8.P 8.3 Measuring Mass and Volume

STEMscopedia — Measuring Mass and Volume

Addressed Benchmark:

SC.8P.8.3: Explore and describe the densities of various materials through measurement of their masses and volumes.

Reflect

Imagine that it is a very hot day. You decide to cool a glass of water by placing several ice cubes in the drink. What happens when you drop the ice into the water? Likely, when you place the first ice cube into the water, it floats to the top.

Suppose you want to add powdered lemonade mix to the water. To do so, you add the mix to the water and stir it with a metal spoon. The metal spoon sinks to the bottom of the glass when it is added to the water. The solid ice floats in the water but the metal spoon does not. The ice behaves differently from the metal spoon. Why does this happen?

Everything on Earth is matter.

You have learned that *matter* is anything that has mass and takes up space, and that *mass* is the amount of matter a substance contains. A large glass pitcher of lemonade has more mass than a single glass of lemonade. (Because the pitcher has more mass, it is also heavier than the glass or a drop of lemonade from the same pitcher. However, do not confuse mass with **weight**.) The common units for measuring mass are the gram (g) and the kilogram (kg). A kilogram is 1,000 grams. The mass of a glass pitcher is about one 1 kg, or 1,000 g. The mass of the glass is about 0.2 kg, or 200 g.

weight – a measure of the pull of gravity on an object

The pitcher, the glass, and the droplet also have *volume*. In other words, they take up space. The unit for representing volume depends on whether the substance is a solid, a liquid, or a gas. The common units for measuring volume of liquids and gases are the milliliter (mL) and the liter (L). There are 1,000 milliliters in one liter. The volume of a solid object is typically measured in cubic centimeters (cm^3) or cubic meters (m^3). One milliliter (mL) is equivalent to one cubic centimeter (cm^3). A little later, we will learn more about finding volume by using formulas such as length times width times height ($l \times w \times h$).

Even a drop of water has mass: about 0.05 grams.

Even though you are not able to see air, it is made of matter. (You can feel this matter on windy days—wind is the movement of particles of air.) Therefore, air has mass and takes up space. If you were to blow up a balloon, you could see that air has volume as the balloon increases in size.

What Do You Think?

