

Oh Buoy!

Description: Students design, construct, and test a device that exhibits positive, neutral, and negative buoyancy.

Learning Objectives: Students will use terminology associated with buoyancy (positive buoyancy, neutral buoyancy, negative buoyancy) to explain the relationship of buoyancy and displacement needed to make an object float.

SCIENCE TOPICS

Inquiry
Density
Volume
Buoyancy
Displacement

PROCESS SKILLS

Performing an
Investigation
Analyzing and
Presenting Data

GRADE LEVEL

4

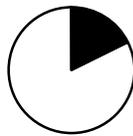
TIME REQUIRED

Advance Preparation



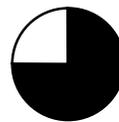
20 minutes

Set Up



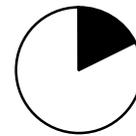
10 minutes

Activity



45 minutes

Clean Up



10 minutes

SUPPLIES

- Modeling clay (1 piece per student)
- Aluminum foil (1 10"x10" square per student)
- Plastic film canister (1 per student)
- Transparent cup (1 per student)
- Paper (1 piece per student)
- Crayons, markers, or watercolors (available for all students)
- Overhead projector & markers OR chalkboard & chalk OR chart pack & markers
- Large clear tub (small animal cage, transparent bowl, or glass pitcher) for demonstration
- Assortment of objects:
e.g., lime, lemon, apple, peach, nuts, can of diet soda, can of regular soda,

rock, pumice, balloon filled with salt, balloon filled with baking soda, tennis ball, baseball, and Ivory soap and other brands of bar soap.

- Paper towels
- *James and the Giant Peach* by Roald Dahl
- Materials to Photocopy: Science Background, Student Procedure, Masters A, B, C, and D

ADVANCE PREPARATION

- Copy Masters A, B, C, D (one per group)
- Get a peach, nectarine, lemon, and lime.
- Find an assortment of objects for testing buoyancy with (see above). Look in your refrigerator, junk drawers, math manipulatives, and the produce section of your grocery store.
- Gather **for each group of 2 students:**
 - Clay
 - Foil
 - Film canisters
 - Cups
- Fill the tub with water.
- Separate clay into equal pieces, about the size of a walnut.
- Tear off equal-sized pieces of aluminum foil.

SET UP

Set up your demonstration area so that you will be able to place objects on a copy of the masters for Positive Buoyancy, Negative Buoyancy, and Neutral Buoyancy.

INTRODUCING THE ACTIVITY

Let students speculate before offering answers to any questions. The answers at the right are provided primarily for the teacher's benefit.

Begin by reading Chapter 18 from *James and the Giant Peach* by Roald Dahl. Finish the selection with:

“But you won't have to swim,” said James calmly. “We are floating beautifully. And sooner or later a ship is bound to come along and pick us up.”

They all stared at him in amazement.

“Are you sure that we are not sinking?,” the Ladybug asked.

“Of course I'm sure,” answered James. “Go and look for yourselves.”

They all ran over to the side of the peach and peered down at the water below.

“The boy is quite right,” the old-Green-Grasshopper said. “We are floating beautifully. Now we must all sit down and keep perfectly calm. Everything will be all right in the end.”

Ask the students the following questions in **bold**. Possible student answers are shown in *italics*.

What do you think? Would you trust a peach to float in the sea?

Ask thumbs up/thumbs down.

What about a nectarine?

Place the nectarine in the water.

What does it mean to be able to float? Can you tell if something would float or sink by looking at it?

Introduce the word “buoyancy” and “positive buoyancy.” Buoyancy is how much something floats or sinks, which is caused by how much more or less dense something is than water. Objects with positive buoyancy float.

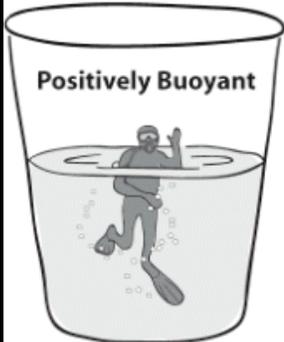
If I said the nectarine has negative buoyancy what does *that* mean?

Objects with negative buoyancy sink. Place the nectarine next to the Master “Negative Buoyancy.”

SCIENCE BACKGROUND

Background information can be found at the end of the activity. Print on a separate page for students to read after doing the activity.

Oh Buoy! Eureka!



Positively Buoyant

Why do some things sink and some things float in water? The ability of an object to float in a liquid or gas is called **buoyancy**. Whether or not something (like a piece of fruit) sinks or floats depends on the density of the object compared to the density of what it is floating in. Density is a term that describes how much of something is in a given space. For example, an elevator with 11 people in it is more dense than the same elevator with only 3 people in it. Buoyancy pushes an object up through water if the object is less dense than the water. This force pushing up on the object is called **up thrust**.

