Session 6
Rising and Sinking

Why does a hot air balloon rise into the sky? Why does ice rise in water when a lump of solid wax will sink in a jar full of melted wax? In this session, we'll generalize the model we've developed about what rises and what sinks, using the idea of balance of forces.

The Video

We begin this session by continuing to connect the ideas of buoyant force, pressure, and density. Hot air balloons provide a wonderful example of a fluid rising in a fluid, but why does the air have to be "hot"?

We revisit the Science Studio swimming pool where children are comparing the weight of objects in and out of the water. What principle might account for the consistent weight differences that they are measuring? "Archimedes's principle" is the standard answer often given, but what does this really mean? Our hosts introduce a model called the "watery ghost" to help us understand this idea.

We then look more closely at the "special case" of floating and hear from yacht designer, Halsey Herreshoff, who shows us that boat builders take the balance of forces into account when determining the size and shape of their designs.

We visit the Young Achievers Science and Mathematics Pilot School in Boston, Massachusetts, where Monique Brinson's third graders try their hands at designing reliable "sinkers" out of aluminum foil and clay. Then back in the Science Studio, a fourth grader compares the ability of two liquids of different densities to "hold up" different-sized pieces of a wax candle.

Joe Reilly's first graders at the Lincoln School in Brookline, Massachusetts, get us thinking about objects "floating" in air with a parachute-making activity that segues nicely back to the Science Studio, where we ask a third grader to account for why some balloons rise and others sink.

The session ends with a look at how the shape of water molecules accounts for the geometry of snowflakes and for the "water anomaly" that allows ice to float in water (while other solids sink in their own liquid state).

Learning Goals

During this session, you will have an opportunity to build understandings of the following concepts:

- The volume of fluid displaced is equal to the volume of the immersed object.
- Archimedes's principle states that the buoyant force on an object is equal to the weight of fluid displaced.
- Rising or sinking depends on the outcome of the battle between two forces: weight and buoyant force.
- Water is an "anomaly" because the shape and arrangement of its molecules make it less dense in its solid form than in its liquid form.

On-Site Activities

Getting Ready (60 minutes)

Activity One—Problem Set and Reading Discussion (40 minutes)

1. With a partner, review the answers from the problem set for Session 5.
2. To prepare for this session, you were asked to think about whether large objects that you encounter in daily life would float or sink if they were placed in a lake. With the whole group, discuss and compare your objects and predictions.
3. With the whole group, review the definitions of density, force, and pressure given in Session 5. Discuss how these definitions informed your particle model concept map for this session.
4. Discuss the Duschl and Gitomer article in the whole group. What does their research say about the "causal link" that explains why a vessel with higher sides or a larger bottom is able to carry more load? Also discuss your thoughts about the "portfolio-based" assessment that was part of the research.

Activity Two—Archimedes's Principle (20 minutes)

1. Archimedes's principle states that the buoyant force on an object is equal to the weight of the fluid displaced. Working alone, think about how your current understanding of the concepts of density and pressure relates to this principle?
2. Explain to your partner why large, steel ships are able to float.

Watch the Video (60 minutes)

As you watch the video, think about the following focus questions:

1. What is the relationship between weight, volume, density, and buoyancy?
2. In the Science Studio, Sara Nia is presented with balloons that either rise or sink, depending on what's in and around them. What are other everyday experiences in which fluids either rise or sink in other fluids?
3. How would you address Monique Brinson's students' ideas about the role of air in rising and sinking?

Going Further (60 minutes)

Facilitators: You will need the following materials for this activity:

- gram scales
- graduated cylinders or beakers with volume markings, filled with enough water so that each group's object can be submerged and no water will overflow
- a variety of small objects:
  - film canisters filled to different levels with ball bearings, marbles, or pennies
  - a golf ball and a solid rubber ball
  - a small pencil
  - dice (different sizes) or other solid game board pieces
  - action figures (not the hollow kind)

On-Site Activities, cont'd.

Predetermine the volume of the objects by submerging them in the graduated cylinder (or beaker) half-filled with water and take the difference of the volume reading before and after. Distribute the cylinders or beakers, gram scales, and the objects, giving half the groups a riser and half a sinker.

1. Working in small groups, try the following experiment:

   a. Without doing any calculations, predict whether the object you've been given will sink or rise when submerged in water.

   b. Weigh and record the mass of your group's object.

   c. Review the concept of the "watery ghost" and then determine the mass of the watery ghost of your object. (Hint: You need the volume of the watery ghost and the density of water.)

   d. Comparing your measurements with the rising and sinking behavior of your objects, check your original prediction of whether the object will rise or sink. (Hint: Which has more mass: the object or its watery ghost?)

   e. Determine the density of your group's object and use this information (along with the density of water = 1 gram per cubic centimeter) to check your prediction in another way.

   f. Test whether your object rises or sinks. Were you correct? Which method did you prefer?

