

**BEFORE YOU READ**

After you read this section, you should be able to answer these questions:

- What is buoyant force?
- What makes objects sink or float?
- How is density calculated?

**California Science Standards**

8.8.a, 8.8.b, 8.8.c, 8.8.d

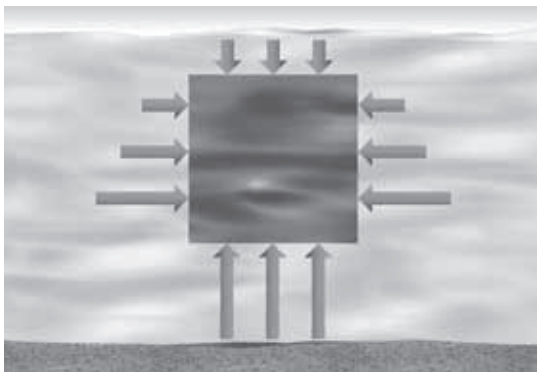
**What Is Buoyant Force?**

Why does an ice cube that has been pushed under the water pop back up? A force called buoyant force pushes the ice cube up to the water's surface. **Buoyant force** is the upward force that a fluid exerts on all objects in the fluid.

Look at the figure below. Water exerts a pressure on all sides of the object in the water. The water produces the same amount of horizontal force on both sides of the object. These equal forces balance one another.

However, the vertical forces are not equal. Remember that fluid pressure increases with depth. There is more pressure on the bottom of the object than on the top. ✓

The longer arrows in the figure below show the larger pressures. You can see that the arrows are longest underneath the object. This shows that the water applies a net upward force on the object. This upward force is buoyant force. It is what makes the object float.



There is more pressure at the bottom of an object because pressure increases with depth. The differences in pressure produce an upward buoyant force on the object.

Buoyant force is what makes you feel lighter when you float in a pool of water. The buoyant force of the water pushes up on your body and reduces your weight.

**STUDY TIP**

**Learn New Words** As you read, underline words you don't understand. When you figure out what they mean, write the words and their definitions in your notebook.

**READING CHECK**

**1. Identify** Why is the force on the bottom of an object in a fluid larger than the force on the top?

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**TAKE A LOOK**

**2. Identify** What produces buoyant force?

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## CALIFORNIA STANDARDS CHECK

**8.8.c** Students know the buoyant force on an object in a fluid is an upward force equal to the weight of the fluid the object has displaced.

**Word Help: displace**  
to take the place of; to move aside

**3. Apply Ideas** A can of soda displaces about 360 mL of water when it is put in a cooler of water. The weight of 360 mL of water is about 3.6 N. What is the buoyant force on the can of soda?

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## TAKE A LOOK

**4. Compare** How is the volume of water that the metal cylinder displaces related to the volume of the metal cylinder?

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## DETERMINING BUOYANT FORCE

Archimedes, a Greek mathematician who lived in the third century BCE, discovered how to find buoyant force. Archimedes found that objects in water *displace*, or take the place of, water. The weight of the displaced water equals the buoyant force of the water. This is now known as **Archimedes' principle**.

You can find buoyant force by measuring the weight of the water that an object displaces. Suppose the block in the figure below displaces 250 mL of water. The weight of 250 mL of water is about 2.5 N. The weight of the displaced water equals the buoyant force. Therefore, the buoyant force on the block is 2.5 N.

The buoyant force pushes up on the block and reduces its weight. Suppose the block weighs 4 N. When the block is in the water, its weight is reduced by 2.5 N. Therefore, the block in the water weighs  $4\text{ N} - 2.5\text{ N} = 1.5\text{ N}$ .



When a metal cylinder is put into a container of water, the cylinder displaces some water. The weight of the displaced water equals the buoyant force on the cylinder.

Imagine that you want to measure the buoyant force on a second block. However, you cannot measure how much water the block displaces. You can determine the buoyant force by measuring how much the block's weight changes when it is placed underwater.

