

# Buoyancy and Density

**Key Concept** Buoyant force and density affect whether an object will float or sink in a fluid.

## What You Will Learn

- All fluids exert an upward buoyant force on objects in the fluid.
- The buoyant force on an object is equal to the weight of the fluid displaced by the object.
- An object will float or sink depending on the relationship between the object's weight, buoyant force, and overall density.
- Density can be calculated from measurements of mass and volume. The overall density of an object can be changed by changing the object's shape, mass, or volume.

## Why It Matters

Understanding buoyant force and density will help you predict whether an object will float or sink in a fluid.

## Vocabulary

- buoyant force
- Archimedes' principle

## READING STRATEGY

**Graphic Organizer** In your **Science Journal**, create an Idea Wheel about the factors that affect density.



**8.8.a** Students know density is mass per unit volume.

**8.8.b** Students know how to calculate the density of substances (regular and irregular solids and liquids) from measurements of mass and volume.

**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.

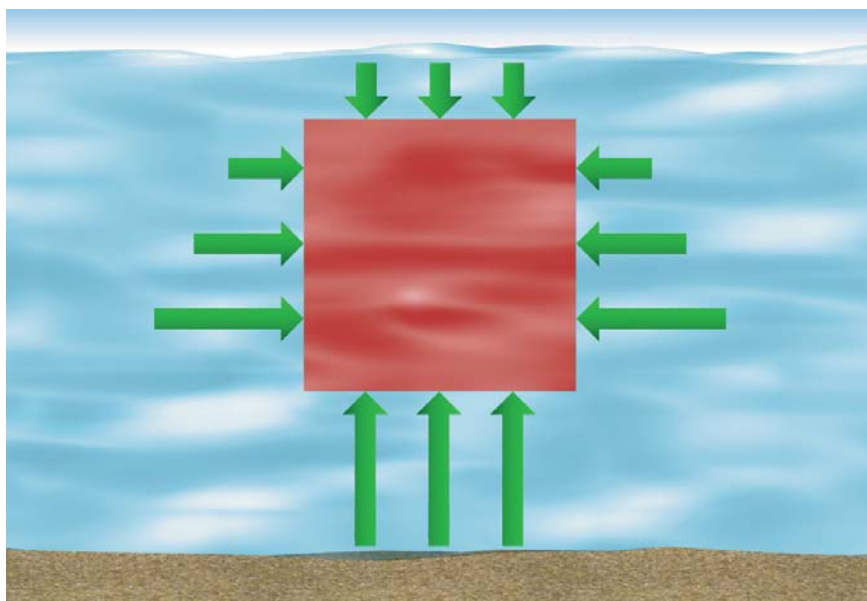
**8.8.d** Students know how to predict whether an object will float or sink.

► Why does ice float on water? Why doesn't it sink? Imagine that you use a straw to push an ice cube underwater. Then, you remove the straw. A force pushes the ice up to the water's surface. The force, called **buoyant force**, is the upward force that fluids exert on all matter.

## Buoyant Force and Fluid Pressure

Look at **Figure 1**. Water exerts fluid pressure on all sides of an object. The pressure that is applied horizontally on one side of the object is equal to the pressure applied on the other side. These equal pressures balance one another. So, the only fluid pressures that may change the net force on the object are at the top and at the bottom. Pressure increases as depth increases. So, the pressure at the bottom of the object is greater than the pressure at the top. This difference in pressure is shown by the different lengths of the arrows in **Figure 1**. The water applies a net upward force on the object. This upward force, which is caused by differences in pressure, is buoyant force.

**Standards Check** Why is the pressure at the bottom of an object in a fluid greater than the pressure at the top of the object? **8.8.c**



**Figure 1** There is more pressure at the bottom of an object because pressure increases with depth. This difference in pressure results in an upward buoyant force on the object.

