Session 5

Density and Pressure

What makes a block of wood rise to the surface of a bucket of water? Why do your ears "pop" if you swim deep underwater? In this session, we will examine density, an essential property of matter. We will also look at how particles of matter are in constant motion, leading to a deeper understanding of fluid pressure. Finally, we will investigate the concepts of pressure and density to explain the macroscopic phenomenon of rising and sinking.

The Video

Session 5 begins with a question about how hard one needs to push a beach ball to get it to go to various depths in a swimming pool. Does the force required vary? We then observe children in the Science Studio expressing their ideas about the factors that determine whether an object sinks or floats in water. As they eliminate weight and shape, they start to ask what other property might reliably account for whether something sinks or floats.

We begin to explore the concept of density, what it looks like on the particle level, and what effect it has on whether something floats or sinks in a fluid. How does density fit into Aristotle's accidental and essential properties?

Next, Steve Bailey at the New England Aquarium explains how some fish are able to adjust their density to maintain the neutral buoyancy they need when they aren't swimming. To see how the concept of density might be addressed in an elementary level classroom, we look in on researcher and teacher Tina Grotzer as she introduces the Understandings of Consequence/Project Zero's Causal Patterns in Density curriculum to Nicole Scalzo's class in Arlington, Massachusetts. The students share their microscopic models, showing the difference between brass and aluminum cylinders that have an equal volume. Their prior ideas about density provide a springboard for further discussion.

We end the session in a swimming pool, where we take an "in-depth" look at fluid pressure through the eyes of our Science Studio children, and return to the questions posed at the outset of the program to find some surprising answers.

Learning Goals

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

- Rising and sinking are dependent on one essential property—density.
- The density of an object can be explained by the arrangement and weight of its particles.
- Pressure in a fluid acts in all directions, increases with depth, and can be explained by the motion of particles.

On-Site Activities

Getting Ready (60 minutes)

Activity One—Problem Set and Reading Discussion (20 minutes)

1. In a small group, review the answers from the problem set for Session 4.
2. Choose a partner. Review and discuss each other's conservation of matter and chemical changes concept maps. Were you able to connect this map with the map that included physical changes in Session 3?
3. To prepare for this session, you were asked to estimate the volume of objects that you encounter in daily life. With the whole group, discuss your objects and estimates.
4. With the whole group, discuss the article by Raghavan et al. What does their research suggest about the challenges that elementary students face in understanding forces in fluids?

Activity Two—Determining Density (20 minutes)

1. With a partner, discuss the density differences among various solids and liquids that you are familiar with. What is the most dense solid you can think of? The most dense liquid? Draw what they would look like under a microscope.
2. If you were given the task of measuring the density and volume of a) the moon and b) a grain of sand, how would you go about it? Try to come up with at least two methods for each.

Activity Three—Rise or Sink? (20 minutes)

Facilitators: Distribute two beakers, one large piece of candle, and one small piece of candle to each group.

1. Working with your partner, try the following experiment:
   a. Take two identical beakers, glasses, or clear plastic cups, and pour the same amounts of water into one and alcohol into the other.
   b. Take the large piece of wax candle, hold it halfway down in the cup of water, and then let it go. Observe what happens.
   c. Take the small piece of candle, and write down your prediction of what will happen if you submerge it and then let go in the cup of water. Then hold it halfway down in the water, let go, and observe what happens.
   d. Take the large piece of candle again and record your prediction (and rationale) of what will happen if you submerge it in the alcohol. Try it and observe what happens.
   e. Based on the result, what do you think will happen with the small piece of candle in alcohol? Discuss the similarities and differences between these experiments.
2. As a whole group, try to explain the "causality" of what happens to the candle in the water and in the alcohol.

Watch the Video (60 minutes)

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

1. What is the definition of density and how is it measured?

2. Think about how you could refine the particle model we've developed up to this point to help the students in the Science Studio better understand density and pressure.
3. While you watch Tina Grotzer's lesson with the fifth graders in Arlington, Massachusetts, pay particular attention to their prior ideas about and analogies for density. Do any of the models they draw surprise you?

Going Further (60 minutes)

1. Session 5 makes a point of distinguishing between rising and floating. With a partner, discuss your understanding of the difference. How would you make this difference clear to your students? Which extensive property of an object might make it float, but not rise?
2. With the whole group, discuss how the models you drew of density in Getting Ready Activity 2 above compare to the ones that the students in Tina Grotzer's classroom drew? How did you and/or the students illustrate these two most important features of our model of density?
   - Space between the particles
   - Mass of the particles

   What aspects could you reasonably expect your students to include? Discuss your answer and illustrations in a small group.

