Educational Innovations Inc®

DEN-350

Steel Sphere Density Kit

Target Age Group: 3-5, 6-8

National Standards

K-4	Physical Science	Properties of objects and materials Density, weight and volume are properties of an object. These properties can be measured using tools such as balances and rulers. Position and Motion of Objects An object's motion can be described by tracing and measuring its position over time. The position and motion of objects can be changed by pushing or pulling. The size of the change is related to the strength of the push or pull.
5-8	Physical Science	Properties and changes of properties in matter A substance has characteristic properties such as density, a boiling point, and solubility, all of which are independent of the amount of the sample. Motion and Forces An object that is not being subjected to a force will continue to move at a constant speed and in a straight line. If more than one force acts on an object along a straight line, then the forces will reinforce or cancel one another, depending on their direction and magnitude.

5 Francis J. Clarke Circle
Bethel, CT 06801

Phone (888) 912-7474
Fax (203) 229-0740

www.teachersource.com

info@teachersource.com

Background Information on Density and Buoyancy

Density is a fundamental property of matter. Density is defined as mass divided by unit volume, usually expressed in grams per cubic centimeter, or kilograms per cubic meter. The Greek letter rho (ρ) is the symbol for density.

$$\rho = m \div v \qquad\qquad \text{density} = \text{mass} \div \text{volume}$$

Often we define density as weight per unit volume; however, this is actually called specific weight.

It is important to distinguish between mass and weight even though we tend to use them interchangeably. Mass is a measure of the quantity of matter and is constant wherever that matter might be in the universe. Weight is the force exerted on a body by gravity, and is proportional to mass. For example, consider a brick that weighs 12 kg on Earth, but only 2 kg on the moon, which has gravity one sixth that of Earth. The mass of the brick hasn't changed, merely its weight.

Although mass is constant, volume is not. More pressure on an object decreases its volume, while increasing the temperature usually increases the volume. Increasing the volume of an object decreases its density; decreasing the volume increases the density. Often it is important to know the temperature and pressure at which the volume was measured. Densities are frequently given at STP, standard temperature and pressure, defined as 0^{o} C (32^{o} F) and 100 kPa (14.504 psi, 0.986 atm, 1 bar).

Specific gravity defines the density of a material as a multiple of the density of another standard material, usually water. Specific gravity is dimensionless. Materials with a specific gravity greater than 1.0 sink in water, those less than 1.0 float. Geologists use specific gravity to help identify minerals.

Buoyancy is the upward force experienced by a submerged object. Consider a visit to the swimming pool. When you float on top of the water you experience very little water pressure. What happens when you jump off the diving board and sink all the way down to the bottom of the deep end? At the bottom of the pool you feel the weight of the column of water on top of you. The difference in water pressure you experience between the bottom of the pool and the surface pushes you upwards so you rise to the surface. This upward push or force is called buoyancy.

If you drop a marble into a graduated cylinder containing water, it displaces a quantity of water equal to the volume of the marble. The volume of the displaced water is the difference between beginning and final volumes as determined by the scale on the cylinder. The size of the buoyant force on an object submerged in any liquid is the same as the weight of the displaced liquid. Objects denser than the liquid sink; objects less dense than the liquid float. Objects shaped like boats also float; in this case the weight of the displaced liquid equals the weight of the boat-shaped object. Objects floating on liquids denser than water will ride higher since a smaller volume of the denser liquid needs to be displaced. People who have difficulty floating in fresh water, ~1 g/cm^3, find it easier to stay afloat in ocean water, ~ 1.025 g/cm^3, and effortless in Utah's Great Salt Lake, ~ 1.24 g/cm^3. This principle of buoyancy is called Archimedes' principle in honor of the Greek mathematician and scientist **Archimedes of Syracuse** who discovered it in 212 BC.

Demonstration Materials

Steel Sphere Density Kit *DEN-350*: Determine the diameter of each ball before class begins.
2 identical plastic containers or bowls (margarine tubs in the 48 oz. range work well)
2 identical cardboard cartons or opaque, plastic bins with opaque lids - large and strong enough to hold ~ 40 lbs
bricks (~ eight), weighing in total about 40 pounds
one sandwich bag
a large bowl of water
a transparent or translucent, one-gallon plastic pitcher, preferably with straight or nearly straight sides
a ruler marked in centimeters and millimeters
sharp pencil or very fine-tipped pen or marker
blindfold
masking tape

Activity Materials

Regularly shaped samples (i.e. spheres, cylinders, rectangular prisms) of assorted waterproof materials

> Include hollow items, but make sure water cannot get inside them! Mark each item with a number. Items might include wooden or plastic toy blocks, ping pong, golf, paddle and other sports balls, dice, sections of wooden dowel rods, Styrofoam or wooden balls from a craft store, super and other toy balls, marbles, and film canisters with lids (*#CAN-300*), with or without added weight inside. Cylinders of assorted materials are included in *#DEN 210, #DEN-952, #DEN- 40,* and *#DEN-102* from Educational Innovations.

