Aspire SWE K-12 Outreach

# Technology of the Deep: Experiments with Buoyant Forces


Society of Women Engineers
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Developed in collaboration with
Education Development Center, Inc.

EDC

## Developer

This activity was developed by the Santa Clara Valley SWE Section.

**Grade Level:** 4-8

**Preparation:** 15 minutes

**Activity Length:** One hour

## Learning Goals

- Students are introduced to the concept of buoyancy.
- Students conduct a series of experiments to study the effects of temperature and salinity (salt content) on the buoyancy of an object in water.
- Students devise ways to make floating and sinking objects neutrally buoyant.

### NATIONAL SCIENCE EDUCATION STANDARDS (NRC)

**Science as Inquiry**

A1. Develop abilities necessary to do scientific inquiry.

**Physical Science**

B1. Develop an understanding of properties of objects and materials. (4)

B2. Develop an understanding of position and motion of objects. (4)

B1. Develop an understanding of properties and changes of properties in matter. (5–8)

B4. Develop an understanding of motions and forces. (5-8)

**Science and Technology**

E2. Develop understandings about science and technology. (5-8)

## STANDARDS FOR TECHNOLOGICAL LITERACY (ITEA)

### The Nature of Technology

1. Develop an understanding of the characteristics and scope of technology.

3. Develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

### Design

10. Develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

### The Designed World

18. Students will develop an understanding of and be able to select and use transportation technologies.

## NATIONAL EDUCATIONAL TECHNOLOGY STANDARDS (ISTE)

None Applicable

## ENGINEERING EDUCATION STANDARDS (McREL)

None Applicable

## PRINCIPLES AND STANDARDS FOR SCHOOL MATHEMATICS (NCTM)

None Applicable

## BENCHMARKS FOR SCIENCE LITERACY (AAAS)

### Habits of Mind – Values and Attitudes

A1. Keep records of their investigations and observations and not change the records later. (5)

A2. Offer reasons for their findings and consider reasons suggested by others. (5) A1. Know why it is important in science to keep honest, clear, and accurate records. (6–8)

## Activity Overview

Have you ever wondered why a hot air or helium balloon rises into the sky and floats through the air? Submarines can move on the water's surface or travel underneath the surface completely submerged. How does the submarine sink into the water and then rise back to the top?

Both the balloon and the submarine use the buoyancy of the air and water – the upward force a liquid or gas exerts on an object.

In this lesson, you will use full soda cans and discover how to make the soda cans float or submerge like a submarine!

## Materials:

- 8 Cup Container (8 Cups equals 2 quart or half gallon) *
- Hot and Cold Tap Water
- Ice Cubes
- 3 Cans Of Soda (Cola, Diet Soda and Orange)
- 1/4 Cup of Salt
- 2 Balloons
- Two 12" Pieces of String Or Ribbon
- Spoon
- Graduated Cylinder
- Measuring Cup

- Tablespoon
- Ruler
- Safety Scissors
- Balance or Kitchen Food Scale
- Modeling Clay (Optional)
- 2 or 3 Square Inches of Styrofoam (Optional)

(Note: You do not have to use an 8 cup container. You can use any size container you like, but you will need to follow the directions in Step 3 to adjust the amount of salt you use.

This demonstration can be a class or team activity. If using student teams duplicate these supplies for each team.)

## Activity Procedure

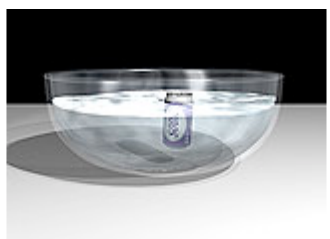
### Steps to Follow:

1. Review the information in the background section.

2. Your container's shape will govern the amount of water (and salt in Step 3) you will need. The container should allow the can to float – there should be some distance between the bottom of the can and the bottom of the container. Preferably, the container should be clear.

   We used an 8 cup container. You may need to use more or less water to observe buoyant behavior.

   Put 5 cups of cold tap water into an 8 cup container. Immerse one can of soda and record its buoyancy behavior on your worksheet (see handouts). Use the ruler and measure the height of the can from the bottom of the container. Label the type of soda in the table. Immerse the second can of soda and again record your results on your worksheet. Did the soda cans behave differently? If so, why?



3. The salt content (salinity) of sea water is approximately 2.5%. Your container's shape will govern the amount of water (and salt) you will need.

   Use the following information to calculate the ratio of water and salt you will need.

   There are 16 tablespoons in a cup. To determine the amount of salt you need, multiply the number of cups of water you use by 16 tablespoons/cup. This equals the number of tablespoons of water you used. Multiply that number by 0.025 (which is equivalent to 2.5%). This is the number of tablespoons of salt you need.

   (Cups Of Water X 16 Tablespoons/Cup X 0.025 = Tablespoons of Salt Needed)

   The container we used needed 5 cups of water to float the soda can. For the water to have 2.5% salt, 2 tablespoons of salt were added.

Stir to dissolve the salt. Again immerse the cans of soda and record what you observe. Did the behavior differ between the two cans? Did it differ from what you observed in Step 2? What might be the cause? How much salt is required before all the sodas can be made to float? Why do objects float more easily in salt water?