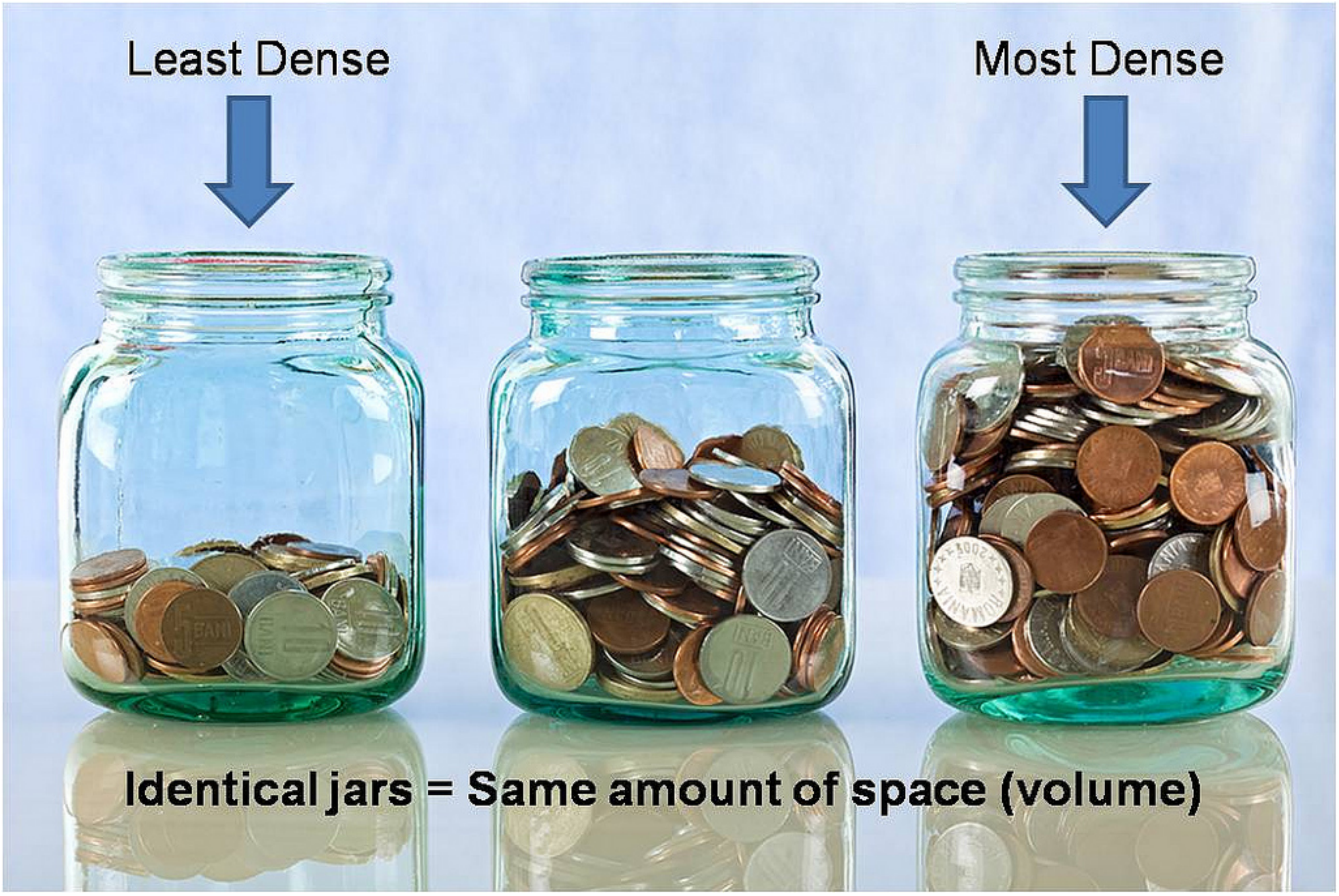
What is density and how does it relate to measuring mass and volume? Let's read on to find out!

Density is a property of matter.

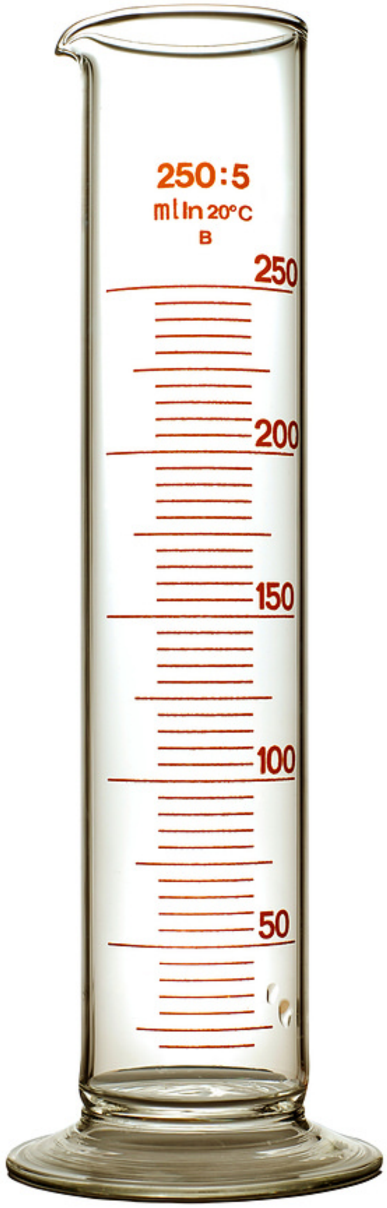
Like mass and volume, density is another physical property of matter. The ice floats in the lemonade because the ice is less dense than the liquid around it. The metal spoon sinks to the bottom of the glass because it is denser than the liquid around it. Density is the amount of matter in a given space. So, density is equal to the mass of a substance divided by the volume of space it takes up. Here is the equation for density:

$d = \frac{m}{V}$, where d is an object's density, m is its mass, and V is its volume

A substance with a greater density has more mass per unit volume; density is a measure of how much mass is packed into a certain space. Look at the three glass jars in the image to the right. Each of the three jars holds the same volume. However, each jar holds a different number of coins. Because each jar has a different mass, each jar also has a different density.



