Student Worksheet #1

Characterizing Electrolytic Materials: Guided Inquiry

Safety
If any part of the circuit heats, disconnect the battery. Keep electrical equipment, such as probes and wires, out of the food itself. Only allow the probes to touch the aluminum foil.

Introduction: In order to process and deliver lots of information as with streaming video, Internet gaming, and cell phone applications engineers are making transistors smaller and faster. These transistors are now so small that "[m]ore than 2 million 45 nm (nanometer) transistors could fit on the period at the end of this sentence" or "more than 100 million 22nm tri-gate transistors could fit onto the head of a pin (1.5mm in diameter).[1] These nanoelectronics allow for faster, smaller and more portable systems (think about your smart phone) and they can manage and store large amounts of data/information (think about the increasing storage capacity of USB drives and computers). To do this, engineers test the properties of various materials including conductivity and resistance. Engineers investigate how these materials function *together* so they can find the best solution for a specific application. This activity emphasizes the engineering practice of *characterizing* a material's properties to use it for a specific application. In this lab, you will be characterizing various food materials for use in a circuit!

Question 1: Which materials will conduct electricity the best? Which materials will be the worst conductors of electricity? **Make a Prediction:**

Question 2: Will the amount of the material affect how well it conducts? Why or why not? **Make a Prediction:**

Materials:
- ammeter or multimeter
- light bulb
- 9V battery
- 9V battery connector
- metric ruler
- 3 alligator clip wires
- 2 alligator clips
- 3 disposable plates
- sheet of aluminum foil
- 3 narrow straws
- 3 wide straws
- 1 cup of each type of condiment: mustard, ketchup, mayonnaise
- hot dog
- scissors
- 4 syringes
- plastic knife

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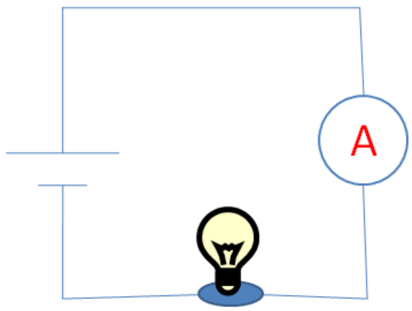
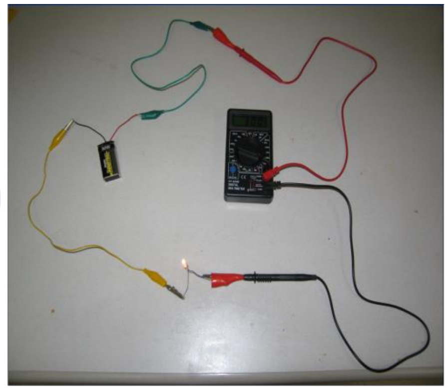
Procedure:

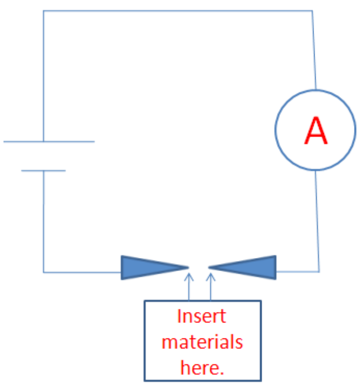
1. Create a circuit as shown:

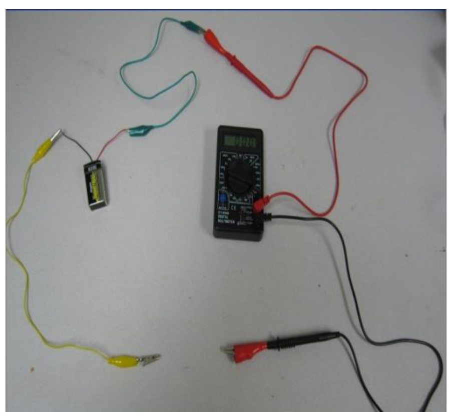




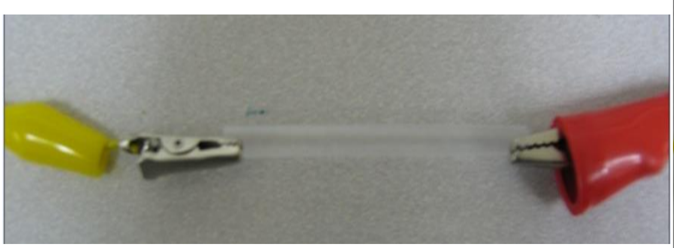
2. Set ammeter to 200 mA. Confirm that the light bulb is on and that the ammeter measures a steady current.

3. Disconnect your light bulb from the circuit. This is where you will insert electrolytic materials (straws with condiments) to test. Your ammeter should now read 0 mA.





4. Insert a narrow straw into your circuit by clipping the alligator clips to each side of the straw. Then, read the current from the ammeter and record it in the table.