   Facilitators: Distribute a gram scale to each pair.
3. With a partner, continue the investigation you began in Getting Ready Activity 3.
   a. Try to reinterpret your predictions and results in light of what you've learned in this session about the relationship between density and rising and sinking.
   b. Calculate the density of the large and small piece of candle. (Hint: find the mass with the scale, and the volume with the markings on the beaker, or graduated cylinder of water.)
   c. Calculate the density of the water in your first beaker.
   d. Write down your prediction of the mass of the same volume of alcohol. Now find the mass of the alcohol and calculate its density. How close was your estimate?
   e. Could you have reliably predicted the results of your original experiment with only measurements of density?

   Facilitators: Distribute a balloon, a glass, and a rubber band to each group. Make available a large clear tank of water for submersing the glasses.
4. With a partner, cut a balloon open and stretch a single layer of rubber across the top of a glass, securing it with a rubber band.
   a. Place the glass upside down (rubber side down) under water and observe what happens to the rubber diaphragm as you bring the glass to different depths.
   b. At one depth, rotate the glass so that the diaphragm faces each side of the tank and then faces upward. Observe what happens to the rubber diaphragm.
   c. What is the microscopic explanation for these phenomena? How does it demonstrate the point made in the video, namely, that pressure increases with depth and that pressure acts in all directions? Discuss your findings with your partner.

Between Sessions

Homework (* = required)

* Reading Assignment

Duschl, R. A., and Gitomer, D. W. (1993). "Diagnosing students' conceptions using portfolio teaching strategies: The case of flotation and buoyancy." *Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics.* J. Novak. Ithaca, New York, Cornell University.

As you read, reflect on what the authors say about the "causal link" that explains why a vessel with higher sides or a larger bottom is able to carry more load.

* Physical Science Problem Set

(Suggested answers are listed in the Appendix.)

1. As official crown inspector for the kingdom of Kerplackistan, you are asked to determine if R. Fink, the king's new crown maker, really used the 500 grams of gold given to him to craft a crown for the king. When you receive the crown, it does indeed have a mass of 500 grams, but you suspect R. Fink of mixing lead with the gold. You measure the volume of the crown by immersing it in water and find it to be around 33 cubic centimeters, and you know that the density of gold is 19.3 grams/cubic centimeter. Did R. Fink cheat the king by mixing his gold with lead?
2. In the video, Steve Bailey explains how some fish use a swim bladder to change their behavior from sinking to rising. When they do this, are they changing mostly their mass or volume? How does a submarine change its behavior from sinking to rising? Does it change its mass or its volume?
3. How would you explain the reason why it takes the same amount of force to hold an object under the water at any depth?

* Ongoing Concept Mapping

Develop a concept map around the idea of how the particle model explains both density and pressure. Be sure to include the following:

- Particles
- Density
- Intrinsic property
- Rising
- Mass
- Pressure
- Collisions
- Sinking
- Volume
- Depth
- Force
- Buoyant force

Guided Journal Entry

Reflect on your understanding of the following pairs of concepts:

- Rising and sinking (as opposed to floating and sinking)
- Density and mass
- Force and pressure

What ideas did you hold before viewing this session? Were you confused about which of these terms you should be using in a particular classroom situation? How have your ideas changed? Do you feel comfortable enough with your understanding to try and explain the differences to your class?

Between Sessions, cont'd.

Guided Channel-TalkPhysicalSci Posting

The video in this session started with children sharing their ideas about which properties can affect whether an object sinks or floats in water. Design an activity in which your students can explore one or several of the following attributes and arrive at the idea that density alone determines whether something rises or sinks:

- Size
- Weight
- Color
- Material (sometimes a good proxy for density with younger children)
- Density
- Shape (holes or not, flat versus round)
- Texture

Could you use this same activity to introduce the concept of density?

Think about how you would follow up Tina Grotzer's density lesson with the fifth graders in Arlington, Massachusetts, to connect the concept of density to the reasons why objects rise or sink in fluids. Make a list of "bridging" activities that you think would work for your students. Discuss your ideas on Channel-Talk.

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 textbook, and can usually be located in some form in the table of contents and/or index.

- Density
- Hydrostatics (liquid pressure)
- Pressure and force
- Buoyancy

* Preparing for the Next Session

For "Getting Ready"

Before the next session, think about whether objects that you encounter every day—cars, trees, rocks, desks, couches, etc.—would rise or sink if you threw them into a lake. (You could even estimate their density and check your answers.) What could you do to make the "risers" sink or the "sinkers" rise? Bring your ideas to the next session.

Between Sessions, cont'd.

Materials Needed for Next Time

- Gram scales
- Graduated cylinders or beakers with volume markings
- Rubbing alcohol (Isopropyl)
- Handful of film canisters
- Handful of small, different-volume objects, e.g., small ball bearings, marbles, golf balls, solid rubber ball, small pencil, dice (different sizes) or other solid game board pieces, action figures (not the hollow kind)
- Pennies
- Extra marbles
- Pieces of cork
- Pieces of wax candle
- Several graduated cylinders or narrow vases
- Epsom salts
- Several different colors of food coloring

Graduate Credit Activities

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