Facilitators: Have these additional materials available:

- Epsom salts
- Food coloring
- Rubbing alcohol (Isopropyl)
- Extra marbles
- Pieces of cork
- Candle

2. Working with a partner, try this experiment:

   a. Measure out 50 milliliter volumes of the following liquids, then add a different food coloring to each one:

      - An Epsom salt solution (1 tablespoon of Epsom salts in 50 milliliters of water)
      - Tap water
      - Rubbing alcohol (Isopropyl)

   b. Take the graduated cylinder provided by the facilitator and pour in first the Epsom salt solution, then the tap water, and finally the alcohol. What do you notice?

   c. Based on what you now know about density and rising and sinking, predict and record what you think will happen when you drop a cork, a marble, and a piece of candle into the cylinder. What is providing the buoyant force in each case? Is there always a buoyant force?

   d. Now drop the three objects into the column. Discuss with your partner whether you were correct or incorrect in your prediction and why.

Between Sessions

Homework (* = required)

Reading Assignment*

"Heating: The Teacher's View." *Children's Learning in Science Research Group at the University of Leeds* (1992) Reprinted from the Leeds National Curriculum Science Support Project Part 4, Leeds City Council/University of Leeds.

As you read, think about how the relationship between heat and temperature described in this article compares to what you have thought about these topics in the past.

* Physical Science Problem Set

(Suggested answers are listed in the Appendix.)

1. Restate Archimedes's Principle in your own words. What role does density play?
2. What is a "watery ghost" and how does it relate to Archimedes's Principle?
3. a. Imagine you have a wooden ring that is 50 cubic centimeters in volume and 42 grams in mass. What would be the mass of the "watery ghost" of this ring? (Recall the density of water at room temperature is about 1 gram/cubic centimeter.)

   b. If we put the ring on the left side of a balance scale and its watery ghost on the right side, which side of the balance would go down? Does this mean the ring will rise or sink when submerged in water?

   c. Would you agree or disagree with the statement below? Why?

   > "If rising happens when the weight of an object (downward) is less than the buoyant force (upward), and the buoyant force is equal to the weight of the watery ghost, a smaller ring would float because its weight would be less."
4. Why is it surprising that the solid form of water (ice) floats in liquid water?
5. We know that a helium balloon rises on Earth because the buoyant force from the air around it is greater than its weight. Similarly, an air-filled balloon sinks because the buoyant force is less than the balloon's weight. How might the behavior of these balloons change if we were able to get a container full of atmosphere from Mars, which is much less dense than Earth's atmosphere, and put the balloons inside it? What if we did the same with a container filled with the atmosphere of Venus, which is much more dense than Earth's atmosphere?

* Ongoing Concept Mapping

Develop a concept map that describes the microscopic picture of rising and sinking in fluids. Try to include the following concepts:

- Buoyant force
- Weight
- Floating
- Fluids
- Archimedes's Principle
- Density
- Water anomaly
- Fluid pressure
- Volume
- Average density
- Particles

Between Sessions, cont'd.

Guided Journal Entry

Think about how the "watery ghost" provides an alternative way to think about rising and sinking rather than simply applying the rule that "an object sinks if it is more dense than the surrounding fluid, and an object rises if it is less dense than the surrounding fluid." Does it help you to visualize the battle between buoyant force and weight as the ultimate reason for rising and sinking?

Guided Channel-TalkPhysicalSci Posting

Although we introduced the idea of the "watery ghost" to help adults understand the connection between density, buoyancy, and rising/sinking, to what extent could this idea be used in your classroom? Design an activity with the goal of getting your students to understand that rising/sinking behavior depends on both the object *and* the fluid in which it is placed (e.g., a wax candle floats in water but sinks in alcohol). Try to adapt the concept of the "watery ghost" to your students' grade level.

Textbook Reading Suggestions

The following are suggestions for several reading topics that may provide additional background and enrichment information. These topics are likely to be addressed in any college-level physics or chemistry textbook.

- Buoyant force
- Weight
- Fluids
- Archimedes's Principle
- Density
- Floating
- Volume
- Average density

* Preparing for the Next Session

For "Getting Ready"

Before the next session, write down times when you remember feeling hot or cold. What is the same or different about these instances, i.e., do you always feel heat or cold with your hands? Are you always outside? People often talk about heat "flowing." What is "flowing" in each situation, and what is it "flowing" from?

Materials Needed for Next Time

- Hot plate
- Same-sized wooden and aluminum blocks (or spoons)
- Tea kettle or large beaker
- Cups or mugs
- Ice cubes (bring in a cooler)

Graduate Credit Activities

Continue your work on the annotated bibliography and action research project.

Notes