Do you know what the force is that pushes down on an object? This force is called **gravity**. If the up thrust is stronger than the pushing down of gravity, the object will

TEACHER DEMONSTRATION

Ask the students the following questions in **bold**. Possible student answers are shown in *italics*.

Next hold up a lemon and a lime.

You said that you could tell if an object is buoyant by looking at it. What do you think about this lemon? Why?

It will float. It will sink. It is smaller than a nectarine, so it will float.

What about this lime?

It will float. It will sink.

What is “Positive Buoyancy”? What is “Negative Buoyancy”?

We will place the objects next to the sign that matches their characteristics. We will classify these items by putting them into appropriate groups.

It will be easier for me to understand what you are thinking if we could have a sign for positive buoyancy and negative buoyancy.

Can someone suggest a hand signal or sign for “Positive Buoyancy”?

We make our hands into a boat shape.

OK. Let's practice our sign for Positive Buoyancy. I will hold up the paper and you make the sign.

Now we know Positive Buoyancy, who can think of a sign for Negative Buoyancy?

We could use a fist making a downward motion.

GOOD! Let's practice both of our signs.

What do you think of this can of soda? Will it have negative or positive buoyancy? Show me your vote using your signs so I know what every scientist in this room is thinking. On the can there is some information: 12 FL OZ. What does that mean?

I will ask one of you to place this can next to its classification. Next let's look at the other can of soda. It also says 12 FL OZ. Show me your prediction with our sign.

What do you think about soap?

Continue with the objects you have brought to test buoyancy. Ask the students to place them next to their classification. If the item does not sink or float, introduce the term “Neutral Buoyancy,” and practice the invented sign for the term.

When you have tested all of the assorted items (but not the peach!), or feel the need to go on, take out a ball of clay. Ask a student to test the clay by placing it in the water.

Why does the clay have negative buoyancy? Can you make the clay have positive or neutral buoyancy? This is scientific inquiry! This is what scientists do.

CLASSROOM ACTIVITY

Students should work in groups of two.

Each group will design ways to make the ball of clay have neutral or positive buoyancy. Have one person in the group fill the cup $\frac{3}{4}$ full of water. The other person should pick up materials: one ball of clay, one sheet of aluminum foil, and a film canister. Each group will

design different ways to make the clay float. Partners should discuss how the design changes the clay to positive or neutral buoyancy. Once students share their design, challenge them to think of another way.

As they work, have each student record their observations on the “Four Square” Data Collection Sheet.

After every group has recorded at least one way to modify the clay, ask students to share their inventions with the class. Analyze, compare, and contrast these ideas and then clean up.

Student Procedure: Oh Buoy

- 1** The oldest student in your group will fill the cup $\frac{3}{4}$ full of water.
- 2** The youngest student will gather materials.
 - Take one ball of clay, a piece of aluminum foil and an empty film canister.
- 3** Check to see if the ball of clay has negative buoyancy.
 - Your challenge is to design an invention to change the buoyancy of the clay.
 - You may use the materials in any ways you can think of.
- 4** Talk about your invention and show each other the sign language for the type of buoyancy the clay has now.

CLASS DISCUSSION

Ask for student observations. Let students guide the discussion and present their hypotheses before discussing explanations.

Ask the students the following questions in **bold**. Possible student answers are shown in *italics*.

What did you find out? Were you able to make the clay have positive buoyancy or neutral buoyancy? How?

Students may share that they made the clay into a boat or wrapped the clay around the film canister. Others may have put the clay into the canister and added a bit of water to make neutral buoyancy. Some may have wrapped the foil around the clay or made a boat out of the foil.

Does the shape of the clay change buoyancy? How?

Students may share that when the clay is a ball, it sinks, but when the clay was flattened into a boat, the clay had positive buoyancy. The clay has the same mass no matter what shape it is; however, the ball takes up a smaller space than the boat shape. When the clay ball is placed on the water, the ball pushes out less water than when the clay is in the boat shape. The boat shape floated because it pushed aside more water.

**Did you notice the water level changing in the cup?
What happened?**

Answers will vary.

Did some shapes take longer to sink than others?

Answers will vary.

What other experiments would you like to do?

Answers will vary.

What did this experiment make you think of?

Swimming with a life preserver or inner tube, boats on lakes and rivers, submarines.

Let's write down what you learned. We will classify your inventions under positive buoyancy, negative buoyancy, or neutral buoyancy. What are ways these objects are similar or different? Let's look at the objects we classified earlier. What ways are they similar to your inventions?

