

## Density, The Ubiquitous Concept: Part 2

Our last e-mail left you with a question:

*How does the volume of water displaced by a chunk of Play-Doh compare with the volume of water displaced by a chunk of Play-Doh of the same mass formed into a boat shape?*

The answer is:

*The boat-shaped object displaces more water. It takes up more space in the water than a Play-Doh chunk does.*

But simply knowing the answer does not mean understanding the ideas that lead to the answer. Today's e-mail considers some of those ideas and gives you the opportunity to think about water displacement as a method of measuring the volume. We will also look at all the *different* volumes of the boat-shaped object.

### Comparing and Measuring Volume by Water Displacement

Make three spheres of Play-Doh of different diameter and different color and drop them in the water.



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Questions:

**a. How do the volumes compare?**

Visual inspection suggests that the volume of the yellow sphere is greater than the volume of the blue sphere which is greater than the volume of the red sphere.

This statement represented symbolically:  $V_Y > V_B > V_R$

**b. Which sphere will displace the greatest volume of water?**

Reasoning suggests that the yellow sphere will displace the most water. It has the greatest volume, so, when sunk, it will take up the most space, moving the water up and out of the way.

**c. Which sphere will displace the least volume of water?**

Reasoning suggests that the red sphere will displace the least amount of water. It has the smallest volume, so, when sunk, it will take up the least space.

**d. How does the volume of water displaced by each sphere compare?**

Reasoning suggests that the volume of water displaced by the yellow sphere is greater than the water displaced by the blue sphere, which is greater than the volume of the red sphere.

This statement represented symbolically:  $V_{\text{water}Y} > V_{\text{water}B} > V_{\text{water}R}$

**The principle (big idea) is that an object immersed (completely covered by a liquid) displaces a volume of the liquid equal to its volume.**



We have just **compared** the volume of objects, determining which was greater or less. But we can also **quantify** the volume of an object by **measuring** it. This can be done using a graduated cylinder.

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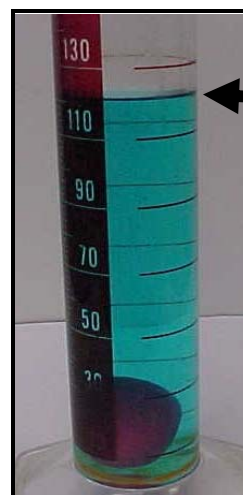
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1. Fill a graduated cylinder with water to some level (e.g., 110 mL).
2. Drop in the sphere.
3. The new reading minus 110 mL is the volume of the sphere.



Water level is at 110 mL

Drop the red sphere in and read the water level



Water level is at 120 mL

$$\text{Volume} = 120\text{mL} - 110\text{mL} = 10\text{mL}$$

Or

**10 cubic centimeters**

Another way to measure the volume of the sphere is to use a piece of string to measure its circumference. From this you can use mathematical formulas to determine the volume.

The piece of string that just fits around the largest part of the sphere measures 8.4 cm. This is the **circumference** of the sphere. The **radius (r)** can be calculated by plugging 8.4 into the formula  $C = 2\pi r$  and now you can use the formula for the volume of a sphere as shown below.

$$C = 2\pi r$$

$$8.4 = 2 * 3.14 * r$$

$$8.4 / 2 * 3.14 = r$$

$$1.34 \text{ cm} = r$$

$$V = \frac{4}{3} \pi r^3$$

$$V = \frac{4}{3} (1.34 \text{ cm})^3$$

$$V = 10 \text{ cubic centimeters}$$

Students will not have the background to understand these concepts until grade 5. As we've just seen, the volume of a sphere or cube or chunk is easy to measure using the water displacement method or a mathematical formula. However, a boat-shaped object offers challenges, because, in that case, there are different ways to look at volume.

Since a boat made from Play-Doh is difficult to make and keep uniform, we will use a jar to represent the Play-Doh boat. We can think of the volume in at least three different ways:

- (1) the volume of water the jar displaces when it is placed into water just to the rim,
- (2) the volume of water the jar can hold

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(3) and, the volume of water the jar displaces when it is resting on the bottom of a container filled with water

How do you think the volumes measured in these three ways compare?



1

model of boat floating

2

model of clay boat sunk

3

model of clay boat filled with water

$$v_1 > v_3 > v_2$$

When we talk to students, we need to be specific about which version of **volume** we are discussing. **Volume is a difficult concept**, and the multiple meanings add to the confusion.

Here are some examples to use with your students:

**Volume 1 (displacement to the rim):** This measurement tells us the volume of the entire jar, its outside and its inside

**Volume 2 (volume of water held by object):** This volume tells us the volume of the plastic the jar is made from

**Volume 3 (displacement of sunken object):** This volume tells us the volume of liquid the jar can hold (its capacity)

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## What do the New York State Standards say?

### Elementary Science Core Curriculum, Standard 4, The Physical Setting

#### Major Understandings

- 3.1d Measurements can be made with standard metric units and nonstandard units.
- 3.1e The material(s) an object is made up of determine some specific properties of the object (sink/float, conductivity, magnetism). Properties can be observed or measured with tools such as hands lens, metric rulers, thermometers, balances, magnets, circuit testers, and graduated cylinders.

### Intermediate Science Core Curriculum, Standard 4, Physical Setting

#### Major Understandings

- 3.1a Substances have characteristic properties. Some of these properties include color, odor, phase at room temperature, density, solubility, heat and electrical conductivity, hardness, and boiling and freezing points.
- 3.1h Density can be described as the amount of matter that is in a given amount of space. If two objects have equal volume, but one has more mass, the one with more mass is denser.
- 3.1i Buoyancy is determined by comparative densities.

**Next week: Archimedes!**