Density and Other Physical Properties

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? It happens because different kinds of matter have different densities. **Density is one of many types of physical properties that matter possesses.**

Look Out!

Everything on Earth is matter.
You have learned that ***matter* is anything that has mass and takes up space**. ***Mass*** is the amount of matter a substance contains, while ***volume*** is the amount of space matter occupies. In addition to mass and volume, matter possesses many ***physical properties***.

What is a physical property?
A physical property is a characteristic that can be observed or measured in matter *without* changing the composition of matter. Physical properties can be observed and are often used to describe matter. Some examples of physical properties include color, texture, freezing point, boiling point, density, and solubility, among many others.

What Do You Think?

Look at the list of physical properties below and try to match the name of the physical property to its description.

Physical Property

1. _____ **electrical conductivity**
2. _____ **hardness**
3. _____ **ductility**
4. _____ **thermal conductivity**
5. _____ **flexibility**
6. _____ **melting point**

Description

A. Ability of material to be pulled into thin wire without breaking
B. Temperature at which a substance Changes states from solid to liquid
C. Ability of an electric current to pass through a material
D. Ability of heat to pass through a material
E. Ability of something to be bent or reshaped without breaking
F. A measure of a material's scratch resistance and the ability of a material to scratch other materials

Density and Other Physical Properties

Reflect

Different materials possess different physical properties.
Why is this important? Because different types of matter have different types of physical properties, materials can be used for a wide variety of purposes.

Physical Properties for Common Materials

Property	Metal 	Plastic 	Wood 	Ceramic 
Ductility	Very ductile; used to make wires	Somewhat ductile at higher temperatures	Not ductile	Not ductile; brittle
Electrical Conductivity	Superb conductor of electricity	Poor conductor of electricity	Poor conductor of electricity	Usually poor conductor of electricity
Flexibility	Very malleable	Some types are flexible; most are at higher temps	Not flexible	Not flexible after heated; brittle
Hardness	Depends upon type of metal	Usually softer but depends upon type	Depends upon type of wood	Hard but brittle, so easily breakable
Melting Point	Varies, generally high	Generally between 120°C and 500°C	Burns at 300°C; melts at 3,500°C	Extremely high
Thermal Conductivity	Excellent conductor	Poor conductor; used as insulator	Poor conductor	Poor conductor

What Do You Think?

Review the different types of physical properties for each type of matter above. Then answer the questions about which materials would be best for certain purposes with a partner. Be sure to justify your answers using the table above and your previous knowledge of the physical properties of metals, plastics, woods, and ceramics.

What type of material would be best to:

- form into wires? _____
- conduct electricity? _____
- hold hot materials without melting? _____
- keep hot substances hot? _____
- melt easily? _____
- keep its shape without bending? _____
- bend easily? _____
- break easily? _____

Reflect

Density

Mass and volume are two physical properties of matter that are required in order to define something as matter. **Density** is the ratio of mass to volume of a substance or object. Another way to define density is mass per unit of volume or mass divided by volume. The formula for density is expressed as the following: **d = m/V** or density = mass ÷ volume.

Mass is the amount of matter contained in an object. The standard units for measuring mass are grams (g) and kilograms (kg), which are equivalent to 1,000 grams. **Volume** is the amount of space an object takes up. The standard units for measuring volume are milliliters (mL) for liquids and cubic centimeters (cm^3) for solids. A milliliter and a cubic centimeter are equivalent.

Look Out!

Mass and weight are often confused. Mass is the amount of matter something contains, whereas weight is a measure of the pull of gravity on an object. Weight changes depending upon gravity, but mass is constant. If a person has a mass of 50 kg on Earth, that person will also have a mass of 50 kg on the Moon. However, weight is not consistent. That same person will weigh 110 pounds on Earth but only 18 pounds on the Moon.

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

Look Out!

A balloon full of air has a greater mass and volume than the same balloon that is deflated. This demonstrates that air is matter.

Even things you cannot see are made of matter. For example, you are not able to see air, but it is made of matter. How can you tell? You can feel this matter on windy days—wind is the movement of particles of air. If you were to blow up a balloon, you could see that air has volume as the balloon increases in size. If you used a balance, the balloon full of air would have greater mass than the empty balloon. Therefore, air has mass and takes up space, so air is matter.

Reflect

Density is a property of matter.

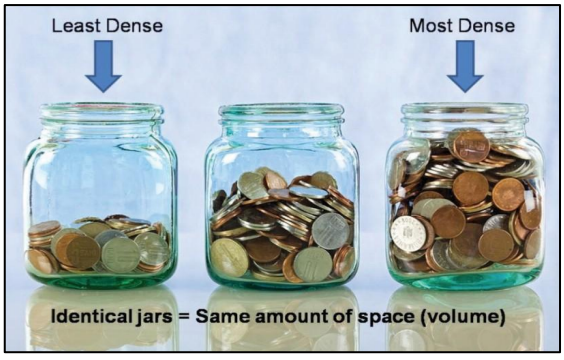
Like mass and volume, density is another physical property of matter. Think back to the example at the start of the text. The ice floats in the lemonade because the ice is less dense than the liquid around it. The metal spoon sinks to the bottom of the glass because it is denser than the liquid around 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

Density and Other Physical Properties

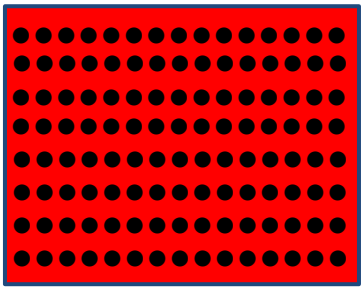
A substance with a greater density has more mass per unit volume. In other words, density is a measure of how much mass is packed into a certain space. Look at the three glass jars in the image to the right.