Under the Neutral Buoyancy sign, I noticed the coke has fluid in it. I made the film canister have neutral buoyancy when I put water in it.

When I changed the shape of the clay or the foil, it had negative buoyancy.

I am wondering why the lemon and lime are different. They look the same.

Let's take the wrappers off of the candy bars and see if they still have negative buoyancy.

Why are soda and diet soda different?

Answers will vary.

Finally, there is a question I want to ask you: what do you think about the peach? Would you take a chance and trust the peach to float? Do you think a peach will have positive, negative, or neutral buoyancy? Why? Did you change your mind?

**Let's research further by reading the Student Page:
Oh Buoy! Eureka!**

EXPLANATION

In-depth background information for teachers and interested students.

If you place a ball of clay in a cup of water, it will sink. The buoyant force on the object determines whether or not an object will sink or float. When you look at the clay in the cup of water, the clay displaces some of the water, and the water level goes up. If you could find the volume of the clay, you would find that its volume equals the volume of the water it displaces. **This doesn't mean that every object of the same mass as the clay would displace the same amount of water.** A marshmallow is less dense than the clay. (The reason for this is that the molecules that make up the marshmallow are not as close together as those that make up the clay. The marshmallow incorporates many small air pockets.) A marshmallow the same **size** as the clay displaces the same amount of water. A marshmallow the same **mass** as the clay would be many times larger, displacing much more water.

Density is the measurement of the mass of an object and is usually measured in grams per cubic centimeter. The density of water is one cubic centimeter. Buoyancy is a function of density.

To determine whether an object will have positive density, both mass and volume must be considered. The relative density of the object compared to that of the fluid is what determines the buoyant force. If the object is less dense than the water it displaces, it has positive buoyancy and will float. If the object is more dense than the water, it will have negative buoyancy and will sink.

It was Archimedes (in his bathtub) that realized that objects in the water displaced their exact volume of water. He realized that a solid object will sink in a fluid if its density is greater than the fluid's density and will float if its density is smaller. (Eureka means "I have found it" in Greek.)

How do life jackets hold you up? A life jacket, or Personal Floatation Device (PFD), has different buoyancy ratings according to how many pounds it can hold up. If a person weighs 200 lbs. on earth, water will typically push up on them with 190 lbs. of buoyancy. A PFD that has 22 lbs of buoyancy can keep most people afloat.

Diet soda floats while regular soda sinks because they have different densities. Diet soda has no sugar in it. Regular soda has so much sugar dissolved in the liquid that it weighs more than water and doesn't float.

OPTIONAL EXTENSIONS

Extension A—Raisins and Soda

Drop raisins in any type of clear carbonated soda. At first the raisins will have positive buoyancy, then negative, then positive again. Have students experiment with various objects at home—perhaps in a tub like Archimedes!

Extension B—Pumice

A volcanic rock, pumice has many spaces for air and has positive buoyancy. Show a piece of pumice floating on water. Have students research how pumice is formed.

Extension C—Cartesian Divers

Have students make Cartesian Divers. Each student needs:

- 1 soda bottle with lid
- 1 eyedropper
- 1 plastic cup
- Water

First each student needs to make the eyedropper very slightly positively buoyant. The eyedropper should be mostly full of water, with a small air bubble at the top. When the dropper is put in a cup full of water, it should just barely float, coming to the surface but not bobbing above the surface.

Then, the soda bottle should be filled to the very top with water and the eyedropper placed inside. Finally, screw the lid on.

When you squeeze the sides of the plastic soda bottle, what happens?

The eyedropper sinks.

What happens when you release the sides?

The eyedropper rises.

The eyedropper rises and falls when you squeeze because its density changes. As you squeeze the bottle, the air bubble inside the eyedropper is squeezed, and it shrinks. The smaller air bubble displaces less water, so there is less buoyant force pushing up on it.

(If eyedroppers are hard to come by, soy sauce packets will work as well. To test if a soy sauce packet has the right buoyancy, just drop it in a glass of water.)

Extension D—Density Column

Make a density column in a graduated cylinder. Pour liquids of different densities slowly into the cylinder and add objects between layers that float on one liquid but not in the next. Liquids include corn syrup, water, vegetable oil, and rubbing alcohol. Objects might include a coin, a piece of plastic, and a cork. You can add colors to the liquids for extra effect.

You can even gently mix salty water with fresh water and float a golf ball on the salt water. Temperature also affects water's density.