## Quick Lab



### Finding the Buoyant Force

1. Use **string** to attach a ball of **modeling clay** to a **spring scale**. Record the weight of the clay.
2. Slowly lower the clay into a **tub** filled with **water**. Do not let the spring scale get wet. Record how the reading changes as the clay enters the water.
3. Record the reading on the scale when the clay is completely underwater.
4. Explain why the reading changed as the clay entered the water.
5. Calculate the buoyant force when the clay was completely underwater.
6. How does the buoyant force relate to the water that was displaced by the clay?




8.8.c

 15 min

### Determining Buoyant Force

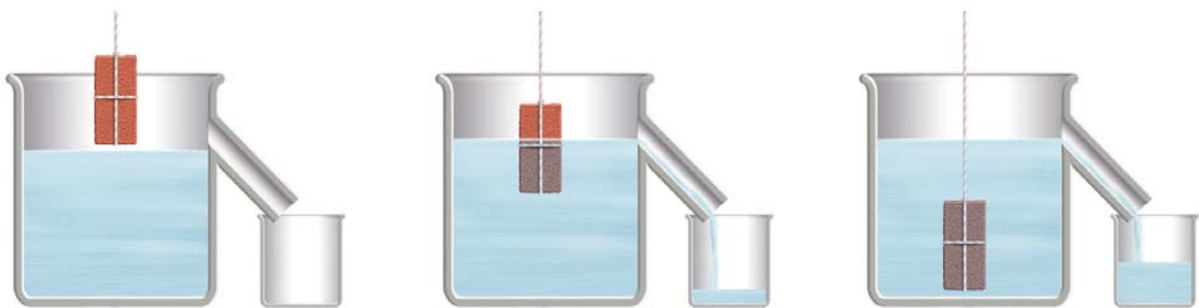
Archimedes (AHR kuh MEE DEEZ) was a Greek mathematician who lived in the third century BCE. He discovered how to find buoyant force. **Archimedes' principle** states that the buoyant force on an object in a fluid is an upward force equal to the weight of the fluid that the object takes the place of, or *displaces*. Suppose the block in **Figure 2** displaces 250 mL of water. The weight of 250 mL of water is about 2.5 N. The weight of the displaced water is equal to the buoyant force acting on the block. So, the buoyant force on the block is 2.5 N. Notice that you need to know only the weight of the water that is displaced to find the buoyant force. You do not need to know the weight of the block. But in order to predict if an object will float or sink, you need to consider the weights of both the displaced water and the object.

**Standards Check** Explain how displacement is used to determine buoyant force.  8.8.c

**buoyant force** (BOY uhnt FAWRS) the upward force that keeps an object immersed in or floating on a liquid

**Archimedes' principle** (AHR kuh MEE DEEZ PRIN suh puhl) 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

**Wordwise displace**  
The prefix *dis-* means "away" or "in different directions."



**Figure 2** As a block is lowered into a container of water, the block displaces a certain volume of water. Then, this same volume of water flows into a smaller container. **What does the weight of displaced water in the smaller container represent?**

## Weight Versus Buoyant Force

An object in a fluid will sink if the object's weight is greater than the buoyant force (the weight of the fluid that the object displaces). An object floats only when the buoyant force on the object is equal to the object's weight.

### Sinking

The rock in **Figure 3** weighs 75 N. It displaces 5 L of water. Archimedes' principle states that the buoyant force is equal to the weight of the displaced water—about 50 N. The rock's weight is greater than the buoyant force. So, the rock sinks.

### Floating

The fish in **Figure 3** weighs 12 N. It displaces a volume of water that weighs 12 N. Because the fish's weight is equal to the buoyant force, the fish floats in the water. In fact, the fish is suspended in the water as it floats.

Now, look at the duck. The duck weighs 9 N. The duck floats. So, the buoyant force on the duck must equal 9 N. But only part of the duck has to be below the surface to displace 9 N of water. So, the duck floats on the surface of the water.