Density can be measured and calculated.
The density of matter is a ratio of an object's mass to its volume. Therefore, you cannot directly measure the density of a substance. You must take separate measurements of the substance's mass and volume. Let's investigate how to determine the density of a few different substances.



- **Density of liquids**: Suppose that you wanted to determine the density of a salt solution. What steps would you follow?
  - First, use a graduated cylinder to measure the volume of a sample of the liquid.
  - Then, use a balance to measure the mass of this volume. To determine the mass of the sample by itself, you will need to subtract the mass of the empty container from the combined mass of the sample and container.

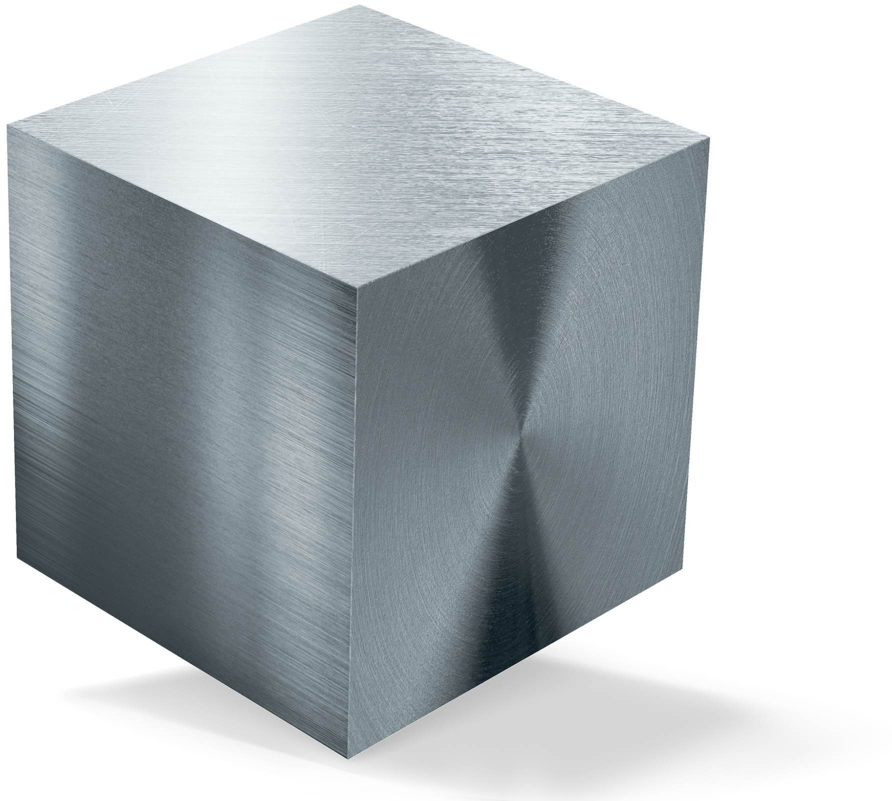
For example, if the mass of 10.0 mL of the salt solution is 10.3 grams, what is the density of the salt solution?

$$d = \frac{m}{V} = \frac{10.3\text{ g}}{10.0\text{ mL}} = 1.03\ \text{g/mL}$$

In other words, the salt solution has a mass of 1.03 g for every 1 mL of water.