Rulers marked with centimeters and millimeters
String and/or ½ inch wide strips of paper to measure circumference
Outside calipers, micrometers and/or drafting compasses (optional, for more accurate diameter measurements)
Calculators
Balance(s) accurate to the nearest gram or better
Useful Information sheet

Demonstration and Introduction

Display the two closed, cardboard boxes, one empty and one with the bricks. Ask a student volunteer to lift the box with the bricks, a difficult task. Then ask the same student to pick up the empty box. He or she will probably expect another heavy load and will lift the box high overhead. Why was one so much harder to lift? Open the boxes to show the contents. Although the boxes are identical, the amounts of material inside them are quite different. The size, volume, of the boxes didn't differ; the mass or weight did.

Display the two steel balls. Determine by a show of hands which ball the students think is the heaviest. Pass the balls around and repeat the question. Did the answer change? Blindfold a second student volunteer, asking her to hold her hands out, palms facing upward. Place each steel ball into a plastic container. To keep the smaller sphere from rolling around in the container put it into a sandwich bag. Place those containers onto the volunteer's hands. Ask her which container is heavier. You may want to repeat this test with other students. Finally, weigh the two balls on the balance to obtain their actual weights in grams. How did the students perceive the mass of the balls? When the balls were displayed, they used their sense of vision alone. When the balls were passed around they used sight and touch; when blindfolded they used touch alone. Which sense is best suited for determining the mass of an object? Why is it important to be able to measure things rather than relying on our senses alone?

Display the large bowl with water. Ask the students what they think will happen when you place the two steel balls into the water and why. After allowing some discussion, by show of hands determine how many students think the hollow sphere will float or sink, and likewise with the solid ball. Place the balls in the water. If the two spheres have about the same mass, why did one float and the other sink?

Volume and mass are properties of an object. As long as we stay on Earth we can substitute the weight for mass for most purposes. Density is a third fundamental property of that object. It is defined as mass divided by unit volume. The Greek letter rho (ρ) is the symbol for density.

$$\rho = m \div v \qquad\qquad \text{density} = \text{mass} \div \text{volume}$$

The two cardboard boxes had the same volume, but very different masses. The box of bricks had more material packed inside so it was much denser than the box filled only with air. The two steel balls have about the same mass, but in one the metal is spread out over a much larger area, the outside shell of the hollow ball, rather than being tightly packed together as in the solid ball.

Using the weights and volumes of the two steel balls determined earlier, calculate the volume of the balls and their densities. Students can record the data in the table on the worksheet. Density is inversely proportional to volume, that is when the volume increases the density decreases and vice versa. The students can demonstrate this to themselves by completing the density calculations on the worksheet for hypothetical hollow balls equal in weight to the actual one.

The hollow ball has a density considerably less than 1 g/cm^3, the solid ball has a density considerably greater than 1 g/cm^3. The density of fresh water is 1 g/cm^3. Anything with a density less than that of fresh water will float in it. Why? Consider a visit to the swimming pool. When you float on top of the water you experience very little water pressure. What happens when you jump off the diving board and sink all the way down to the bottom of the deep end? At the bottom of the pool you feel the weight of the column of water on top of you. The difference in water pressure you experience between the bottom of the pool and the surface pushes you upwards so you pop up to the surface. This upward push or force is called buoyancy. The size of that upward, buoyant force is equal to the weight of water displaced by the object, in this case you.

Ask if any of the students ever swam in the ocean, or better yet, in Utah's Great Salt Lake. Sea water, about 1.025 g/cm^3, is a bit denser then fresh water. A smaller volume of sea water needs to be displaced so it is easier to float in it. The water in the Great Salt Lake is even denser at 1.24 g/cm^3; not only is it easier to float it's very difficult to sink at all!

Bring out the plastic pitcher, about half full of water. Place a piece of masking tape vertically on the pitcher, starting a few centimeters below the water level and extending at least twelve centimeters above it. Ask a student volunteer to mark the current water level on the tape, being careful to avoid parallax error. Drop in the solid ball. Ask the student to mark the new water level on the tape. That difference in water level represents the water displaced by the steel ball, which is equal to the volume of the ball. The weight of that volume of water is much less than the weight of the ball so the ball sinks.