### Buoying Up

If it dives underwater, the duck will displace more than 9 N of water. So, the buoyant force on the duck will be greater than the duck's weight. When the buoyant force on the duck is greater than the duck's weight, the duck is *buoyed up* (pushed up). An object is buoyed up until the part of the object underwater displaces an amount of water that equals the object's entire weight. Thus, an ice cube pops to the surface when it is pushed to the bottom of a glass of water.

**Standards Check** What causes an object to buoy up? 🏠 8.8.c

## SCHOOL to HOME

### Floating Fun

Fill a sink with water. Ask an adult to help you find five things that float in water and five things that sink in water. Discuss what the floating objects have in common and what the sinking objects have in common. In your **Science Journal**, list the objects and summarize your discussion.

### ACTIVITY

**Figure 3** Will an object sink or float? The answer depends on the amount of buoyant force in relation to the object's weight.

Weight = 12 N  
Buoyant force = 12 N  
**Fish floats and is suspended in the water.**



Weight = 9 N  
Buoyant force = 9 N  
**Duck floats on the surface.**



Weight = 75 N  
Buoyant force = 50 N  
**Rock sinks.**



## Density and Floating

Think again about the rock in the lake. The rock displaces 5 L of water. But volumes of solids are measured in cubic centimeters ( $\text{cm}^3$ ). Because 1 mL is equal to 1  $\text{cm}^3$ , the volume of the rock is 5,000  $\text{cm}^3$ . But 5,000  $\text{cm}^3$  of rock weighs more than an equal volume of water. So, the rock sinks. Because mass is proportional to weight, you can say that the rock has more mass per volume than water has. Mass per unit volume is density. The rock sinks because it is denser than water. The duck floats because it is less dense than water is. The density of the fish is equal to the density of the water.

**Standards Check** Explain why volume and mass affect whether an object will sink or float in water. 🐸 8.8.a, 8.8.d

### More Dense Than Air

Why does an ice cube float on water but not in air? An ice cube floats on water because ice is less dense than water. But most substances are *more* dense than air. So, there are few substances that float in air. An ice cube is more dense than air, so ice doesn't float in air.

### Less Dense Than Air

One substance that is less dense than air is helium, a gas. In fact, helium has one-seventh the density of air under normal conditions. So, helium floats in air. Because it floats in air, helium is used in parade balloons, such as the one shown in **Figure 4**.



**Figure 4** Helium in a balloon floats in air for the same reason that an ice cube floats on water: the helium is less dense than the surrounding fluid.

## MATH FOCUS

### Finding Density

Find the density of a rock that has a mass of 10 g and a volume of 2  $\text{cm}^3$ .

**Step 1:** Write the equation for density. Density is calculated by using this equation:

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

**Step 2:** Replace mass and volume with the values in the problem, and solve.

$$\text{density} = \frac{10 \text{ g}}{2 \text{ cm}^3} = 5 \text{ g/cm}^3$$

### Now It's Your Turn

1. What is the density of a 20  $\text{cm}^3$  object that has a mass of 25 g?
2. A 546 g fish displaces 420 mL of water. What is the density of the fish? (Note: 1 mL = 1  $\text{cm}^3$ .)
3. A beaker holds 50 mL of a slimy green liquid. The mass of the liquid is 163 g. What is the density of the liquid?

## INTERNET ACTIVITY

### Trapped with No Bottle

You are stranded on a desert island and want to send a distress message in a bottle. But you do not have any bottles! Go to [go.hrw.com](http://go.hrw.com), and type in the keyword HY7FLUW.

## Determining Density


To determine the density of an object, you need to know the object's mass and volume. You can use a balance to measure the mass of an object. But finding the volume of the object takes a little more work.

### Volume of a Regular Solid

Some solids, such as cubes or rectangular blocks, have regular shapes. To find the volume of one of these objects, use a ruler to measure the length of each side. Then, multiply the three lengths together to find the volume of the object.