- **Density of solids with defined shapes**: Some solid substances may have a defined shape, such as a cube or a rectangular prism. How could you determine the density of this solid?
  - First, determine the volume. For a rectangular prism, use a ruler to measure the object's length, width, and height. Then, use the formula $l \times w \times h$.
  - Finally, use a balance to measure the mass of the object.

For example, if each side of an aluminum cube measures 2.0 cm, and the mass of the cube is 6.0 g, what is the density of the cube?



$$d = \frac{m}{V} = \frac{6.0\ g}{2.0\ cm \times 2.0\ cm \times 2.0\ cm} = 0.75\ g/cm^3$$

Every cubic centimeter (cm^3) of the cube contains 0.75 g of aluminum.

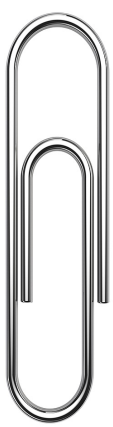
- **Density of solids with undefined shapes**: Other solid substances have an undefined shape, such as a rock or a gold ore nugget. How could you determine its density?
  - First, use water displacement to determine the volume. To do this, measure an initial volume of liquid in a graduated cylinder. Drop the object into the water, and then record the final volume of water in the graduated cylinder. The volume of the object is equal to the change in volume between the two measurements.
  - Then, measure the mass of the object using a balance.

For example, a gold ore nugget is placed into 12.0 mL of water, and the water volume increases to 14.0 mL. If the mass of the gold ore is 38.6 g, what is the density of the gold ore?

$$d = \frac{m}{V} = \frac{38.6 \text{ g}}{14 \text{ mL} - 12 \text{ mL}} = \frac{38.6 \text{ g}}{2 \text{ mL}} = 19.3 \text{ g/mL or } 19.3 \text{ g/cm}^3$$

Every cubic centimeter (cm^3) of the nugget contains 19.3 g of gold.

Now you try!
Take a look at the following photographs below. The picture on the left shows a paper clip. The picture in the middle shows a cup of coffee. The picture on the right shows cubes of ice. How could you determine the density of each object?



Look Out!

Everyday Life: Why is it easier to float in saltwater than in freshwater?

Have you ever noticed that it is much easier to float in the ocean compared to a swimming pool? The ocean is made of saltwater. In other words, seawater contains a large amount of dissolved salts. This salt increases the density of seawater compared to freshwater. Saltwater has a density of 1.03 g/mL, while freshwater has a density of 1.00 g/mL. Because saltwater is slightly denser, it holds up objects—and people—more easily than freshwater.

What Do You Think?

You can use density to identify unknown substances.
How can density be used to identify an unknown substance? Look at the table below. The density of each substance in the table is known. For example, water at room temperature has a density of 1.00 g/mL, while corn syrup has a density of 1.38 g/mL.

Substance	Density (g/mL)
Pure water	1.00
Corn syrup	1.38
Ice	0.897
Balsa wood	0.12
Brass	8.4
Gold	19.3

Suppose you were given an unknown solid with a mass of 43 g and a volume of 5.1 cm^3. Can you use density to identify the substance? (Remember: 1 cm^3 = 1 mL) The answer is below.

So what is the identity of the unknown substance from above? First, calculate its density:

$$d = \frac{m}{V} = \frac{43\ g}{5.1\ cm^3} = 8.4\ g/cm^3 = 8.4\ g/mL$$

According to the table on the previous page, brass has a density of 8.4 g/mL. So, the unknown solid is likely made of brass.

Try Now

Density, Mass, or Volume?
Density, mass, and volume are properties of substances. Decide whether each statement in the table below describes density, mass, or volume. (Some statements describe more than one property.) After completing the table below, write each statement in the correct section of the Venn diagram below.

