Chapter 5

Density and Buoyancy

You read about heat in Chapter 4. In this chapter, you'll learn a little more about heat and learn about two new concepts—*density* and *buoyancy*. Take a guess at what these terms mean. You may have heard them before. Here are a couple of hints: Density helps explain why a piece of steel sinks in water and a beach ball floats. And, buoyancy explains why a huge piece of steel in the shape of a ship floats!

Key Questions

1. ***How does the density of a block of steel compare to the density of a steel boat?***

2. ***Why do beach balls float?***

3. ***How does a scuba diver sink and float?***

5.1 Density

It's impossible for a person to lift real boulders because they're so heavy (Figure 5.1). However, in the movies, superheroes move huge boulders all the time. And at the end of a scene, a stagehand can pick up the boulder and carry it away under one arm. How is this possible?

Mass and weight

Mass is the amount of matter in an object

Can you lift a huge boulder? You could if the boulder was made of plastic foam! A fake boulder has much less mass than a real boulder, even when both boulders are the same size. *Mass* is the amount of matter in an object. Remember, in the SI Units measurement system, mass is measured in kilograms and grams. A kilogram is 1,000 times bigger than a gram. While kilograms are used to measure the mass of boulders, grams are used to measure small objects. You will usually use the gram unit in science class.

Mass vs. weight

What is the mass of your body? You are probably familiar with measuring your weight, but not your mass. Mass and weight are not the same thing. *Mass* is the amount of matter in an object. *Weight* is a measure of the pulling force of gravity on mass. In the English system, weight is measured in pounds. The SI unit is called a *newton*. It takes 4.448 newtons to make one pound. You can think of a newton as a little less than a quarter-pound.

Weight on other planets

The force of gravity is different on every planet in our solar system. As a result, your weight would change if you visited another planet. A boy who weighs 445 newtons (100 pounds) on Earth would weigh 1,125 newtons on Jupiter! However, his mass stays the same on both planets (Figure 5.2). This is because mass measures the amount of matter a body contains, not how much that matter is pulled by gravity.

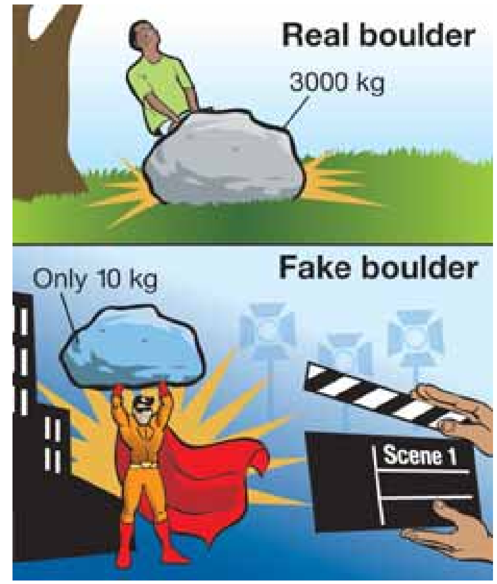


Figure 5.1: *A real boulder versus a fake boulder.*

	Mass (kg)	Weight (newtons)
Earth	45.5	445
Jupiter	45.5	1,125

Figure 5.2: *Mass versus weight on Earth and Jupiter. Weight changes from place to place, but mass stays the same.*

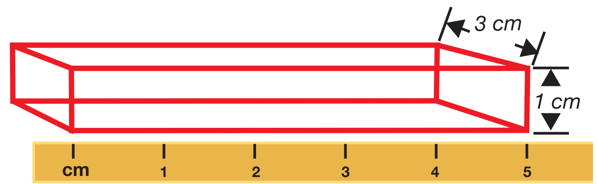
Volume

A solid cube or rectangle

Volume is the space that something takes up. To find the volume of a solid cube or rectangle, you measure the length, width, and height of the object. Then you multiply the length, width, and height together. If your measurements are in centimeters, the volume unit will be cubic centimeters, or cm^3.

Volume of a rectangular box:

$5\ cm \times 3\ cm \times 1\ cm = 15\ cm^3$



Odd-shaped objects

You can find the volume of an odd-shaped object, like a key, by placing it in water. This is often done in a container called a *graduated cylinder*. First, the volume of water in the graduated cylinder is noted. Then, the key is placed in the graduated cylinder. The key pushes aside an amount of water equal to its volume, causing the water level to rise. The volume of the key is equal to the volume of the water with the key in it (28 mL) minus the volume of the water without the key (25 mL).