### Volume of an Irregular Solid

Many things do not have a regular shape. So, you cannot easily calculate the volume of these objects. Instead, you can find the volume through water displacement. By measuring the volume of water that the object pushes aside, you find the volume of the object itself.

**Standards Check** Compare the methods for finding the volume of a regular solid and the volume of an irregular solid.  8.8.b

## Quick Lab



### Will It Sink or Float?

In this activity, you will predict whether an object will sink or float, plan a procedure to determine the density of the object, and test your prediction.

#### ► Try It!

1. Examine a **regular solid**.
2. Predict whether the object will sink or float in water.
3. Plan an investigation to determine the density of the object and to test your prediction. Materials that may be helpful include a **metric ruler**, a **balance**, an appropriate formula for volume, a **plastic tub**, and **water**.
4. Record the steps that you plan to follow, and show your procedure to your teacher. If your procedure is approved, conduct your investigation. Record all of your data.



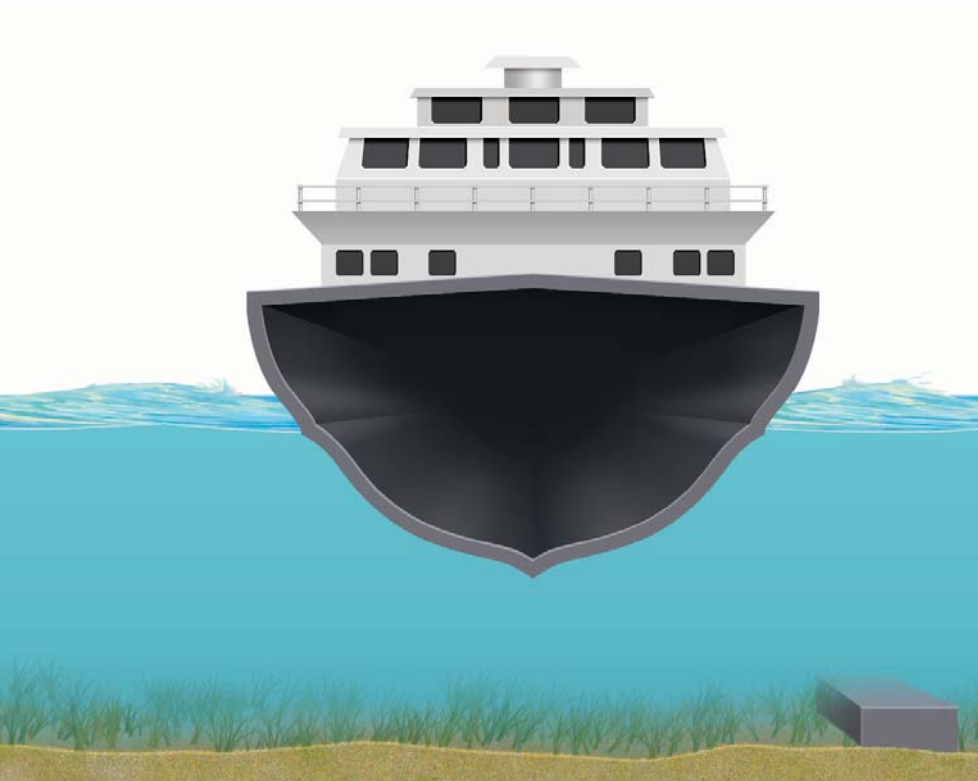
8.8.a  
8.8.b  
8.8.d  
8.9.a  
8.9.b  
8.9.f

#### ► Think About It!

5. Was your prediction correct?
6. Explain how you can use densities to better predict whether an object will sink or float in a fluid.
7. Evaluate the accuracy of your data based on how the solid behaved when placed in water.



25 min



**Figure 5** A block of steel is denser than water, so the block sinks. But shaping that block of steel into a hollow form results in less overall density. So, the ship floats.

## Changing Overall Density

Steel is almost 8 times denser than water. Yet huge steel ships cruise the oceans with ease. But hold on! You just learned that substances that are denser than water will sink in water. So, how does a steel ship float?

