Volume

059

Volume is a quantity that describes an amount of space. When you measure volume, you want to know one of two things:

Either - How much space does an object take up?

Or - How much empty space is in a container?

The empty space in a container is also called **capacity.**

A unit of volume used with SI prefixes is the **liter** (L). The table lists volume units based on a liter. These units are often used to describe the volumes of liquids and gases.

SI Units of Volume

Unit Name	Symbol	Multiple of a liter	Example
kiloliter	kL	1000	You could fit 1 kiloliter of material in a box measuring 1 meter long, 1 meter high, and 1 meter wide.
hectoliter	hL	100	A hectoliter of water is enough to give 100 marathon runners a 1-liter bottle of water each.
dekaliter	daL	10	A dekaliter equals five 2-liter bottles of soda pop.
liter	L	1	Soda pop and water are sold in 1-liter and 2-liter bottles.
deciliter	dL	0.1	If you drink one-half pint of milk, then you drink a little more than 2 deciliters of milk.
centiliter	cL	0.01	A sip of water is about 1 centiliter (or 10 mL).
milliliter	mL	0.001	A teaspoon holds about 5 milliliters of a liquid.

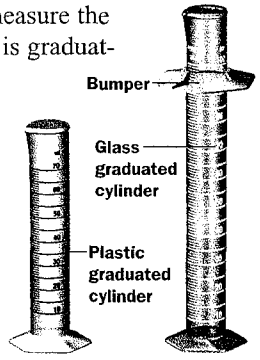
Science Alert

A milliliter (mL) is equal in value to 1 cm^3 and 1 cc. As a general rule, use mL to record liquid volumes (except in medicine where cc is commonly used). When recording the volume of a solid, use cm^3.

060

Measuring Liquid Volume

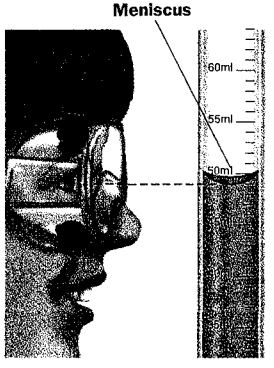
A **graduated cylinder** is a narrow container used to measure the volume of liquids. As its name suggests, the cylinder is graduated, or marked, with units of volume. Some graduated cylinders are made of glass. Others are made of clear or cloudy plastic.



Glass graduated cylinders have a plastic bumper, or cylinder guard, that slides up and down the cylinder. The bumper helps to keep the cylinder from breaking if it falls over. It should be about one-quarter the way down from the top of the cylinder to work.

How to Use a Graduated Cylinder

1. Pour liquid into the graduated cylinder.
2. Move your head so the top of the liquid in the cylinder is at eye level.
3. Look for the meniscus (meh-NIHS-kus), the curved surface of the liquid. You may find it easier to see the meniscus if you hold a sheet of white paper behind the graduated cylinder.
4. A water meniscus is about as thick as a nickel. Read the volume at the bottom of the meniscus. If the volume is between two marks on the cylinder, estimate the volume.



Volume = 49 mL

Did You Know?

A meniscus forms because the liquid sticks to the inside surface of the container. Liquids form a meniscus in glass graduated cylinders. No matter what liquid you have, always read a meniscus at the bottom of the curve.

061

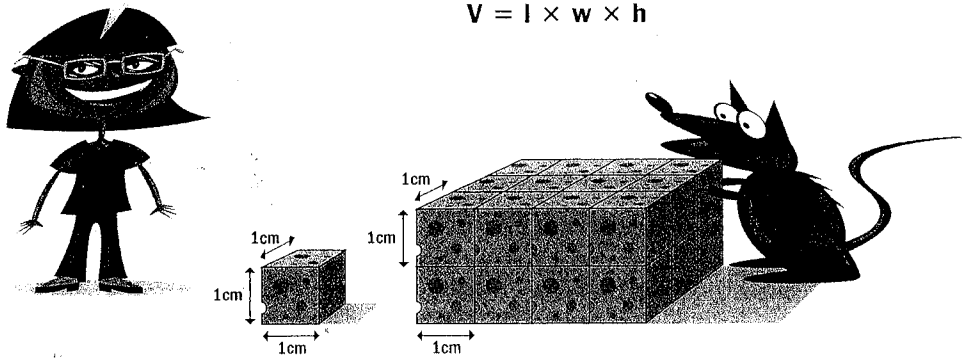
Volume of Rectangular Solids

One way to describe volume is to take a length unit and make a cube. The cubic centimeter (cm^3 or cc) is a common unit of volume. It is usually used to measure the volume or capacity of a rectangular solid, or box. The volume of a box equals its length times its width times its height. In mathematical language, you can write:

Rectangular solids are also called boxes!

