Northeast Community College
Diversified Manufacturing Technology
Introduction to Maintenance Technology

Ohm's Law

PURPOSE:

In this experiment you will study the principles of Ohm's law by examining the basic relationships of voltage, current, and resistance in an electric circuit.

DISCUSSION:

Electric current is the flow of negatively charged electrons through a conductor and is measured in amperes (A) using an ammeter. The amount of electric current depends upon the flow (or quantity) of charges that pass a given point in one second. The flow of electrons is due to a potential difference (voltage) between two points. If there is not a potential difference between two points you will not receive a voltage reading when using a voltmeter.

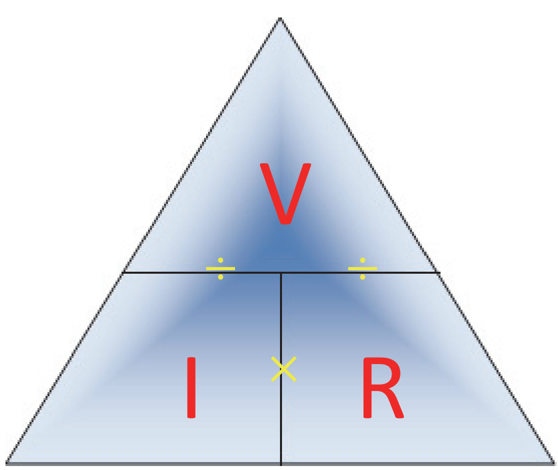
A circuit is a closed path that allows electrons to flow. In order for current to move through a circuit, there must be some sort of power supply such as a battery to maintain the necessary voltage. A battery that is connected in a circuit creates that potential difference between the positive and negative terminals due to chemical reactions that are occurring within the battery itself. As the voltage causes electrons to flow from the negative terminal to the positive terminal of the battery, the energy produced is generally converted to heat energy and/or light energy.

An individual by the name of Georg Ohm was the first to determine a relationship between voltage, current, and resistance in a circuit. This relationship is identified as Ohm's Law. Ohm's law applies to all circuits, from the simplest to the most complex. Ohm's law states: current is directly proportional to the voltage and inversely proportional to resistance. Mathematically expressed:

Potential Difference (Voltage) = Current x Resistance
V (Volts) = I (Amperes) x R (Ohms)

*Note – Some literature will replace the "I" with the letter "E"

Ohm's law provides a valuable tool for technicians in not only providing a means to calculate numerical values, but provides a basic understanding of electricity that can be used to troubleshoot a process.



$$V = I \times R$$

$$I = V / R$$

$$R = V / I$$

If someone reports smoke or the smell of smoke near an electrical panel, could you determine the root cause in order to correct the situation?

PROCEDURE:

1. Refer to the circuit shown in Figure 5-1

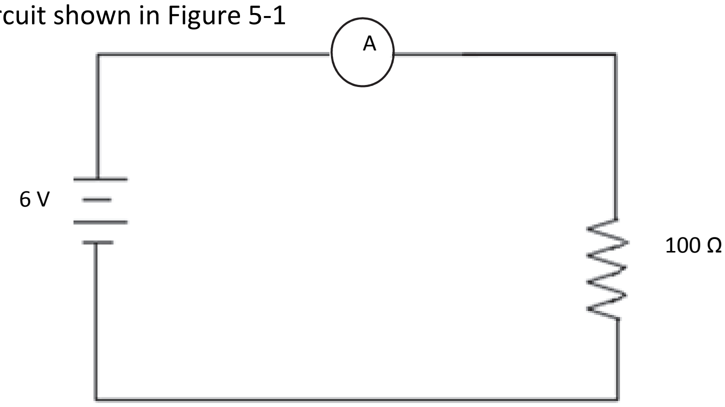


Figure 5-1

a. Using Ohm's law and the indicated voltage and resistance, calculate and record the current:

Calculated current______________ A

b. Construct circuit 5-1 using the PHET Circuit Construction Kit.
Measure and record the current using the standard ammeter and the circuit voltage. Remember that the circuit must be physically interrupted to insert the ammeter and measure current.

Measured current ____________ A

Circuit Voltage _______________ V

c. Are the calculated and measured current the same, or about the same? If they are not, you have made either a calculation error or a measurement error.