Step 4

Step 5

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5. Set the ammeter to 10 A. Cut aluminum foil to be 8 cm long and 2 cm wide. Touch the alligator clips to the foil *for only an instant*. The ammeter may read “1” if the current is too high to measure. Record the current in the table on page 4. **Note: When the current is very high, it is called a *short circuit.* If this occurs, immediately disconnect the circuit.**

Each person will individually do steps 6–13 on one electrolytic material (condiment):

6. Cut your narrow straw 8 cm from one end.

7. Use the syringe to inject your electrolytic material (ketchup, mustard, or mayonnaise—each person in your group will do a different condiment) into the straw to completely fill it with a little bit coming out of each end. *Do not get air bubbles in your straw. It will prevent current from flowing.*

8. Stick a piece of aluminum foil on both ends of the straw so that it touches the condiment. Insert your straw into your circuit by putting a probe at each end of the straw. *Make sure the aluminum doesn’t touch each other, or it will create a short circuit.*

9. Set your ammeter to 200 mA. Read the ammeter to measure the current that is flowing through the circuit. Record the material, length, diameter, and the amount of current flowing through the electrolytic material in the table.

10. Cut your narrow straw in half (so it is 4 cm), and repeat steps 7–9.

11. Repeat steps 7–9 again, but this time use an 8 cm piece of the ***wide*** straw.

12. Cut your wide straw in half (so it is 4 cm), and repeat steps 7–9.

13. Share your data with your group.

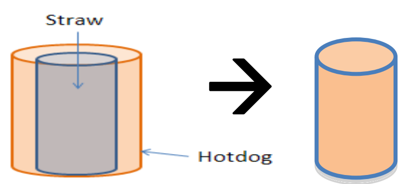
As a group:

14. Test the current of a hot dog.

   a. Cut a large straw 4 cm from the end.
   b. Cut the ends off the hot dog. Cut the hot dog to be a little longer than your straw.
   c. Stick the straw through the middle of the hot dog. Then push it all the way through the hot dog and **push it out the other side.** You should now have a straw with a hot dog in it.
   d. Put a piece of aluminum foil on each side of the straw.
   e. Test the amount of current and record your data in the table.

While pushing: Straw (inside) with hotdog (both inside and outside)

After: Straw (outside with hot dog inside)



Record your Observations:

Which straw	Material	Length (cm)	Diameter (cm)	Radius (cm)	Area (cm^2)	Current (mA)
	straw	8				
	aluminum	8				
Narrow straw	ketchup	8				
	ketchup	4				
Wide straw	ketchup	8				
	ketchup	4				
Narrow straw	mustard	8				
	mustard	4				
Wide straw	mustard	8				
	mustard	4				
Narrow straw	mayonnaise	8				
	mayonnaise	4				
Wide straw	mayonnaise	8				
	mayonnaise	4				
	hot dog	4				

Analyze the Results:

1. Calculate the **radius** and **area** for each length of electrolytic material, and complete the table above. Use these equations:

Equation for calculating *radius*

$$r = \frac{d}{2}$$

where *r*: radius and *d*: diameter

Equation for calculating *area*

$$area = \pi r^2$$

where *r*: radius

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2. Complete the chart below. Calculate the **resistance** and **resistivity** of the materials listed
3. in the chart below using **one** of your measurements. Use the 4 cm length measurements on the wide diameter straw for each of these calculations. *Note: The* ***current*** *must first be converted from* **mA** *to* **A** *by dividing the amount in mA by 1000 to use these equations.*

Equation for calculating *resistance*		**Equation for calculating *resistivity***		
resistance = $R = \frac{V}{I} = \frac{\text{voltage}}{\text{current}}$		resistivity = $\rho = \frac{AR}{L} = \frac{\text{cross-sectional area} \times \text{resistance}}{\text{length}}$		
Material	**Voltage (V)**	**Current (A)**	**Resistance (Ω)**	**Resistivity** (Ω*cm)
ketchup	9			
mustard	*9*			
mayonnaise	*9*			
hot dog	*9*			

4. Organize your results from the most conductive material to the least conductive material. Include the straw and the aluminum foil.

1.	2.	3.
4.	5.	6.

Draw Conclusions:

1. Which material conducted the best?
   Which material conducted the worst?
   Why do you think some materials conduct better than others?

2. Was there a relationship between length and how well it conducted? If so, how were they related?
   What do you think causes this?

3. Was there a relationship between the cross-sectional area of the straw and how well it conducted? If so, how are they related?
   What do you think causes this to occur?

4. Depending on the properties of a material, it will have a specific resistivity. What do you think resistivity is?
   What measurement during the lab would resistivity affect the most?
   What relationship would exist between this measurement and resistance?

5. What was the purpose of using a plastic straw and aluminum foil in order to take our measurements?

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