Floating and Sinking Activity 3.

- Objectives: (1) To explore how the density of a material doesn't change with the size of the material and (2) to explore how density of the object, compared to the solution's density, determines floating and sinking
- Material and Setup: Each group should be given three rectangular slabs of the same material but of different sizes. But the material should be different from one group to the next so that some groups will have all floating objects (like wood) or all sinking objects (like a solid dense plastic). Rulers are needed to measure volume and mass balances to measure mass.

- Student Instruction: Students were asked to predict which of the three slabs would float or sink. They were asked to record their predictions in a journal. Before actually testing the prediction, students were asked to calculate the density of the rectangular slabs and compare them to water.
- Instructor Note: Our goal was to tease out the misconception that size matters (which was a student suggestion in Activity 1). Students tested their prediction by placing their slabs into a tub of water. Then, students took appropriate measurements to calculate the density of water and the density of each of their slabs so that they could (1) compare slab density to water density (for the floating and sinking) and (2) verify that the density of each slab is the same. The material density calculations were facilitated because the slabs were rectangular and thus, it was easy to find the volume using length, width, and height.
- Results: We asked the students to report on the board the density of all of their slabs and report if they floated or sank. This makes an easy comparison to help students recognize that objects denser than water sank.
- Discussion/Conclusion: Using the results from all the groups, we can conclude that an object that is denser than water will sink. We tied the results of this activity back to our first floating/sinking activity by asking them why the pencil, the toothpick, and the Popsicle stick all floated.
  - Follow-up questions:
    - Two objects made of the same material and same mass have different shapes. How do their densities compare? How do their volumes compare?
    - Compare the density of 10 g of glass to 20 g of glass

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Floating and Sinking Activity 4.

- Objective: To explore how solution composition affects water density and to explore how floating and sinking properties depend on both object and solution densities.
- Material and Setup: Each group is given one film canister, a 400 mL beaker filled with saturated salt water, and 50 pennies.

- Student Instructions: Students were told that the density of the saturated salt solution was 1.2 g/mL. [Alternatively, students could discover this themselves, by measuring the mass and volume of this salt solution, using a graduated cylinder and balance.] They were also given the average mass of a film canister with lid (5.9 g), the average volume of a film canister (42 mL), and the average mass of one penny (2.8g). [Again, students might be challenged to measure each of these quantities themselves.] With this information, they were asked to predict the minimum number of pennies to sink their canister in the saturated salt water. Once they publicly shared their predictions, they tested their predictions. They were asked to record their testing strategies, predictions, observations, and conclusions in a journal.
- Instructor Note: You should make the saturated salt water solution at least a day before class because salt is slow to dissolve. During the activity, we monitored student progress and offered advice on how to set up the calculations necessary to make their predictions. Some students' misconceptions include (1) trying to include the volume of the pennies in their calculation and (2) trying to use the density of pennies in their calculation.
- Results: For the canister to sink, the object density must be greater than the solution density. With some guidance, students will eventually develop the following mathematical equation: Object Density > Salt Water Density [i.e. $(m_{canister} + X\ m_{pennies})/V_{canister} > 1.2 g/ml$]. Here, X is the number of pennies and students then solve for X. Using our average numbers given above, X is 16 pennies. If your students do not have the algebraic skills to get an exact prediction, you can have them predict whether it would take more or less pennies to sink the canister in salt water compared to fresh water.
- Discussion/Conclusion: During the discussion we highlighted the fact that the density of salt water was greater than the density of fresh water. Because salt water has a greater density, the object density must be larger to sink in salt water compared to in fresh water.
  - A follow-up question: Ask students why they feel like they float better in the ocean compared to in freshwater lakes. Here we were looking for them to say

that the object density (their bodies) hasn't changed but the solution density (the ocean water versus fresh water) has changed. The ocean water has more salt so its density is greater compared to fresh water.

- Students can be asked to predict which of the plastic solids in Activity 3 would float in salt water. Some of the objects which previously sank in tap water will float in salt water (if their density is between 1.0 and 1.2 g/mL). Students can then test their prediction.

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Activity for Exploring Archimedes' Principle

- Objective: Explore the relationship between the mass of a floating object and the mass of the displaced water
- Material and Setup: Each group was given one film canister, string, some washers (roughly 5 g each about the size of a quarter), a mass balance, and a 500 ml graduated cylinder with markings every 5 ml. The string is to be attached to the canister to gently transport the canister in and out of the narrow graduated cylinder. This will make it easy for students to add or remove washers. Washers were used because each was 5 grams. Thus adding one washer displaced an easily measurable 5 ml of tap water. Alternatively, about 2 pennies have an equivalent mass of one washer.

- Student Instruction: After discussing the fact that a heavier object, which still floats, sinks further into the water as compared to a lighter object, we instructed the students to determine what relevant measurements they could take to explore this phenomenon (such as water level *rise* and mass of canister plus contents). Then, from their measurements, see if they can identify a pattern of this phenomenon. They were asked to record their testing strategies, predictions, observations, and conclusions in a journal.
- Instructor Note: Archimedes' Principle, $F_{bouyant} = gd_{liquid}V_{displaced}$, relates the buoyant force on an object to the volume of the object that is under the water (often called the “displaced water”), and it is equally applied to objects that float and sink. The g is the gravitational acceleration near the Earth’s surface, 9.8 m/s^2 and d_{liquid} is the liquid density. For this activity, we focused solely on floating objects because when the object is in equilibrium, Newton’s Second Law suggests that the weight force must equal the buoyant force, $F_{bouyant} = m_{object}g$. Archimedes’ Principle combined with Newton’s Second Law gives that $m_{object}g = gd_{liquid}V_{displaced}$, which can be simplified, by dividing both sides by g, to get: $m_{object} = d_{liquid}V_{displaced}$. To interpret the results of this activity, students created a graph, drew “best fit” lines to their data, and calculated the slope of this line. They discovered that the slope equals the

density of the liquid. Building on their knowledge of density, they were able to demonstrate that the mass of the displaced liquid (which is $d_{liquid}V_{displaced}$) equals the mass of the floating object. This concept is very easily confused with regular density because the equation is almost identical: m = dV. But, for density, *m* represents the object's mass, *V* represents the object's volume, and *d* represents the object's density. For Archimedes' principle, the *m* represents the object's mass, *d* represents the liquid's density, and *V* represents the volume of the object under water. The equations look so similar because of the theoretical underpinning of Archimedes' principle. Also, Archimedes' Principle applies even to objects that sink, but this activity does not explore that situation.

- Results: Since the density of tap water is roughly 1.0 g/ml and we used 5 g washers, then the water level will rise about 5 ml for every washer added. In the graduated cylinders that we used, 5 ml is measurable.
- Discussion/Conclusion: Each group puts its results on the board and we held a class discussion. Archimedes' Principle for floating objects is somewhat transparent from these results: The mass of the canister + washers equals the mass of the displaced water.
    - A follow-up question: Ask students how much water would be displaced if you placed a canister with 10 pennies into a saturated salt water solution (1.2 g/ml).