Volume = length × width × height

V = l × w × h



EXAMPLE: The length, width, and height of a stack of mini cheese cubes is 4 cm, 2 cm, and 3 cm, respectively. Volume = length × width × height, so to calculate its volume, multiply:

4 cm × 2 cm × 3 cm = 24 cubic centimeters

Notice that the volume unit makes sense, since cm × cm × cm = centimeter cubed, or a cubic centimeter (written as cm^3).

The stack of cheese cubes takes up 24 cubic centimeters of space. Each cube has a volume of 1 cubic centimeter.

Did You Know?

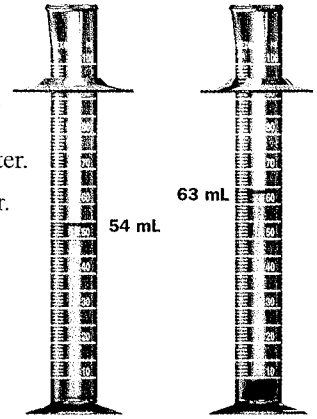
A liter equals exactly 1 cubic decimeter. A milliliter equals exactly 1 cubic centimeter.

062

Volume of Irregularly Shaped Solids

Have you ever noticed that when you get into a tub filled with water, the water level rises? The water rises as it is **displaced,** or pushed away. The volume of water pushed away is equal to the volume of the part of your body that is underwater.

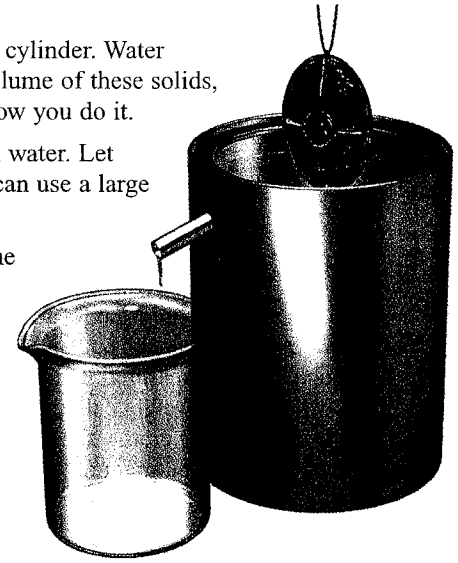
You can use the displacement of water to find the volume of an object that does not have a regular shape, if the object sinks in water.



63 mL water + object
− 54 mL water alone
9 mL (9 cm^3) object

1. Partly fill a graduated cylinder with water. Record the volume of the water.
2. Gently lower the object you want to measure into the water. This makes the water rise. Record the volume at the new water level.
3. Subtract your first volume reading (the volume of only the water) from your second volume reading (the volume of the water and the object).
4. The difference in volume is equal to the volume of the object you are measuring.

Some objects won't fit into a graduated cylinder. Water displacement can be used to find the volume of these solids, but the procedure differs a bit. Here's how you do it.



1. Fill an overflow can to the top with water. Let extra water run out of spout. (You can use a large beaker instead of an overflow can.)
2. Hold a beaker under the spout of the overflow can.
3. Place the object you want to measure into the overflow can. This will cause water to flow from the spout into the beaker.
4. Use a graduated cylinder to measure the amount of water collected in the beaker.

063

Mass

Mass is a measure of the amount of matter in a solid, liquid, or gas. All solids, liquids, and gases have mass because they are all made of matter (rather than energy). The mass of an object is measured using a laboratory balance. Mass is recorded in units such as kilograms (kg), grams, or milligrams. The **gram** (g) is the unit of mass that is used with SI prefixes to create other units.