First, measure the weight of the block by hanging it from a spring scale. Next, lower the block into the water. Read the weight of the block in the water from the spring scale. The buoyant force is equal to the change in the block's weight when it is placed underwater.

For example, suppose the block weighs 5 N out of the water and 3 N in the water. The buoyant force on the block is  $5\text{ N} - 3\text{ N} = 2\text{ N}$ .

# What Makes Objects Float or Sink?

An object in a fluid will sink if its weight is greater than the buoyant force. An object floats only when the buoyant force is equal to or less than the object's weight. ✓

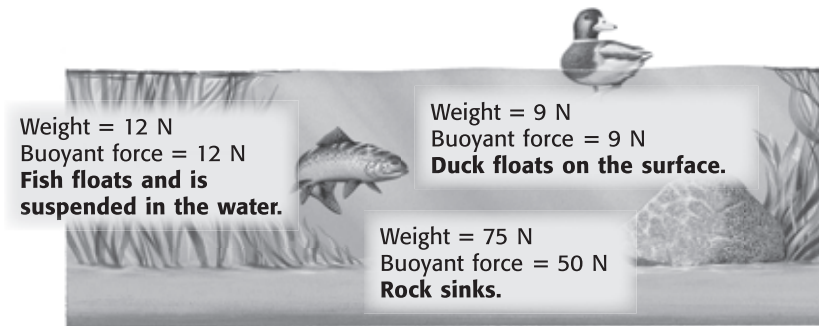
## SINKING, FLOATING, AND BUOYING UP

The rock in the figure below weighs 75 N. It displaces 5 L, or about 50 N, of water. According to Archimedes' principle, the buoyant force is about 50 N. Since the weight of the rock is greater than the buoyant force, the rock sinks.

The fish in the figure weighs 12 N. It displaces a volume of water that weighs 12 N. The buoyant force and the fish's weight are equal, so the fish floats in the water. It does not sink to the bottom or rise to the surface—it is *suspended* in the water.

The duck in the figure weighs 9 N. If the duck's body was completely underwater, it would displace a volume of water that weighs more than 9 N. Therefore, the buoyant force on the duck is greater than the duck's weight. The buoyant force causes the duck to be *buoyed up*, or pushed toward the surface.

An object is buoyed up until the part underwater displaces an amount of water that equals the object's weight. Therefore, the part of the duck that is underwater displaces 9 N of water.



## READING CHECK

**5. Identify** Will an object sink or float if its weight is less than the buoyant force?

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## Critical Thinking

**6. Apply Concepts** If the duck weighed 10 N, would more or less of the duck be underwater?

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## TAKE A LOOK

**7. Explain** Why does the fish float in the middle of the water?

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Situation	Size of the buoyant force	Result
The object's weight is greater than the weight of the water it displaces.	less than the weight of the object	The object sinks.
The object's weight is equal to the weight of the water it displaces.	equal to the weight of the object	The object floats.
The object's weight is less than the weight of the water it displaces.	greater than the weight of the object	The object is buoyed up.

## How Does Density Affect Floating?

Remember that *density* is the mass of an object divided by its volume. An object will sink in a fluid if the object's density is greater than the density of the fluid. An object will float in a fluid if the object's density is less than the density of the fluid. If the fluid and the object have the same density, the object will be suspended in the fluid. ✓

### ✓ READING CHECK

8. **Define** What is density?

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Think again about the rock in the water. How does the density of the rock compare to the density of water? The volume of the rock is 5 L, and it displaces 5 L of water. The weight of the rock is 75 N, and the weight of 5 L of water is 50 N. The weight of an object is a measure of its mass. In the same volume, the rock has more mass than water. Therefore, the rock is more dense than water.

The rock sinks because it is denser than water. The duck floats because it is less dense than water. The fish floats suspended in the water because it has the same density as the water. ✓

### ✓ READING CHECK

9. **Explain** How does an object's density determine whether it floats or sinks?

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### MORE DENSE THAN AIR

Why does an ice cube float on water but not in air? An ice cube floats in water because it is less dense than water. However, most substances are more dense than air. The ice cube is more dense than air, so it does not float in air.