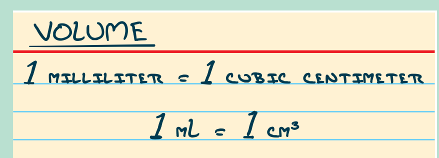
What is the volume of the key?

SOLVE IT!

On Great Skies Airlines a carry-on suitcase can be no more than 12 kg and 30,000 cm^3. Does the following suitcase qualify as a carry-on? Explain your answer.

STUDY SKILLS

Remember important information by writing it down on flash cards.



Keep your flash cards with you so that you can study them when you have free time.

Density

What is density? Think again about the fake boulder mentioned earlier. A fake boulder has to have the same volume as a real boulder, so it will look realistic. However, for a person to be able to lift the fake boulder, it must have a much lower mass than a real boulder. **Density** is the word used to describe the comparison between an object's mass and its volume. Specifically, density is the mass of an object divided by the volume of the object. A real boulder has a greater density than a fake boulder made of plastic foam.

Density depends on two things All matter is made of tiny particles called atoms. The density of a material depends on two things:

1. The mass of each atom or molecule that makes up the material.
2. The volume or amount of space the material takes up. This is related to how closely the atoms or molecules are "packed" in the material.

A material like plastic foam has low density. Plastic foam has individual molecules that are low in mass and not packed very close together. Additionally, plastic foam has air pockets. A material like rock has individual molecules that are higher in mass than the atoms of plastic foam, and they are packed more closely to one another. This means rock has a higher density than plastic foam (Figure 5.3).

Solids, liquids, and gases Like solid objects, liquids and gases are made up of atoms and molecules and have mass and volume. As with solids, you can find the density of a liquid or a gas too!

VOCABULARY

density - the mass of an object divided by the object's volume.

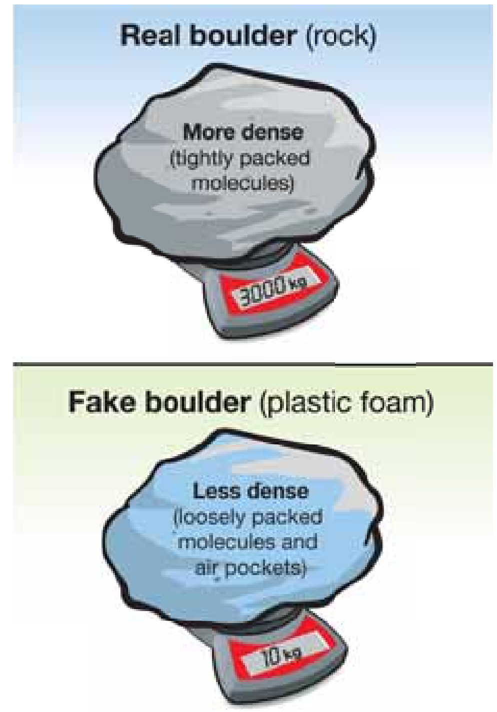


Figure 5.3: *The density of a real boulder is greater than the density of a fake boulder.*

Finding density

Doing the math

The density of an object is found by measuring the object's mass and volume then dividing the mass by the volume. Division can be shown with a slash mark (/). The slash is read as the word "per." A density of 2.7 g/cm^3 is read as: two point seven grams per cubic centimeter.

DENSITY

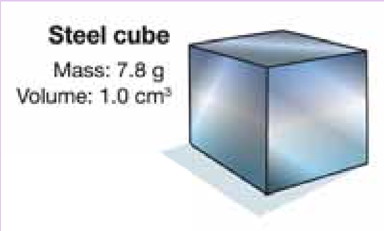
Density (g/cm^3) → $$D = \frac{m}{V}$$ ← *Mass* (g), ← *Volume* (cm^3)

What is the density of an aluminum metal block that has a mass of 27.0 g and a volume of 10.0 cm^3?

D = m/V
D = 27.0 g/10.0 cm^3
D = 2.7 g/cm^3

SOLVE IT!

Use the mass and volume data for a steel cube and a steel nail to calculate the density of these objects.



How does the density of the steel cube compare to the density of the steel nail?