Place the hollow sphere onto the water. Mark this new water level. The distance between it and the second mark represents the volume of weight displaced by the floating ball. This weight of water equals the weight of the hollow ball. It provides just enough force, or "push", to keep the hollow ball from sinking.

Ask another student to push and hold the sphere just beneath the surface of the water. Mark this fourth water level on the tape. The distance between the second and this fourth mark represents the volume of water that would be displaced by the hollow ball if it sank. It is equal to the volume of the ball but weighs much more. The student has to apply constant force with his hand to keep the hollow sphere under water. Ask the student how hard he has to push on the ball to keep it underwater.

Optional activity: Consider calculating the volumes of water displaced for the steel ball and hollow sphere to confirm that the relationships stated above are true. A sample calculation using actual experimental results follows below. Changes of a millimeter in measurement of the water column height or diameter of the pitcher will make significant changes in the calculated volumes or weight, so expect margins of error of at least ten percent. Ask the class what possible sources of error are in the procedure.

Solid Steel ball: mass = 129g volume = 17.5 cm^3 **Hollow ball**: mass = 140g volume = 1073 cm^3

	Inside diameter of pitcher at the center of the column of displaced water (cm)	Radius r (cm)	Area πr^2 (cm^3)	Height of displaced column of water (cm)	Volume of displaced water (cm^3)	Percent difference from actual values
Submerged steel ball	15.1	7.55	179	0.1	17.9	2.3% high
Floating hollow ball	15.2	7.6	181	0.7	127	10% low
Hollow ball barely submerged	15.5	7.75	189	5.6	1058	0.14% low

Ship builders need to know the maximum amount of water that can be displaced by a ship before it sinks, and the minimum amount of water it must displace to keep from tipping over. Ballast is loaded onto empty cargo ships to increase the displacement. The largest cruise ships displace 100,000 tons, which is the maximum amount the ship itself, the passengers and crew, and their luggage can weigh.

Note: After you finish, be sure to dry the solid ball carefully. To prevent it from rusting, apply a thin coat of oil before returning it to its plastic bag for storage.

Activity: Sink or Float?

This activity provides practice in measuring the dimensions, calculating the volume, and determining the density of regularly shaped objects.

Provide each team of students with the *Useful Information* sheet, the worksheet, and access to the measurement tools and objects of unknown density. The task for the students is to measure the weight and dimensions of the objects to calculate their volumes and densities, and predict whether an object will sink or float in water based on their calculations. Be sure to have enough objects so even the speediest team will not run out of items to measure in the allotted time. Conclude the activity by dropping the items into water to confirm their answers.

Lesson by:
Cynthia B. House
Thomas Middle School
Arlington Heights, Illinois

Worksheet

What happens to density when the volume changes? density = mass ÷ volume

The density of fresh water is 1.0 g/cm^3

	Mass (g)	Volume (cm^3)	Density (g/cm^3)	Float or Sink in Fresh Water?
Steel Ball				
Hollow steel ball				
Hollow steel ball with twice the original volume (original volume x 2)				
Hollow steel ball with half the original volume (original volume ÷ 2)				
Hollow steel ball with one quarter the original volume (original volume ÷ 4)				
Hollow steel ball with one eighth the original volume (original volume ÷ 8)				

If the volume increases, but the mass stays the same, the density ______________________________.

If the volume decreases, but the mass stays the same, the density ______________________________.

Sink or Float?

Object Number	Description (shape? material? hollow?)	Mass (g)	Volume (cm^3)	Density (g/cm^3)	Float or Sink in Fresh Water?

Worksheet (Sample)

What happens to density when the volume changes? density = mass ÷ volume

The density of fresh water is 1.0 g/cm^3

	Mass (g)	Volume (cm^3)	Density (g/cm^3)	Float or Sink in Fresh Water?
Steel Ball	129	17.5	7.37	sink
Hollow steel ball	140	1070	0.131	float
Hollow steel ball with twice the original volume (original volume x 2)	140	2140	0.065	float
Hollow steel ball with half the original volume (original volume ÷ 2)	140	535	0.262	float
Hollow steel ball with one quarter the original volume (original volume ÷ 4)	140	268	0.522	float
Hollow steel ball with one eighth the original volume (original volume ÷ 8)	140	134	1.04	sink

If the volume increases, but the mass stays the same, the density gets smaller.

If the volume decreases, but the mass stays the same, the density gets bigger.

Sink or Float?

Object Number	Description (shape? material? hollow?)	Mass (g)	Volume (cm^3)	Density (g/cm^3)	Float or Sink in Fresh Water?
1	Cylinder, metal, solid	25.6	10.4	2.46	sink
2	Sphere, plastic, hollow	3.23	20.6	0.157	float