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.

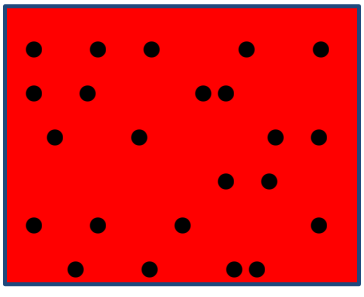


What Do You Think?

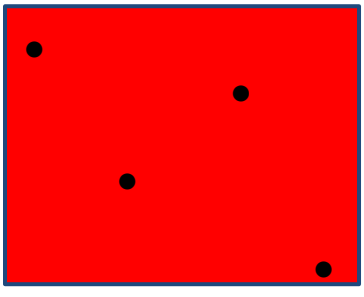
When looking at a substance and its three states of matter, *usually*, but not always, solids are the densest, liquids are in the middle, and gases are the least dense. (Water is a notable exception because ice is less dense than the liquid form of water.) Look at the drawings below depicting the density of mercury's molecules in a solid, liquid, and gas.



When in solid form, mercury has many molecules close together and in a structured grid-like matrix.

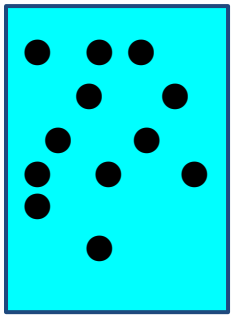


When in liquid form, mercury has some molecules moderately close together but able to flow.

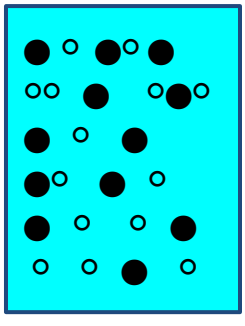


When in gas form, mercury has few molecules spaced far apart.

- From looking at the illustrations above, why do you think solid mercury is denser than liquid or gaseous mercury?
- Look at the illustrations on the right. Both show depictions of water. The illustration on the left is fresh water and the illustration on the right is salt water. Which liquid do you think is denser? Explain.
- Why do you think the same volume of pure gold is denser than pure aluminum?



Fresh water with H_2O (water) molecules

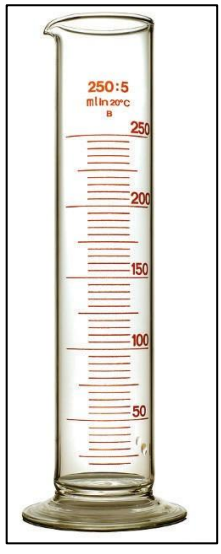


Salt water with H_2O (water) and NaCl (salt) molecules

Density and Other Physical Properties

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.

If the mass of 10.0 mL of the salt solution is 10.3 grams, what is the density of the salt solution?

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

- **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 cm, and the mass of the cube is 6 g, what is the density of the cube?

V = 2 cm x 2 cm x 2 cm = 8 cm^3

$$\textbf{d} = \frac{\textbf{6 g}}{\textbf{8 cm}^3} \qquad \textbf{d} =$$

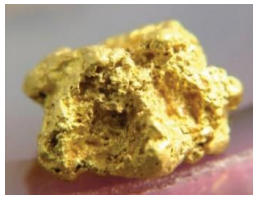
Every cubic centimeter (cm^3) of the cube contains 0.75 g of aluminum.

- **Density of Solids with Undefined Shapes:** Other solid substances have an undefined shape, such as a rock or a gold 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 nugget is placed into 12 mL of water, and the water volume increases to 14 mL. If the mass of the gold is 38.6 g, what is the density of the gold?

$$d = \frac{m}{V} = \frac{38.6\text{ g}}{14\text{ mL} - 12\text{ mL}} = \frac{38.6\text{ g}}{2\text{ mL}} =$$

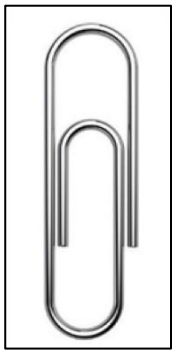
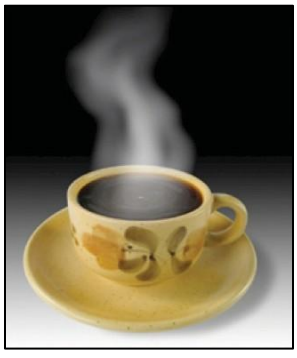
Every cubic centimeter (cm^3) of the nugget contains 19.3 g of gold.



