1103 Period 16: Electrical Resistance and Joule Heating

Activity 16.1: What Does the Electrical Resistance of a Wire Depend Upon?

1) Measuring resistance

a) Resistor length, \( L \)  Use a multimeter to measure the resistance of the wires on the green board.

1) Measure the resistance of the thin 30 cm nichrome wire. _________
2) Measure the resistance of the 15 cm nichrome wire. ______________
3) Does resistance \( R \) increase or decrease with increasing length \( L \) ? ______________

b) Resistor thickness, \( A \)

1) Using a multimeter, measure the resistance of the thick 30 cm wire. ______________
2) Does resistance \( R \) increase or decrease with increasing cross-sectional area \( A \) ?

c) Resistivity: The resistance of wires also depends upon the resistivity \( (\rho) \), of the wire material.

Use connecting wires to connect a 3-battery tray, a one-bulb tray, and a piece of copper in series. Note the brightness of the bulb. Then replace the copper with other materials and note the brightness of the bulb. Based on the brightness of the bulb, indicate which materials have high resistance, intermediate resistance, and low resistance.

<table>
<thead>
<tr>
<th>Material</th>
<th>Bulb brightness</th>
<th>Resistance</th>
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<tbody>
<tr>
<td>1) Copper</td>
<td></td>
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<td>2) Plastic</td>
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<td>3) Graphite</td>
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<tr>
<td>4) Glass</td>
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<tr>
<td>5) Iron</td>
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d) Relationship between \( R, L, A, \) and \( \rho (\text{rho}) \). We have found that the resistance of a wire \( R \) is directly proportional to length \( L \) and inversely proportional to the cross-sectional area \( A \). For a given type material, the resistivity \( \rho \) is directly proportional to the resistance. Using these variables, write an equation for the resistance of a wire.

e) The resistivity of copper at room temperature \( (20^\circ \text{C}) \) is \( 1.7 \times 10^{-8} \ \Omega \cdot \text{m} \). What is the resistance of a piece of copper wire 0.10 meters long with a cross-sectional area of 0.01 meters\(^2\) ?
Activity 16.2: How Do High Resistance Wires Affect Current Flow?

2) **The effect of increased resistance**

   a) Use a digital multimeter to measure resistance of the 30 cm thin wire (the middle wire) on the green board. Note: do **NOT** connect the wire to a battery when measuring its resistance.

   b) Connect a 4 bulb tray to a 3 battery tray using connecting wires. Note the brightness of the 4 bulbs. Will the brightness of the bulbs change if the 30 cm wire on the green board is added to the circuit in series with the 4-bulb tray and the batteries?

   Prediction: _______________  Answer: _______________

   c) Your instructor will show you how to connect the 30 cm high resistance wire to the circuit. Explain what happens when the wire is added to the circuit.

3) **Calculating joule heating**  Your instructor will discuss joule heating. How much joule heating occurs in the high resistance wires?

   a) Using the digital multimeter, measure the voltage across the 30 cm high resistance wire. __________

   b) Using your measurement of the resistance of the wire from part 2), calculate the amount of current through the high resistance wire when it is connected in series to the battery and the bulb tray.

   c) Calculate the amount of joule heating in the high resistance wires.

   d) Group Discussion Question: Do you think joule heating in a wire is an advantage or a disadvantage?
Activity 16.3: How Does Temperature Affect Resistance?

4) A heated resistor: Your instructor will show you how to measure the resistance of a light bulb. First, measure the resistance of the bulb at room temperature before it is plugged in.

   a) As shown in the diagram, use a digital multimeter on the ohms setting to measure the resistance of the UNPLUGGED bulb. _____________________

   b) Next, measure the resistance of the light bulb when it is hot. Plug the bulb into a wattmeter and plug the wattmeter into a power strip. Use the wattmeter to measure the bulb’s voltage and current while it is operating.

      Voltage across the bulb _____________
      Current through the bulb _______________.

   c) Calculate the resistance of the light bulb when it is operating.

   d) How does the calculated resistance when the bulb is hot compare to the measured resistance when the bulb is at room temperature?

   e) Group Discussion Question: When is an incandescent light bulb filament most likely to burn out – when the bulb is first turned on, while it is lit, or when it is turned off? Why?
5) **A cooled resistor:** Use connecting wire to connect in series a 3 battery tray, a single bulb tray, and a resistor. Note the brightness of the bulb. **(Caution:** the resistor will quickly become very hot.) Your instructor will give you liquid nitrogen. **(Caution:** liquid nitrogen quickly freezes skin. Avoid getting liquid nitrogen on your skin.)

   a) Carefully put the resistor into the liquid nitrogen and note the bulb’s brightness. What happens to the brightness of the bulb? ____________________________

   b) Does resistance increase or decrease as the temperature decreases?

   c) Group Discussion Question: Why did the bulb’s brightness change?
Period 16 Exercises: Joule Heating

Write answers to the questions below. Show your mathematical steps and the units of the quantities. This sheet with your answers should be turned in at the beginning of Period 17.

1. Comparing the resistance of wires:
   The wire resistors shown below are made from the same material. For each pair, which wire would you expect to have greater resistance? Why?

   a)  

   b)  

   c)  

2. Calculating joule heating in a wire bulb filament:

   a) An incandescent light bulb operates at 120 volts. It has a resistance of 200 ohms while lit. How much power is used for joule heating in the light bulb? (Hint: This is a two-step problem with two equations needed to find the answer.)

   b) Why do you think an incandescent bulb’s filament is made of high resistance metal instead of a less resistant metal, such as copper?