The Case of the Mixed Up Sub

Michael Dyre
St. Labre Indian School
Ashland, MT

Research Host:

Paul R. Standley, Ph.D.
Midwestern University, Glendale, AZ

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Grade Level:

High School

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Purpose:
This activity works best with curricula dealing with the density of fresh & salt H_2O, as one would find in an estuary such as the Chesapeake Bay. This also could be adapted to fit a biology or physics class.

Objectives:
Students will be able to:
- determine the properties that require a submarine captain to keep a close watch on the surrounding changing marine environment.
- use these properties to design and build a pseudo-sub capable of being neutrally buoyant in fresh water.
- transfer this fresh water sub into a marine environment.
- observe and record any changes that occur in the salt water.
- determine and carry out changes to the sub's design, making it neutrally buoyant in sea.
- develop a basic understanding of the density differences between fresh and salt water.

Materials:
- material to represent the hull of a submarine (plastic soda straws cut into four cm sections work well)
- BBs for ballast
- salt (NaCl)
- chewing gum (bubble gum works best, water- insoluble clay works well too)
- metric ruler
- 2 plastic beakers (400-500mL)
- water supply

Procedure:
1. The lab report that follows may be a little too "cookbook" for some. Depending on the class, you may wish to change this procedure and make it much more open-ended. I have used this for middle and high school earth science, as well as in an upper-level high school oceanography class. It is enjoyed by all.
2. Students use information given in the background section of the lab to identify the forces that control a submarine's movements through the ocean.
3. Students should be divided into groups of two. If materials allow, you may wish to give each student the opportunity to become a submarine engineer.
4. Most of the materials are inexpensive (with the exception of the beakers) or may be easily obtained from a local fast food restaurant (with the manager's permission of course).
5. Students are to determine what materials that are provided will act to provide ballast and buoyancy.
6. Students will then design (make sure they explain their design to you) their sub so that it is positively buoyant in fresh water.

7. The students will then transfer their sub to salt H_2O and will need to alter it to make it positively buoyant in salt H_2O.

Safety:
No real safety hazard raises its ugly head during this procedure. It is always smart to be careful when working with water on a tile floor.

Additional Notes:
There may be a need for additional ballast to insure neutral buoyancy. You may need to supply an additional BB (or some other smaller, relatively dense object) to their setup. The following lab setup does not include the need to make the sub **neutrally buoyant** in sea H_2O. This additional procedural step is probably not feasible if you are constrained to a 45-50 minute class period.

Some students may get frustrated trying to achieve a truly **neutrally buoyant** sub. Instruct those that do that they may also obtain the same final result if they are able to produce a near **neutrally buoyant** sub (i.e., If the sub is placed in the middle of the H_2O column, it would either sink or rise slowly).

Where to Go from Here:
Let the students explore the seasonal effects and changes that occur as fresh H_2O invades a sea or an ocean. You may also wish to have them explore the tidal affects that occur as a dense wedge of salt H_2O creeps quietly up a river bed.

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Laboratory Set Up

Purpose:
Is there a noticeable difference in density between fresh water and seawater?

Materials:
- plastic straw (4 cm long)
- chewable sucrose paste (gum)
- sodium chloride
- 2 beakers
- a single BB
- metric ruler
- plastic spoon

Background:
Once a submarine is submerged, the commander does not want to worry about it sinking to the bottom or (unless desired) rising back to the surface. He wants to remain in a balance **(buoyant)** with the water that surrounds the sub. This is called being **neutrally buoyant**. He does not have to work to remain at this depth. This way all of the sub's energy may be used to propel it forward and look for the enemy.

To make submarines neutrally buoyant, engineers & designers balance two forces: **gravity,** which pulls the sub down, and **buoyancy,** which pushes it up. They do this by adjusting ballast. **Ballast** is a material or mass that provides stability. Submarine tests were first conducted in pools of fresh water. Subs that passed this test were then transferred to seawater and tested, but were unable to submerge. Let's see if you can determine why a submarine commander's life is NO piece of cake.

Procedure:
Part 1: Creating Your Own Personal Sea
1. Fill a beaker ¾ with hot water from the sink.
2. Add 3 teaspoons of NaCl and stir.
3. Set this beaker aside allowing it to cool to room temperature (or as close as possible).

Part 2: Creating the Perfect Neutrally Buoyant Sub
1. Add lumps of gum on both ends of the straw.
2. Put the sub into the beaker of fresh water (fill to ¾ full):
   If the sub floats, the lumps are too light, or **positively buoyant**.
   If the sub sinks, the lumps are too heavy, or **negatively buoyant**.
3. Carefully adjust the ballast of the sub until its top will remain just below the surface of the water. The sub is now **neutrally buoyant**.

Part 3: Buoyancy of Your Sub in Your Sea

1. Check to make sure that your salty sea beaker has reached room temperature.
2. Place the neutrally buoyant sub in the seawater and notice what has changed.
3. Clean, dry & replace all materials to their proper location. You may also deep-six the sub.

Data Questions:

1. What purpose does the gum have in this experiment?

2. Why wouldn't you want water to enter the straw?

3. What happens to your sub when it is placed in seawater?

4. Is there a difference in density between fresh and seawater? What is the difference?

5. What clues allow you to determine this answer?

6. How does density affect buoyancy?

7. What would you have to do to make this sub neutrally buoyant in the seawater sample?

8. What would happen to this neutrally buoyant sub (in #7) if it were placed in the Great Salt Lake (even saltier than average ocean H2 O)? Would it sink or float? Please explain your answer in terms of density.