4. Compute the density of one of the cans of soda as follows:

   Density = (Mass of Can) / (Volume of Can)

   Use the balance or kitchen scale to determine the mass (weight) of the can in grams. Assume that the volume of the can is 385 ml. Use the above formula to compute its density. The density of water is about 1 g/ml. How does the density of the can of soda compare to the water? Record your results on your worksheet (see handouts) and on the board in class. Based on these measurements, explain the results you observed in Steps 2 and 3.

5. Use a graduated cylinder to determine the exact volume of each can of soda. Does this value differ significantly from the approximation which was used? If so, use this value to compute the density. How does this new calculation of density compare to that of water?

6. Repeat Steps 2-3 using warm to hot tap water instead of cold. (Be careful - do not use water over 100$^{o}$F). Does the can behave differently in warm water? Repeat Steps 2-3 placing ice cubes in the water. Does this make a difference?

7. Optional - If you have a can which is floating, how could you make it neutrally buoyant (neither floating nor sinking)? Attach objects to the can to test out your ideas. (We used modeling clay.) Why would you want to create an object which is neutrally buoyant?

8. Optional - If you have a can which sinks to the bottom, how could you make it neutrally buoyant? (We used one half of a 1.5" Styrofoam ball. Some of the Styrofoam became saturated with water.) Attach objects to the can to test out your ideas.

9. Optional - Run the experiments using each can in a six pack of the same kind of soda. Do you observe any differences? Record your results on your worksheet (see handouts). If so, what might explain the difference?

## Handouts

### Words to Know

- buoyancy
- density
- float
- force
- graduated
- neutrally buoyant
- pressure
- salinity
- sink
- submerged

## Background Information

Fluid dynamics is the study of how gases and liquids behave. A fluid can be either a gas or a liquid. All substances have three states of matter: solid, liquid, and gas. When a substance is in a solid state, its molecules are all lined up and rigid. Its volume and shape are fixed. An ice cube (solid water) remains an ice cube no matter what size or shape a container you put it in.

A liquid, on the other hand, has molecules that are more fluid and moveable. It has a fixed volume, but it can take the shape of its new container. You can pour a quantity of water from a glass to a cube, but if the cube has a smaller volume than the glass, the water will run over the top! A gas has molecules that are completely free to move about, contracting and expanding at will. A gas has no fixed volume or shape. If you take a deep breath of air (a gas), the air you take in expands to fill all the compartments of your lungs. If you blow that breath into a balloon, for instance, the volume in the balloon is much smaller than the volume in your lungs.


We measure the number of molecules in a given volume of fluid and call it density. Since the volume of a liquid is constant, its density, the mass (measured by the number of molecules) in a fixed volume, is also constant. A liquid is considered to be incompressible; the density is constant and you can't squeeze more mass into the same volume. With a gas, you can continue to add molecules into a given volume, or you can squeeze the same number of molecules into a smaller volume. When you do this, the density changes and the gas is called a compressible fluid.

Buoyancy is the final concept we want to discuss here. When an object is immersed in a fluid, what makes it float? Archimedes' principle states that the fluid exerts an upward force on the object equal to the weight of the fluid that is displaced by the object. This means that if you have an object whose mass is less than that of the fluid, the fluid forces will push that object up! This is why a boat floats or a hot air balloon floats through the air. The weight of the boat (its mass times gravity) is less than the weight of the water it displaces. In Activity 3, the students built boats and placed pennies in them. As long as the boats displaced a large volume of water, multiple pennies could be placed in them. If the foil boats didn't displace much water, then they wouldn't be able to hold many pennies. The wadded up piece of foil didn't displace very much water at all, and the weight of the wad was greater than the weight of the water it displaced, so it sunk to the bottom.

Hot air balloons also work on the buoyancy principle. As the air heats up, its density decreases. Once the balloon is expanded to its full size, its volume is fixed. As the density continues to decrease that means the mass is decreasing. Since weight is the mass times gravity, the weight of the hot air is less than the weight of the cooler air it is displacing, and the balloon rises into the air!

Seawater is a mixture of water and salt. The salinity of a liquid is defined as the weight of the dissolved salt divided by the weight of the liquid. The salinity of seawater is typically about 0.035. Generally, this is written as 35 0/00 or 35 parts per thousand.

## Engineering Project Notebook For___________________________

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### Buoyancy Observed

| Type of Water: | Type of Soda: | Type of Soda: | Type of Soda: |
|---|---|---|---|
| Cold Water | Height: | Height: | Height: |
| Cold Salt Water | Height: | Height: | Height: |
| Hot Water | Height: | Height: | Height: |
| Hot Salt Water | Height: | Height: | Height: |
| Ice Water | Height: | Height: | Height: |
| Ice Salt Water | Height: | Height: | Height: |

### Density Calculation

| Type of Soda | Mass in Grams | Density in Grams/ml |
|---|---|---|
| Cola | | |
| Diet Soda | | |
| Orange | | |

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## Soda Six-Pack Calculation

| Type of Soda | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| | | | | | | |
| Height | | | | | | |
| Weight (grams) | | | | | | |