Circuits

Goals: Observe the behavior of current and voltage in resistors and lamps. Use a digital multimeter to measure volts, amps and ohms.

APPARATUS

A circuit is connected set of electrical components. The components are connected to form one or more closed conductive loops to allow current to flow. In this laboratory we will use a number of different components including a power supply, switch, resistors, lamps and a digital multimeter (DMM). The DMM is designed to measure either volts, amps, or ohms and is therefore can be used as a voltmeter, ammeter or ohmmeter.

A circuit diagram is a representation of the components of the circuit and their connections. It does not indicate the physical orientation of the components. Each type of component has its own symbol. A series of alternating short and long lines represents a power supply. A diagonal line connected on one end repersents a switch. A zig-zag line represents a resistor. Meters are represented by circles with the symbol of the unit measured inside. Components like power supplies and resistors are frequently labeled with a specific value or with variable name for reference. Figure 1 is a typical circuit diagram.

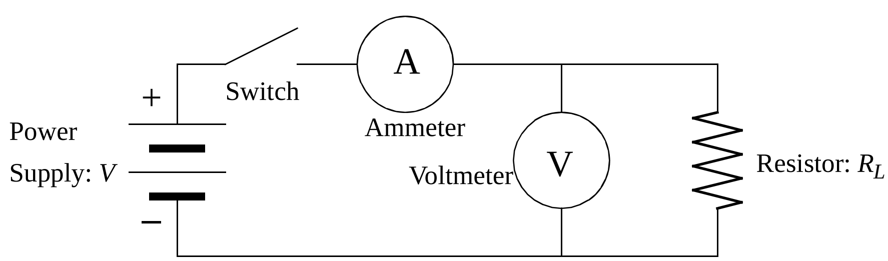

FIGURE 1. **Circuit diagram to measure Ohm's Law.**

Building a circuit from a diagram begins by finding the needed components. Each component is connected to other components with wires or other conductors. The points where lines connect the symbols on the diagram indicate where the components are connected in the actual circuit. Note that the components have at least two ends and it matters how the ends are connected. If both ends of a component are not connected, no current can flow through that component. In place where conductor line connect on the diagram, the conductors should also connect in the circuit. These connections between wires can occur any place along the wire since all points of the conductor are at the same potential.

There are two fundametally different ways of connecting components together. In a series connection, like the lamps in Figure 2, one terminal of one lamp is connected to one terminal of the other lamp. In a parallel connection, like the lamps in Figure 3, each terminal of one lamp is connected to a terminal of the other lamp so that both terminals of both lamps are connected to one and only one terminal of the other. Note that orientation of the lamps on the figures do not change their meanings.

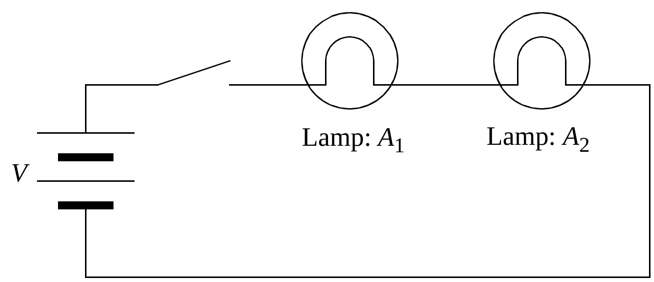

FIGURE 2. Circuit diagram with two lamps in series.

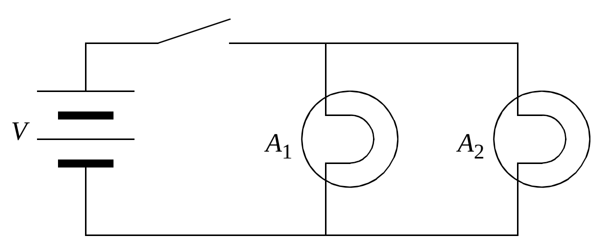

FIGURE 3. Circuit diagram with two lamps in parallel.

Circuits often don't show the position of the meter to make a measurement. An ohmmeter is used on a component that is not connected in a circuit, otherwise the mesurement may be biased by the other components connected to the component that is being measured. A voltmeter is used in parallel with the component that is being measured. That means that each end of the voltmeter is at a different end of the component. An ammeter is used in series with a conductor in a circuit. That means that the conductor has to be disconnected to insert the ammeter. If an ammeter is used in parallel with a component it will cause a short circuit and the fuse will blow. Because it is often inconvenient to disconnect a circuit, it is often possible to find the current by measuring the voltage across a resistor in series with the conductor and applying Ohm's Law.