2. Change the 100Ω resistor in Figure 5-1 to a 10Ω resistor. This decreases the resistance by a factor of 10.

a. According to Ohm's law what should happen to the current?

b. Measure and record the current using the PHET Circuit Construction Kit you built in step 1. Be sure to adjust your resistance across the resistor to 10Ω.

Measured current _____________A

c. Is this the current you expected?

3. Add a light bulb into the circuit in accordance with Figure 5-2.

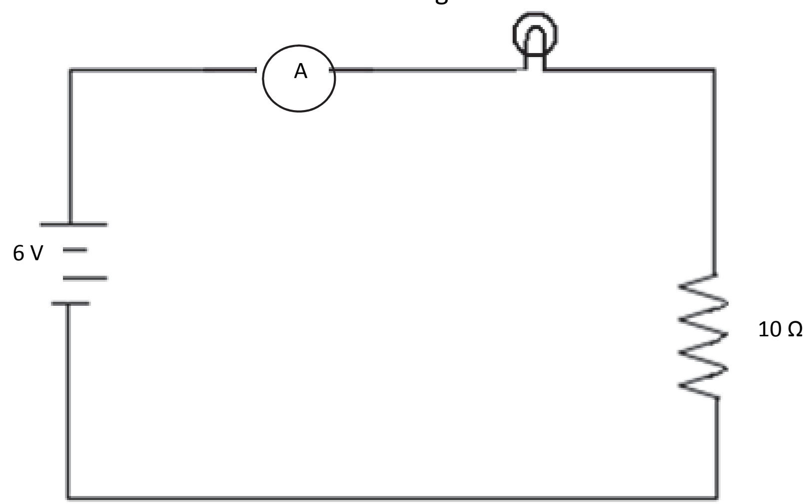


Figure 5-2

a. Using Ohm's law and the indicated voltage and resistance in Figure 5-2, calculate and record the current:

Calculated current ______________ A

b. Measure and record the current and voltage using the standard ammeter:

Measured current _______________A

Circuit Voltage __________________V

c. Are the calculated and measured currents the same? If no, list potential sources of error?

4. In steps 1-3 you should have been able to identify some relationships between current and resistance. Use that information to assist you in answering questions 4a – 4 d.

    a. Discuss how current and resistance are related? In other words, if one changes resistance, how does that change impact current?

    b. List three ways in which you could increase the resistance in the circuit (if necessary try different circuit designs using the PHET simulator).

    c. Discuss how one might increase the strength of the light without changing the amount of resistance?

    d. Explain how your answer in 4c would cause the light to shine brighter.

5. Change your battery to a 1.5 V cell and the resistor to 100Ω as shown in Figure 5-3. Notice that the potential difference across the circuit is about one-fourth the value of that circuit using the 6 volt battery. Use the voltmeter and the PHET circuit simulation to verify.

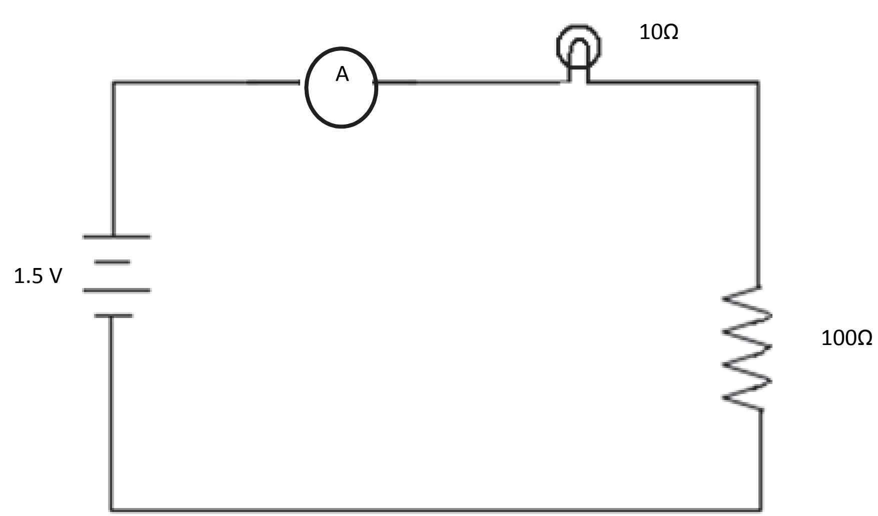


Figure 5-3

a. Using Ohm's law, calculate the current in Figure 5-3.