### LESS DENSE THAN AIR

One substance that is less dense than air is helium, a gas. When a balloon is filled with helium, the filled balloon becomes less dense than air. Therefore, the balloon floats in air, like the one in the figure below.



This balloon floats because the helium in it is less dense than air.

## TAKE A LOOK

10. **Infer** The balloon in the picture is filled with about 420,000 L of helium. Does 420,000 L of air have a greater or smaller mass than the 420,000 L of helium in the balloon? Explain your answer.

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## How Is Density Calculated?

To determine the density of an object, you need to know its mass and volume. Use the following equation:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Let's see how to do a density problem. Find the density of a rock that has a mass of 10 g and a volume of 2 cm<sup>3</sup>.

Step 1: Write the equation.  $\text{density} = \frac{\text{mass}}{\text{volume}}$

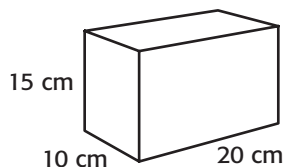
Step 2: Substitute and solve.  $d = \frac{10 \text{ g}}{2 \text{ cm}^3} = 5 \text{ g/cm}^3$

You can measure the mass of an object using a balance. To find its volume, use one of the methods below.

### FINDING VOLUME OF A RECTANGULAR SOLID

Some objects, such as shoeboxes, are shaped like cubes or rectangular blocks. To find the volume of one of these objects, use a ruler to measure the length of each side. Multiply the three lengths together to find the object's volume.

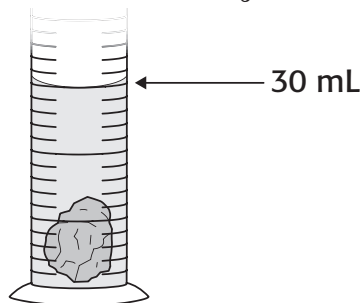
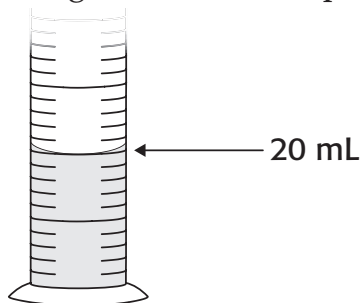
#### Volume of a Regular Solid



$$\begin{aligned} \text{length} \times \text{width} \times \text{height} &= \\ 20 \text{ cm} \times 10 \text{ cm} \times 15 \text{ cm} &= 3,000 \text{ cm}^3 \end{aligned}$$

### FINDING VOLUME OF AN IRREGULAR SOLID

Many things do not have a rectangular shape. You can find the volume of one of these objects using water displacement. To do this, place the object into a known volume of water. Then, measure how much the volume of the water changed when the object was added. The change in volume is equal to the volume of the object. ✓



You can find the volume of an irregular object by water displacement. The volume of the object in the figure is 10 mL.

## Math Focus

**11. Calculate** Find the density of a gold coin that has a mass of 180 g and a volume of 10 cm<sup>3</sup>.

### READING CHECK

**12. Explain** Why should you use water displacement to find the volume of an irregular solid?

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## What Affects an Object's Density?

The total density of an object can change if its mass or volume changes. If volume increases and mass stays the same, density decreases. If mass increases and volume stays the same, density increases.

### CHANGING SHAPE

Steel is almost eight times denser than water. Yet huge steel ships cruise the oceans with ease. If steel is more dense than water, how can these ships float? The reason a steel ship floats has to do with its shape. If the ship were just a big block of steel, it would sink very quickly. However, ships are built with a hollow shape. The hollow shape increases the volume that the steel takes up without increasing the mass of the steel.



A block of steel is denser than water, so it sinks. If that block is shaped into a hollow form, the overall density of the form is less than water. Therefore, the ship floats.

Increasing the volume of the steel produces a decrease in its density. When the volume of the ship becomes large enough, the overall density of the ship becomes less than water. Therefore, the ship floats. ✓

Most ships are built to displace more water than is necessary for the ship to float. Ships are made this way so that they won't sink when people and cargo are loaded onto the ship.