Extension E—Fish

Have students research how fish change their buoyancy. (The swim bladder in a fish controls the fish's buoyancy. When a fish becomes positively buoyant, gases leave the swim bladder and go into the blood. If the fish becomes negatively buoyant, air enters the swim bladder.)

Extension F—Scuba divers and submarines

Have students research how divers and submarines control their buoyancy.

Extension G—Do the OMSI activity about density: “Big Things come in Little Packages” from Experiencing Chemistry.

CROSS-CURRICULAR CONNECTIONS

SUBJECT	Activity
LANGUAGE ARTS	It was Archimedes (in his bathtub) who realized that an object will sink in a fluid if its density is greater than that of the liquid. Read <i>Mr. Archimedes' Bath</i> by Pamela Allen (Picture Puffin, 1997) and research more about Archimedes. Write and act out a play—“Eureka!”
MATH	Students determine the volume of water displaced by different objects.

MUSIC

Sing to the tune "Row, Row, Row Your Boat:"

*Row, row, row your boat
Take on a camel with a hump
Now your boat has negative buoyancy
You had better jump!*

*Row, row, row your boat
Design a fish ladder
Neutral buoyancy is half water
Dead fish would make you sadder.*

*Row, row, row your boat
You have sprung a leak
Make sure to wear your life preserver
Positive buoyancy is not weak.*

Next, make up a rap about buoyancy.

HOME ECONOMICS

A whole peach is usually just barely positively buoyant. Canned peaches are negatively buoyant. Have students preserve fruit and research the chemical changes that take place in canning. Have students explore why canning changes the density of the fruit.

RESOURCES

Movie: Bill Nye the Science Guy: Buoyancy, 1994

The concept of buoyancy is taught by Nye and accompanied by visuals such as hot air balloon rides, boats, surfboards, and children tossed in pools.

<http://www.engineering.usu.edu/jrestate/workshops/buoyancy/boats.html>

Directions on how to build a foil boat.

<http://www.dctech.com/eureka/coloring/>

You can print out this book about Archimedes on paper and paint or color on it, or you can save it on your computer and color it in with a graphics program.

Mr. Archimedes' Bath

Allen, Pamela (Picture Puffin, 1997)

Paddle to the Sea

Holling, Clancey (Houghton Mifflin Co., Boston, 1969)

Sink or Swim!: The Science of Water

Taylor, Barbara (Random House Books for Young Readers, 1991)

A Drop of Water: A book of Science and Wonder

Wick, Walter (Scholastic, 1997)

In this science picture book there are photographs of drops, splashes, bubbles, snowflakes, and spiders' webs with a simple text about molecules, surface tension, water vapor, ice, and the water cycle.

GLOSSARY

Archimedes's

principle: The buoyant force is equal to the weight of the displaced fluid.

Buoyancy: How much a fluid pushes up on a submerged object. Whether or not an object floats or sinks is based on not only its mass but also on its volume (i.e., the amount of water it displaces). An object will sink if its mass is greater than the buoyant force.

Density: The ratio of mass to volume of an object. Wood is more dense than Styrofoam because the same volume of wood weighs more—it has more mass in the same amount of space.

Gravity: Force that tends to draw all bodies in the Earth's sphere toward the center of the Earth.

Mass: The amount of stuff that is in an object. The more massive something is, the harder it is to move it.

Negative

buoyancy: An object that weighs more than the amount of water it displaces will sink because it has negative buoyancy. The force of the water pushing up is less than the force of gravity pulling down.

Neutral

buoyancy: An object that weighs the same as the amount of water it displaces will be in the middle of the water because it has neutral buoyancy. The force of the water pushing up is the same as the force of gravity pulling down.

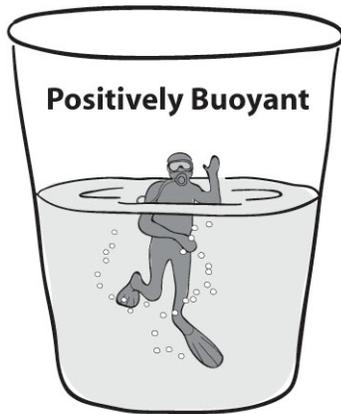
Positive

buoyancy: An object that weighs less than the amount of water it displaces will float because it has positive buoyancy. The force of the water pushing up is greater than the force of gravity pulling down.

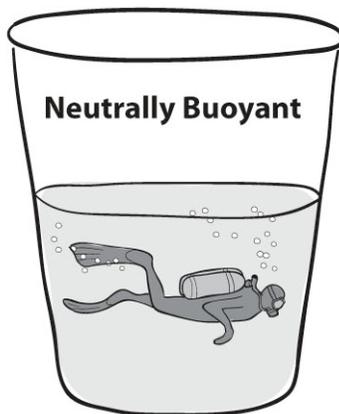
Volume: The space an object takes up.