Calculated Current _______________ A

b. Measure and record the current and the circuit voltage of Figure 5-3.

Measured Current _______________A

Circuit Voltage __________________V

c. How does the circuit voltage compare to the circuit voltage of Figure 5-2 in which you testing using the 100Ω resistor?

d. What relationships can you determine thus far between voltage and current?

6. List three ways in which you can increase the voltage in the circuit. (If necessary try different circuit designs using the PHET simulator).

7. If you have 10 ohms of resistance in your circuit, and you measure a current of 0.45 amps, what is your voltage?

8. How many D cell batteries would you have to connect in series to achieve the voltage calculated in question 7? (Each D battery is 1.5 V)

The circuits in which you've just completed designing and testing in steps 1-8 assumed that the only sources of resistance in the circuit were the battery, the resistor, and the lamp. By assuming the wires provided zero resistance, your calculated current and measured current were the same value (or should have been). In real-life situations the measured values will not equal the calculated value but should be within $\pm$ 15% of the calculated value. The reason for the difference is the wires used to make your circuit or any electronic device always have some resistance, although minimal. Knowing how to determine the wire resistance can be as important as knowing how wire characteristics will affect your circuit.

One way to determine the resistance of a metal wire is based upon the following calculation:

Resistance = Resistivity of wire × length of wire ÷ cross-section area of wire

$$R = \frac{\rho L}{A}$$

Resistance (R) = total opposition to flow of electrons in a wire

Resistivity (ρ) = the inherent resistance of specific types of metals

Length (L) = how long or short a wire is

Area (A) = area of the cross section of the wire (circumference)

Table 5-4 below (from the CRC Handbook of Chemistry and Physics, 57th Edition, 1976-1977, CRC Press, p. F167-168; CRC Handbook of Chemistry and Physics, 90th Edition, 2009-2010, CRC Press, p. 12-14, p. 15-37) shows values for resistance (of a 10-ga *solid* wire at 20ºC) and resistivity for selected common metals.

TABLE 5-4

Resistance and Resistivity for Selected Common Metals		
	10-ga wire Resistance Ohms/ft	Resistivity 10^{-8} ohm-m @ 25° C
Silver	0.000944	1.617
Copper	0.000999	1.712
Gold	0.00114	2.255
Aluminum	0.00164	2.709
Iridium	0.00306	4.7
Brass	0.00406	6.13
Nickel	0.00452	7.12
Iron	0.00579	9.87
Platinum	0.00579	10.7
Steel	0.00684	11.8
Lead	0.0127	21.10

9. Using the PHET Resistance in a Wire simulation, complete the following questions.

a. How does increasing and decreasing the area (circumference) of a wire affect resistance?

b. How does increasing and decreasing the length of a wire affect resistance?

c. How does increasing and decreasing the resistivity of a wire affect resistance?

10. Calculate the Resistance of a #10 gauge copper wire that has a diameter of 0.0640cm and a length of 5 meters. The accepted value of resistivity of copper is 0.000000017Ω-m.

11. Use the knowledge you've gained throughout this laboratory activity to predict the following:

    a. What will happen to the current in a circuit if the voltage is kept constant but the wire diameter is increased?

    b. What will happen to the current in a circuit if the voltage is kept constant but the wire length is increased?

    c. What will happen to the resistance if you change from a copper wire, which is a good conductor, to an iron wire, which does not conduct as well?

d. What will happen to the current if the resistance is unchanged by the voltage is increased?

e. What will happen to the current if the resistance is unchanged but the voltage is decreased?

Resources:

1. University of Colorado Boulder (n.d.). PhET - Circuit Construction Kit.

Founded in 2002 by Nobel Laureate Carl Wieman, the PhET Interactive Simulations project at the University of Colorado Boulder creates free interactive math and science simulations. PhET sims are based on extensive education research and engage students through an intuitive, game-like environment where students learn through exploration and discovery.

2. Grant Statement

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