THEORY

The electrical behavior of a component or group of components can be characterized in terms of the current (I) as a function of the voltage (V). The ratio of voltage to current in EQ 1 is called the resistance (R).

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

When the current is graphed as a function of current this becomes a V-I graph. Some components are observed to make a line of constant slope with zero intercept on the V-I graph and are called ohmic devices. The inverse of the slope of the line on the V-I graph is equal to the resistance for an ohmic device.

Voltage is a measure of the electrical potential. Like mechanical potential energy, a charge that changes electrical potential has work done by the electric force. Since the electric force is conservative then the work done through a closed loop of a circuit is zero. If components that raise the potential like power supplies are positive voltage and resistive devices are negative voltage the sum of all voltages in a circuit loop add to zero. This is Kirchhoff's Voltage Law and can be expressed as EQ 2.

$$\sum_{loop} V_i = 0 \quad \text{(EQ 2)}$$

Current in a circuit is a measure of the charge flowing past a point per unit of time. Since charge is conserved and does not accumulate in a conductor in a circuit, all the current that goes into a junction of conductors must be zero. If currents that flow into a junction are positive then currents that flow out of the junction are negative. This is Kirchhoff's Current Law and can be expressed as EQ 3.

$$\sum_{junction} I_{in} = 0 \quad \text{(EQ 3)}$$

DATA COLLECTION

OHM'S LAW

1. Before connecting the components in the circuit measure and record the resistance of each resistor with the DMM using a setting to measure ohms (Ω).
2. Connect the components to build the circuit in Figure 1. Make sure the switch is open before turning on the power supply. Set the ammeter to the amp scale (A).
3. Turn on the power supply and set the voltage (V) to 0.2 V as measured by the voltmeter.

4. Record the current measured by the ammeter.
5. Repeat steps 2 and 3 for voltage values of 0.5 V, 1.0 V, 2.0 V and 5.0 V.
6. Remove the resistor and replace it with a different valued resistor. Repeat steps 2 through 4 for this second resistor.
7. Remove the resistor and replace it with a lamp. Repeat steps 2 through 4 for the lamp.

SERIES AND PARALLEL CIRCUITS

8. Keep in mind the instructions in steps 1 and 2 and connect the components to build the circuit in Figure 2. Set the voltage V equal to 5.0 V and close the switch.
9. Use the DMM to measure the voltage drop across lamp A_1 and record the result. Remember that a voltmeter measures in parallel to the component.
10. Use the DMM to measure the voltage drop across lamp A_2 and record the result.
11. Use the DMM to measure the resistance of two resistors R_1 and R_2 and record the values.
12. Replace the two lamps in the circuit in step 8 with the two resistors from step 11 and measure the voltage drop across each resistor as in steps 9 and 10.
13. Open the switch and insert an ammeter in series with the switch. Close the switch and record the current.
14. Repeat steps 8 through 10 for the circuit in Figure 3.
15. Replace the lamps in the circuit from step 14 with the two resistors and repeat steps 13 and 14.

DATA ANALYSIS

16. Place the data from steps 4 and 5 in a table and plot the current vs. the voltage from that data.
17. Find the slope of the line I/V for from the plot and use the inverse of the slope to find the resistance R according to EQ 1.
18. Repeat steps 15 and 16 for the data from step 6.
19. Repeat step 15 for the lamp data from step 7.
20. Add the value of the voltage source in step 8 and subtract the voltage drops measured in steps 9 and 10 to get the total voltage change around the circuit loop.
21. Rearrange EQ 1 to solve for the current and use the two values of the resistors and the voltage drop in step 15 to find and record the current through each resistor.
22. Add the current measured by the ammeter in step 15 and subtract the two currents found in step 21 to find the total current into the junction of the resistors.

OBSERVATIONS

For each of these questions make your observation and support it by answering the question “Why?”.

According to your data and the graphs in steps 17 and 18, did the resistors obey Ohm’s Law?

At what voltage did the lamp first begin to glow in step 7?

Based on your graph and analysis in step 19, is the lamp an ohmic device?

How did the brightness of the lamps compare within the circuits from Figure 2 and 3 and how did they compare in brightness between those two circuits?

According to your data in step 20, did the circuit obey Kirchoff’s Voltage Law (EQ 2)?

According to your data in step 22, did the circuit obey Kirchoff’s Current Law (EQ 3)?