Weight: How much gravity pulls on an object; how heavy it feels. The more mass an object has, the more weight it will have.

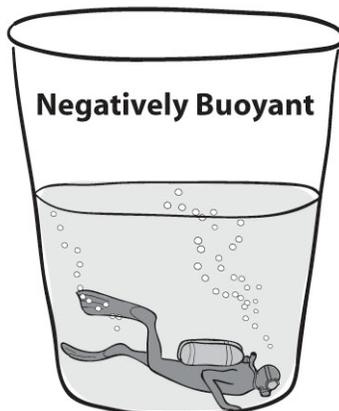
Oh Buoy! Eureka!



Why do some things sink and some things float in water? The ability of an object to float in a liquid or gas is called **buoyancy**. Whether or not something (like a piece of fruit) sinks or floats depends on the density of the object compared to the density of what it is floating in. **Density** is a term that describes how much of something is in a given space. For example, an elevator with 11 people in it is more dense than the same elevator with only 3 people in it. Buoyancy pushes an object up through water if the object is less dense than the water. This force pushing up on the object is called **upthrust**.



Do you know what the force is that pushes down on an object? This force is called **gravity**. If the upthrust is stronger than the pushing down of gravity, the object will float to the surface or have **positive buoyancy**. If the two forces, upthrust and gravity, are equal, the object will stay in the middle of the water. This is called **neutral buoyancy**. When an object is more dense than water, the object will sink or have **negative buoyancy**.



Archimedes, the Greek scientist who lived more than 2000 years ago, made a famous discovery. While Archimedes was taking a bath, he observed that the upward or buoyant force on his body was equal to the mass of the water that spilled out of the bathtub. He yelled "Eureka!" because he was so excited that he figured this out.

How do you know if the density of one object is more or less than another one? You can't always tell by looking at it. You can't tell by the size, either. If you have a ball of clay and a marshmallow the same size, which one will float? The marshmallow will float because it is less dense than water. The clay will sink because it is more dense than water. Let's compare this to the elevator. The size of the ball works the same way as the box of an elevator. There is more clay in the ball than marshmallows since marshmallows are full of air. Because there is not a lot of air in clay, the clay must pack together tightly to fill the same space. This makes it more dense. Objects that have lower densities than water will float, while objects that have higher densities than water will sink.

Why does clay that is shaped into a ball sink while the same amount of clay made into a boat floats? A clay ball is more dense than water, but when you take the ball of clay and flatten it into the shape of a boat, you make the clay take up more space. An object's density is also determined by the size, or volume, of the object. If the same amount of stuff takes up more space, it has a larger volume and is less dense. A clay ball will sink but if you take the same clay ball and flatten it out, it will float.

Buoyancy is also what allows large boats to float. Although a boat carrying lots of heavy items has a lot of mass, the large surface area and the air in it allows it to float. The buoyant force is stronger than the force of gravity.



Submarines can have positive and negative buoyancy. They have negative buoyancy when the submarine fills its hulls with water. Can you guess what makes a submarine have positive buoyancy? Air!

All objects obey this principle of buoyancy. Clouds float in air and ships float on the sea. Rivers carry big boulders and fish swim in water. Icebergs float with only one-ninth of their volume above water and logs float on water. Submarines can remain underwater and Earth's great continental slabs or plates move on the Earth's crust. Eureka! You too, have now observed the principle of buoyancy!

Student Procedure:

Oh Buoy

- 1** The oldest student in your group will fill the cup $\frac{3}{4}$ full of water.
- 2** The youngest student will gather materials.
 - Take one ball of clay, a piece of aluminum foil, and an empty film canister.
- 3** Check to see if the ball of clay has negative buoyancy.
 - Your challenge is to design an invention to change the buoyancy of the clay.
 - You may use the materials in any way you can think of.
- 4** Talk about your invention and show each other the sign for the type of buoyancy the clay has at different stages.
- 5** Now, think of another invention!
- 6** Keep trying and sharing with each other until your teacher asks you to clean up.
- 7** Record the buoyancy, draw a picture, think of four descriptive words, and write a description of what you found on the “Four Square Data Collection” so that you will be ready to share with your fellow scientists.

Name of Scientist: _____ Date: _____

Oh Buoy!

Four Square Data Collection

Positive Buoyancy, Negative Buoyancy, or Neutral Buoyancy?	A Drawing of Your Invention:
Four Descriptive Words:	A Short Sentence about the Invention:

Negative Buoyancy

Positive Buoyancy

Neutral Buoyancy