Density and Other Physical Properties

What Do You Think?

Take a look at the following photographs. 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? Would you have to use different methods for each?


Try Now

You can use density to identify unknown substances. How can density be used to identify an unknown substance? Look at the table on the right. The density of each substance in the table is known. For example, water at room temperature has a density of 1 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? (*Hint:* Remember that 1 cm^3 = 1 mL) The answer is on the next page.

Everyday Life: Why is it easier to float in salt water than in fresh water?

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

Density and Other Physical Properties

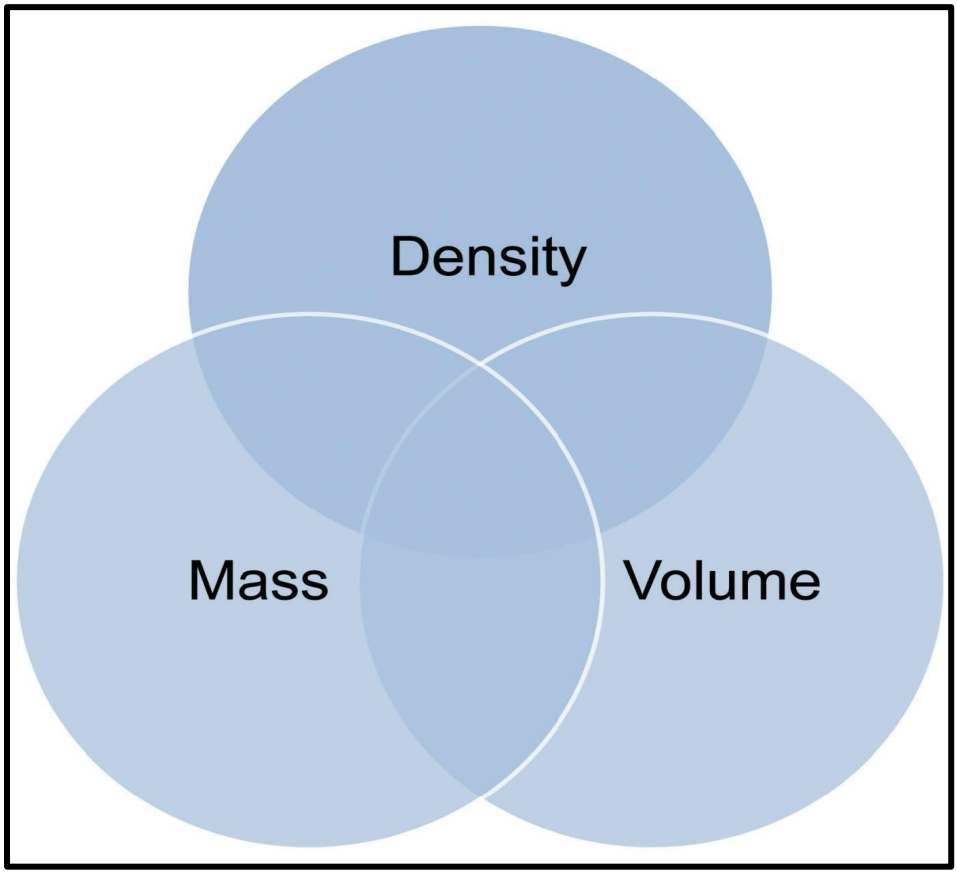
So what is the identity of the unknown substance? First, calculate its density:

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

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

Density, mass, and volume are three examples of physical properties of substances. Decide whether each statement describes *density*, *mass*, or *volume*. (Some statements describe more than one property.) Then write the statement in the correct section of the Venn diagram below.

Density, Mass, or Volume?	
• Can be used to identify an unknown substance	• Is the amount of matter in a certain amount of space
• Is a physical property of matter	• Is used to determine density
• Can be measured with a balance	• May be calculated using data from a balance and a graduated cylinder
• Is the amount of space an object takes up	
• Can be measured with a graduated cylinder or a ruler	• Is the amount of matter a substance has



Density and Other Physical Properties

Reflect

Do physical properties of matter change?
The simple answer is that it depends on the property. Pretend you have a big piece of wood and a small piece of wood from the same tree. The masses and the volumes of those two pieces of wood will be different because they depend upon the sizes of the samples. However, the densities of both pieces will be the same because the ratio of mass to volume remains constant.

There are two types of physical properties--extensive properties and intensive properties. What is the difference?

- **Extensive properties** depend upon the amount of substance present.
- **Intensive properties** do NOT depend upon the amount of substance present.

What Do You Think?

Look at the mineral pictured to the right. Think about which properties listed in the box below are ***extensive*** and which are ***intensive***. Sort the properties by writing each property under the correct category.

Physical Properties of Matter

color	shape	temperature	ductility	melting point
boiling point	mass	flexibility	hardness	surface area
magnetism	density	electrical conductivity	thermal conductivity	volume

Physical Properties	
Extensive Properties	**Intensive Properties**