SEE ALSO
250 Matter
276 Gravity

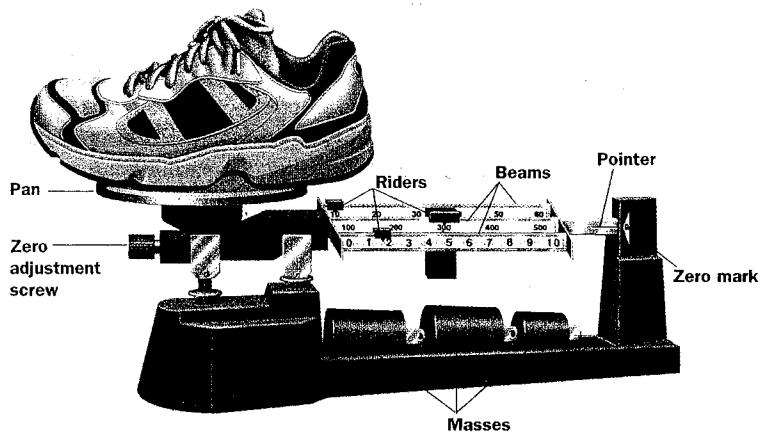
SI Units of Mass

Unit Name	Symbol	Multiple of a gram	Example
kilogram	kg	1000	One liter of water has a mass of 1 kilogram.
hectogram	hg	100	A baseball has a mass of about 1.5 hectograms.
dekagram	dag	10	Two U.S. state quarters have a mass of just over 1 dekagram.
gram	g	1	A one-dollar bill has a mass of about 1 gram.
decigram	dg	0.1	A paper clip has a mass of about 5 decigrams.
centigram	cg	0.01	A large black ant has a mass of about 1 centigram.
milligram	mg	0.001	One dekagram of table salt contains about 1 milligram of iodine.

064

Using a Triple-Beam Balance

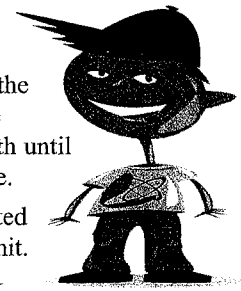
One measuring device for mass is the **triple-beam balance.** On one side of the balance is a pan (or platform) on which you place the object to be measured. On the other side are three beams. Each beam has a sliding weight called a rider. The first beam might be marked in intervals of 10 grams; the second in 100 grams; and the third in tenths (0.1) of a gram up to 10 grams.



How to use a triple-beam balance:

1. Set the balance on a level surface. Make sure the pan of the balance is clean and empty.
2. Move all riders to zero. Make sure the two largest riders rest in the notches in the beams.
3. Look at the pointer to make sure it reads zero. If it does not, you must zero the balance. Turn the zero adjustment screw just a teeny bit at a time until the line on the pointer comes to rest at the zero mark on the scale. Turning the screw clockwise lowers the pointer; counterclockwise raises it.
4. Place the object you want to measure on the pan. This causes the pointer to rise.
5. Gently slide the largest rider across the beam until the pointer drops below the zero mark on the scale. When you reach this point, back the rider up one notch.
6. Slide the next-sized rider as you did in step 5. Again, back the rider up one notch when the pointer mark drops below the scale line.
7. Slide the smallest rider along its beam. If the rider causes the pointer to drop below the zero mark, begin sliding it in the opposite direction. Continue sliding the rider back and forth until the pointer lines up exactly with the zero mark on the scale.
8. Record the mass by adding the sum of the measures indicated by the riders. Make sure that you are adding all the same unit.
9. Remove your object from the balance. Slide all riders back to zero.

Always make sure that your measuring device reads zero when there is no mass on the pan. If it does not read zero, you must adjust the device to get an accurate measurement.



Finding Density

Density is a measurement of how much matter is packed into a certain volume of a substance. Density is an example of a derived quantity—that is, a quantity that is found by using measurements of other quantities. The most common unit of density is grams per cubic centimeter (g/cm^3). Grams per milliliter is also common. Note that 1 cm^3 = 1 mL.

To find the density of an object, you must first measure its mass and its volume. Divide the mass by the volume to find the object's density.

The density of a substance mostly stays the same. For this reason, knowing the density of an object may give you a clue as to what the object is made of.

EXAMPLE: Pure 24-karat gold has a density of 19.3 g/cm^3. A person at a cart is selling "pure gold" bracelets for a very low price. You doubt they are pure gold and decide to check one out. The mass of the bracelet is 26.7 grams. Its volume is 3 cm^3. What is the bracelet's density? Is the bracelet pure gold?

$$\text{density} = \frac{\text{mass}}{\text{volume}} \quad \text{or} \quad d = \frac{m}{v}$$

$$\text{density} = \frac{26.7\ \text{g}}{3\ \text{cm}^3}$$

$$\text{density} = \frac{8.9\ \text{g}}{\text{cm}^3}$$

The bracelet is not pure gold.

Density is also useful for predicting if something will sink or float in water. Pure water has a density of 1 g/cm^3. Materials with a density greater than water sink in water. Gold, with a density of 19.3 g/cm^3, sinks in water. Materials with a density less than water float in water. Corn oil, with a density of only 0.93 g/cm^3, floats in water.

The density of a material changes with temperature. Ice (0.9 g/cm^3), for example, is less dense than liquid water (1.0 g/cm^3). For most other materials, density increases as temperature decreases.