Lab: Penny Boats

FOR THE TEACHER

Summary
In this lab, students will explore Archimedes’ Principle and how it relates to density. Each student will be given a piece of aluminum foil and asked to design and build a boat that will hold as many pennies as possible without sinking when placed in water.

Grade Level
Middle or High School

NGSS Standards
- MS-ETS1-1: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
- MS-ETS1-2: Evaluate competing design solutions using a systematic process to determine how well the meet the criteria and constraints of the problem.

Objectives
By the end of this lab, students should be able to
- Determine the mass of a boat based on the volume of water it displaced.
- Use the density equation to determine an unknown variable: mass, volume or density.
- Examine real world situations where a boat has a density greater than 1.0 g/ml.

Chemistry Topics
This lab supports students’ understanding of
- Density
- Water Displacement
- Measurement
- Data Collection

Time:
Teacher Preparation: 15 minutes
Lesson: 60-70 minutes

Materials (Per lab group)
- Displacement tank
- Aluminum foil, 10x10 cm
- ~ 40 pennies
- ~ 2L of water (dependent on size of displacement tank)
- 100 mL Graduated Cylinder
- Electronic balance
- 300 mL Beaker
- Scissors
- Ruler

Safety:
- Always wear safety goggles when handling chemicals in the lab.
- Students should wash their hands thoroughly before leaving the lab.
- When students complete the lab, instruct them how to clean up their materials and dispose of...
any chemicals.
- Do not consume lab solutions, even if they’re otherwise edible products.

**Teacher Notes**
- It is helpful if the teacher precuts the aluminum foil squares (10 x 10 cm) and organize lab supplies prior to the lab.
- Small lab groups of 2-3 students work well for this activity.
- When completing this lab, groups need to have either pre-1982 or post-1983 pennies. Pennies minted prior to 1982 were full copper and weigh more than the Copper coated Zink pennies of today. Do not mix and match these pennies or results will not be accurate.
- Depending upon the age/level of students you can have students measure and cut their own aluminum foil for use in the lab.
- The teacher should inform students that the overflow tanks must be filled to the absolute maximum capacity in order to have the surface tension of the water broken during water displacement which will create the overflow of drops into the graduated cylinder.
- Before beginning the lab, students should watch the Bill Nye Video, Buoyancy (Season 1, Episode 5). Student questions are included, and a class discussion should follow the video.

**FOR THE STUDENT**

**Lesson**

**Bill Nye Video: Buoyancy**

**Instructions**
View the video Bill Nye Buoyancy and answer the following questions.

*Remember that Archimedes’ Principle states that the buoyant force is equal to the weight of the fluid displaced.

**Questions**
1. What word means to push a fluid, like water, out of the way?
2. The displaced water of the model boat equals the ______________________of the boat and the ______________________ that the boat displaces.
3. What property of a boat allows it to float even if it is made of something that normally sinks?
4. What happens if a thing displaces as much water as it weighs?
5. What is the name of the Principle that tells us about buoyancy?
6. Explain the pen cap/ submarine and fish swim bladder:
7. Describe negative buoyancy and give an example:
8. Describe positive buoyancy and give an example:
9. Describe neutral buoyancy and give an example:
Lab - Penny Boats

Background
You will design and build a penny boat using a given piece of aluminum foil as your material. Your goal is to design a boat that will hold as many pennies as possible without sinking. Remember that Archimedes’ Principle states that the buoyant force is equal to the weight of the fluid displaced.

Pre-lab Questions
1. Define the following terms:
   a. Independent Variable:
   b. Dependent Variable:
   c. Hypothesis:

Materials
- 40 Pennies
- 10 cm x 10 cm square of aluminum foil
- Beaker
- Graduated cylinder
- Displacement tank
- Balance

Safety
- Always wear safety goggles when handling chemicals in the lab.
- Wash your hands thoroughly before leaving the lab.
- Follow the teacher’s instructions for cleanup of materials and disposal of chemicals.
- Do not consume lab solutions, even if they’re otherwise edible products.

Procedure
1. Obtain a piece of aluminum foil and use a ruler to measure a 10 cm x 10 cm square.
2. Build your boat by folding or creasing the aluminum foil into a shape you think will displace the most amount of water. When done, measure the mass of the boat. Record the mass in the data table provided.
3. Measure the mass of an empty beaker on your balance. Record the mass in the data table provided.
4. Make a guess as to how many pennies the boat will hold. Record your guess in the data section.
5. Describe and draw your boat design under the data section.
6. Fill up displacement tank with water to its maximum capacity. At this point a small amount of water will come out of the spout into the sink.
7. Measure the mass of an empty beaker on your balance. Record the mass in the data table provided.
8. Place the beaker under the overflow spout, and then place your boat in displacement tank.
9. Add one penny to the boat at a time, until the boat starts to sink.
10. Record the number of pennies (not including the one that sank it) in the data table.
11. Calculate the mass of the boat + the pennies (not including the one that sank it) in the data section. This is: (Mass of 1 penny x # of pennies your boat held) + mass of boat.
12. Calculate the mass of the displaced water that was collected in the beaker during displacement. Do this by measuring the mass of the beaker containing the water, and then subtract the mass of the empty beaker that you recorded earlier.
13. Then pour it into a graduated cylinder to measure the volume. Record in the data table.
14. Clean up any spilled water and your work area. Retrieve and dry off the pennies and return them to your teacher.

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**Data**

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<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Mass of Boat (g)</td>
<td></td>
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<tr>
<td>Mass of 1 dry penny (g)</td>
<td></td>
</tr>
<tr>
<td>My boat will hold # of Pennies (your guess)</td>
<td></td>
</tr>
<tr>
<td>Mass of empty beaker (g)</td>
<td></td>
</tr>
<tr>
<td>Number of pennies held by the boat before sinking</td>
<td></td>
</tr>
<tr>
<td>Mass of boat + pennies (g)</td>
<td></td>
</tr>
<tr>
<td>(Mass of 1 penny x # of pennies your boat held) + mass of boat</td>
<td></td>
</tr>
<tr>
<td>Mass of beaker containing water (g)</td>
<td></td>
</tr>
<tr>
<td>Mass of displaced water (g)</td>
<td></td>
</tr>
<tr>
<td>Volume of displaced water (ml)</td>
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</tbody>
</table>

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**Analysis**

1. Compare the *mass* of the water displaced and *volume* of water displaced. Were they similar values? Explain. (Think about the density value of water if you need help!)
2. What connections can you make about the mass of the water displaced and the mass of your boat & pennies?
3. How does this lab demonstrate Archimedes’ Principle (use your book/laptop if necessary)?
4. If a boat has a displacement of 4000 lbs. and weighs 2300 lbs., will the boat float? Explain. (Think about Archimedes’ principle and look at your own data for help!)
5. How much cargo could you put into the above boat prior to it sinking?

**Conclusion**
Do some research online and explain why ships are built with *bulkheads* and *water tight compartments*. Why would it be beneficial to produce ships with this compartment type construction?