### CHANGING MASS

A submarine is a ship that can travel both on the surface of the water and underwater. Submarines have *ballast tanks* that can open to let seawater flow in. When seawater flows in, the mass of the submarine increases. Therefore, its overall density increases. When seawater is pushed out, the overall density of the submarine decreases.

### TAKE A LOOK

**13. Compare** What is the volume of the ship compared to the volume of the steel used to make the ship?

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### READING CHECK

**14. Explain** How can changing the shape of an object lower its overall density?

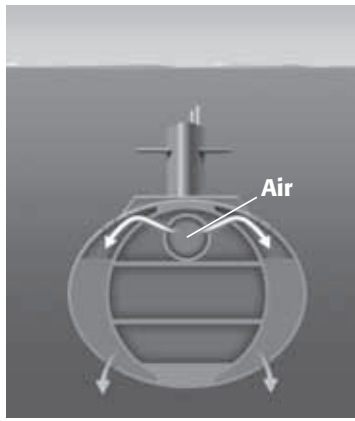
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Water flows into the ballast tanks. The submarine becomes more dense and sinks.



Compressed air forces water out of the ballast tanks. The submarine becomes less dense and floats to the surface.

## TAKE A LOOK

**15. Describe** How does a submarine increase its density?

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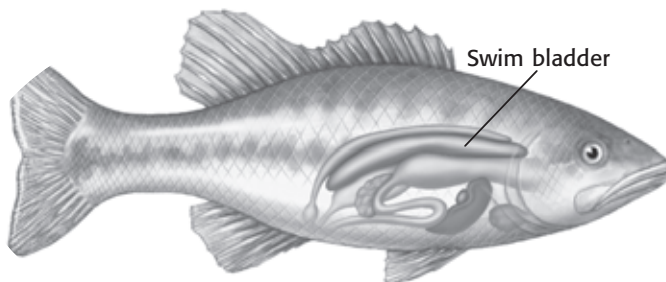


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## CHANGING VOLUME

Some fish can change their overall density by changing their volume. Most bony fish have an organ called a *swim bladder*. This swim bladder can fill with gases or release gases. The gases are less dense than the rest of the fish. When gases go into the swim bladder, the overall volume of the fish increases, but the mass of the fish does not change as much. This lowers the overall density of the fish and keeps it from sinking in the water. ✓

The fish's nervous system controls the amount of gas in the bladder. Some fish, such as sharks, do not have a swim bladder. These fish must swim constantly to keep from sinking.



Most bony fish have a swim bladder, an organ that allows them to adjust their overall density.

## ✓ READING CHECK

**16. Explain** How do most bony fish change their overall density?

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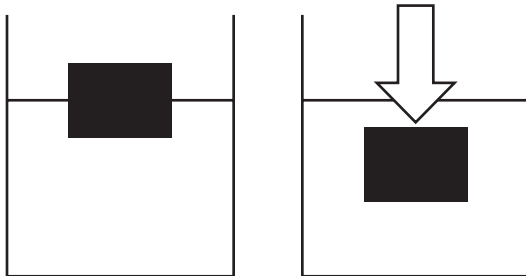
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## SECTION VOCABULARY

**Archimedes' principle** the principle that states that the buoyant force on an object in a fluid is an upward force equal to the weight of the volume of fluid that the object displaces

**buoyant force** the upward force that keeps an object immersed in or floating on a liquid

1. **Predict** In the left-hand figure, a block of wood is floating on the surface of some water. In the right-hand figure, the block of wood is pushed beneath the surface of the water. In the space below, predict what will happen to the wood when the force in the right-hand figure is removed. Use the term *buoyant force* in your answer.



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2. **Calculate** A container that is filled with mercury has a mass of 4,810 g. If the volume of the container is 355 mL, what is its overall density? Show your work. Round your answer to the nearest tenth.

3. **Identify** Give two ways that an object's overall density can change.

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4. **Explain** How can knowing an object's density help you to predict whether the object will float or sink in a fluid?

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