### Changing the Shape

The secret of how a ship floats is in the shape of the ship, as shown in **Figure 5**. What if a ship were just a big block of steel? If you put that block into water, the block would sink because it is denser than water. So, ships are built with a hollow shape. Imagine that the amount of steel in the ship is equal to the amount in the block. The hollow shape increases the volume of the ship. Remember that density is mass per unit volume. As volume increases, density decreases if the mass stays the same. So, an increase in the ship's volume leads to a decrease in the ship's density. Thus, ships made of steel float because their *overall density* is less than the density of water.

Most ships are built to displace more water than is necessary for the ships to float. Ships are made this way so that they will not sink when people and cargo are loaded on the ships.

## Quick Lab



8.8.a  
8.8.d

### Ship Shape

1. Roll a **piece of clay** into a ball the size of a golf ball, and drop it into a **container of water**. Record your observations.
2. With your hands, flatten the ball of clay until it is a bit thinner than your little finger, and press it into the shape of a bowl or canoe.
3. Gently place the clay boat in the water. Record your observations.
4. How does the change of shape affect the buoyant force on the clay? How is that change related to the overall density of the clay boat? Record your answers.



15 min

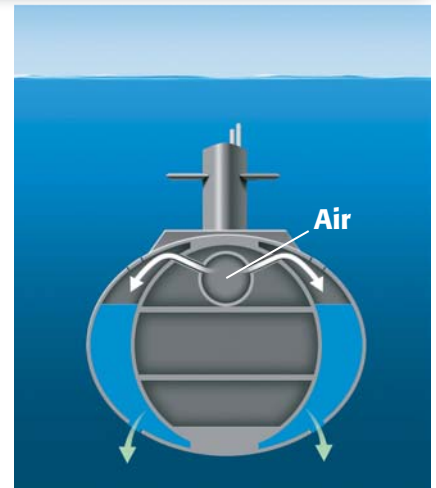
**Figure 6** Controlling Density Using Ballast Tanks



When a submarine is floating on the ocean's surface, its ballast tanks are filled mostly with air.



Vent holes on the ballast tanks are opened to allow the submarine to dive. Air escapes as the tanks fill with water.



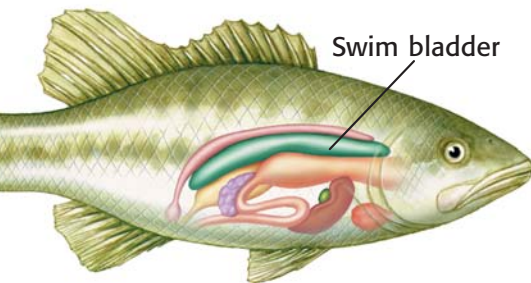
Vent holes are closed, and compressed air is pumped into the ballast tanks to force the water out, so the submarine rises.

### Changing the Mass

A submarine is a special kind of ship that can travel both on the surface of the water and underwater. Submarines have *ballast tanks* that can be opened to allow sea water to flow in. As water is added, the submarine's mass increases, but its volume stays the same. The submarine's overall density increases so that it can dive under the surface. Crew members control the amount of water taken in. In this way, they control how dense the submarine is and how deep it dives. Compressed air is used to blow the water out of the tanks so that the submarine can rise. Study **Figure 6** to learn how ballast tanks work.

### Changing the Volume

Like a submarine, some fish adjust their overall density to stay at a certain depth in the water. Most bony fishes have an organ called a *swim bladder*, shown in **Figure 7**. This swim bladder is filled with gases that are produced in a fish's blood. The inflated swim bladder increases the fish's volume, which decreases the fish's overall density. Thus, the fish does not sink 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.



**Figure 7** Most bony fishes have an organ called a swim bladder that allows them to adjust their overall density.

**Standards Check** How does a swim bladder enable a fish to float?

 8.8.d