↶ ↷ B I x² x₂ ▦ Ω

Statement	Density, Mass, or Volume?
Can be used to identify an unknown substance	
Is a physical property of matter	
Can be measured with a balance	
Is the amount of space an object takes up	
Can be measured with a graduated cylinder or a ruler	
Is the amount of matter in a certain amount of space	

Statement	Density, Mass, or Volume?
Is used to determine density	
May be calculated using data from a balance and a graduated cylinder	
Is the amount of matter a substance has	

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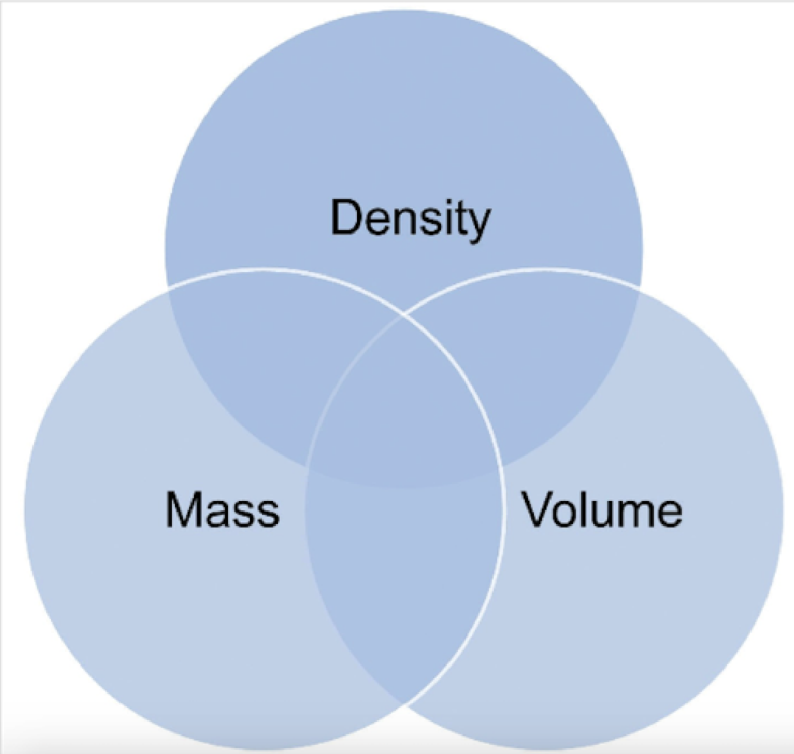

Connecting With Your Child

Water Pollution and Density
Follow this procedure with your child to explore the density of several liquids:

1. Gather the following materials:
   - ½ cup water
   - ½ cup oil (vegetable, canola, or olive oil)
   - ½ cup corn syrup
   - red liquid food coloring
   - green liquid food coloring
   - spoon
   - large, clear glass jar with lid
2. Stir 3–4 drops of red food coloring into the water.
3. Stir 3–4 drops of green food coloring into the corn syrup.
4. Mix all three of the liquids together in the jar. Wait 10–15 minutes, and then observe the mixture.

Here are some questions to discuss with your child:

1. Which liquid sank to the bottom, and which liquid rose to the top? Why did this happen?
2. Which liquid is the most dense, and which liquid is the least dense? How do you know?
3. What would happen if you poured another ½ cup of water into the jar?

Now that your child has observed the relative densities of oil and water, you may wish to discuss the relationship between density and certain forms of water pollution. When pollution is dumped into a pond or stream, organisms are put in harm's way. One property of pollution that determines its effect on a water system is the density of the pollutant. For example, because oil has a lower density than water, during an oil spill, most of the oil floats on the top of the water. This causes harm to the animals that interact with the surface of the water. This is why you may observe birds, ducks, and other surface animals suffering significant damage when oil spills occur. Other substances, such as heavy metals from industries, may sink to the bottom of the water because of their high density. This can hurt the organisms at the bottom of the water. Because this pollutant falls to the bottom of the water, it can more easily go unnoticed until a large fish kill has occurred.

Encourage your child to conduct Internet research to answer these questions about water pollution:

1. How can heavy metal pollution affect a water system?
2. How can an oil spill affect a water system?
3. How do scientists clean up different types of pollutants based on their densities?