circuit, connect the ohmmeter across the small bulb (refer to "Using a Digital Multimeter", *Example 1*). Measure and record the resistance of the bulb.

   b. The black box on your bench contains a resistor and an LED; its exact contents are described later (*Step 4*). Connect the ohmmeter to the black box (**Figure 1**) to measure the resistance of (a) the resistor and (b) the LED.

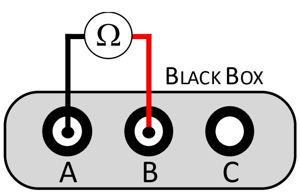


Figure 1a: Measuring resistance of Resistor

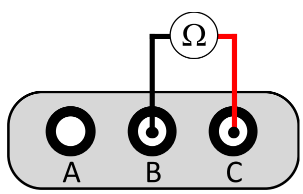


Figure 1b: Measuring resistance of LED

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 report, again noting that no meters are included. The symbols that will be used in circuit diagrams are found at the end of this section (**Table 1**).

   b. Assemble the circuit above 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. The bulb will slowly increase in brightness; if not, have your instructor check your circuit. *Do not exceed 6.0 volts at this time, as shown on the power supply's "voltage" meter.*

   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 report.

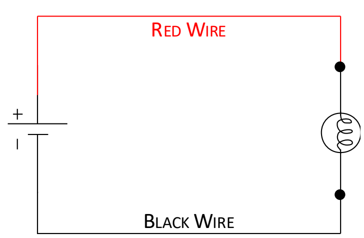


Figure 2a: Bulb circuit *without* meters

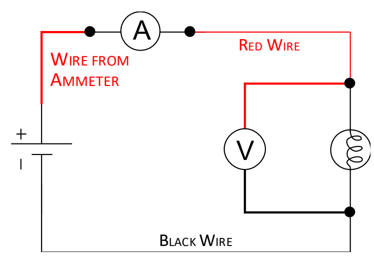
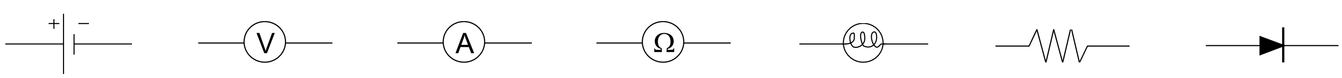


Figure 2b: Bulb circuit *with* meters

   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 report. Don't forget the units!

   f. 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*): **P = I·V**. Calculate the power of the bulb, and calculate the % difference with the published value (1.65 *W*).

TABLE 1: COMMONLY USED CIRCUIT SYMBOLS:



DC Voltage	Voltmeter	Ammeter	Ohmmeter	Bulb	Resistor	LED

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 <u>straight line *through the origin*</u> when plotting I vs. V; the resistance of the element can be determined from the inverse-slope of the line. If an element produces a non-linear graph, than its resistance cannot be accurately determined with this method, <u>so you will not need to apply a linear fit to non-linear Excel data</u>.

   <u>*Bulb*</u>:

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

b. With the bulb still connected to the circuit, adjust the power supply so that the reading on the voltmeter is 7 *V* (the maximum you will use). Measure and record the current on the ammeter in your report and on Excel.

c. Decrease the voltage 1.0 *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.

- 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}

The Black Box: You will next examine two other circuit elements using a black box containing a resistor and an LED. The box allows you to easily connect these elements to your circuit. **Figure 3** is a top view of the box; note that the connector labeled **A** has a large resistor, connector **B** a plain wire, and connector **C** has an LED and a small resistor in series (the small resistor is in place to protect the LED from high currents if the box is connected incorrectly, so we can pretend it's not there). The wires from the power supply and the voltmeter will be attached to the different labeled connectors, depending on which element is to be measured as part of the circuit.

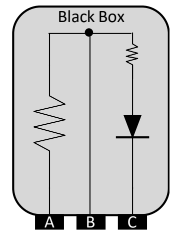


Figure 3

Resistor:

e. Turn off the power supply, and remove the small bulb from the circuit. Attach the wires that were connected to the bulb to connectors **A** and **B** on the box (**Figure 4**); also attach the wires from the voltmeter to **A** and **B**. Change the ammeter setting to '20m' DCA, and the voltmeter to '200' DCV.

f. Your circuit now has the large resistor connected in place of the bulb. Draw a new circuit diagram (*not Figure 4!*), using the resistor symbol from *Table 1*.

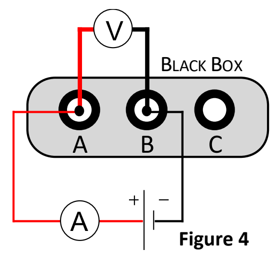


Figure 4

g. Adjust the power supply so that the reading on the voltmeter is 10.0 *V*. Create a new data table in your report and Excel, and then measure and plot I vs. V on a *second* graph, again decreasing the voltage in 1.0 *V* increments. Keep the current units in *mA*, and be sure to include {0,0} as a data point as before.

LED:

h. Now move the wires from the ammeter and power supply to the **A** and **C** connectors; this will replace the large resistor with the large resistor-LED combination (**Figure 5**). Move the voltmeter wires to the **B** and **C** terminals to measure the voltage across the LED.

i. Draw a new circuit diagram (*not Figure 5!*), using the LED symbol from *Table 1*.

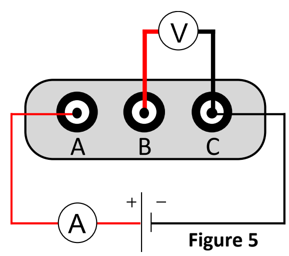


Figure 5

j. Create *Table 2* in your report, with voltages ranging from 12.0 *V* down to 0.0, in 1.0 *V* increments:

Table 2: Data Collection for LED

V (*volts*) *As read on power supply*	V (*volts*) *Measured on voltmeter*	I (*mA*) *Measured on ammeter*
12.0		
11.0		
etc.	*etc.*	*etc.*
1.0		
0.0	0.0	0.0

k. Create a table in Excel containing just the second and third columns from *Table 2*.

l. Switch the ammeter to '20m' DCA, and adjust the voltage on the power supply to 12.0 *V as read from the power supply's 'voltage' meter*.

m. Decrease the voltage that is displayed on the power supply in 1.0 *V* increments. For each voltage setting as read from the power supply, measure I and V from the ammeter and voltmeter, respectively, and record in *Table 2*.

n. 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 element(s) are *ohmic*, that is, they behave as predicted by Ohm's Law (linear points *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 (*briefly explain why the resistance is calculated from the reciprocal of the slope!*)

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

d. 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 percent 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.
- If a circuit element is not ohmic, what can you say about its resistance from 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**