The density of a material is always the same

The density of a material is always the same under the same conditions. This is true regardless of how much of the material you have. For example, the density of aluminum metal is always 2.7 g/cm^3. Aluminum foil, aluminum wire, or an aluminum brick all have the same density. This is true as long as you have a sample of aluminum metal that is not hollow and does not have any other materials mixed with it.

5.1 Section Review

1. How does measuring mass differ from measuring the weight of an object?
2. On Earth a package weighs 19.6 newtons. What is the mass of this package on Earth? (Hint: On Earth, 1 kilogram weighs 9.8 newtons.)
3. Imagine you could mail this package to Neptune. What would the mass of the package be on Neptune?
4. What is the volume of a solid rectangle with dimensions of 2 cm × 5 cm × 8 cm?
5. The volume of water in a graduated cylinder is 88 mL. After a small object is placed in the cylinder, the volume increases to 100 mL. What is the volume of the object? First give your answer in milliliters, then in cubic centimeters.
6. Density relates what two measurements to each other?
7. What is the density of an object with a mass of 35 grams and a volume of 7 cm^3?
8. Will the density of a material always be the same, regardless of its size? If so, why?
9. Use Table 5.1 to help you answer the following questions.
   a. The volume of 100 grams of a substance is 100 milliliters. Calculate the density. What might this substance be?
   b. The volume of 5 grams of a substance is 2 cm^3. Calculate the density. What might this substance be?
   c. What is the volume of 10 grams of air?

Table 5.1: Densities of common materials

	Rock (granite)	Water	Air
Average density (g/cm^3)	2.5	1.0	0.001

Very dense wood!

Tabebuia trees, commonly called "Ipe" (pronounced e-pay), grow in the Amazon rainforest. The wood of these trees is extremely hard and dense. In fact, *Tabebuia* wood is so dense that it sinks in water. A single plank can have a mass of as much as 159 kilograms. That's more than the mass of an average household refrigerator (about 100 kilograms)!.

Tabebuia trees grow in the Amazon Rainforest.
Photo: Don Deering, NASA/LBA Project

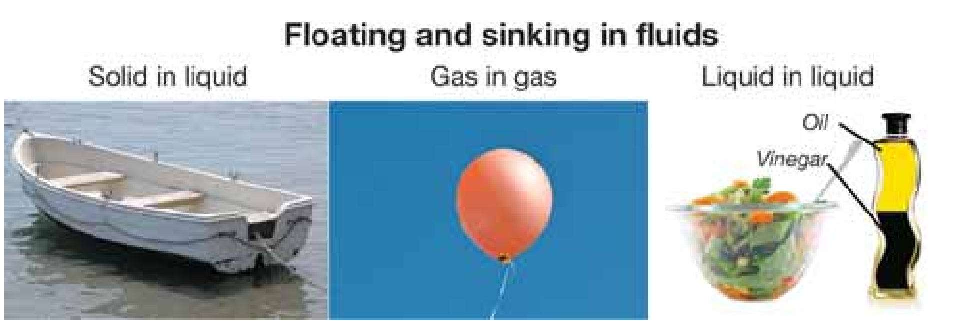
5.2 Buoyancy

Why do some things float and others sink? Ice cubes can float in a glass of water, but a pebble will sink. People usually float in water, but scuba divers can sink to different depths to explore a coral reef or a sunken ship. What causes things to float and sink?

Floating and sinking

Fluids Matter that can flow is called a **fluid**. "Fluid" does not mean the same thing as "liquid." Liquids and gases are both fluids. Under the right conditions, solid matter that is made of small particles also can flow. The ground shaking during an earthquake can turn soil into a fluid! When this happens, cars and other solid objects can sink into the ground.

Solids, liquids, and gases can float and sink We are used to talking about a solid object, like a boat, floating or sinking in a fluid like water. Figure 5.4 gives examples of objects that help people float safely in water. But other examples of floating and sinking exist. Vinegar sinks to the bottom of a bottle of oil-and-vinegar salad dressing. This is a liquid-in-a-liquid example of sinking. A balloon filled with helium gas floats in air. This is a gas-in-a-gas example of floating.



VOCABULARY

fluid - matter that can flow, usually a liquid or a gas.

MY JOURNAL

Make a list of five objects (all made of different materials) that float in water, and a list of five objects (all made of different materials) that sink in water.

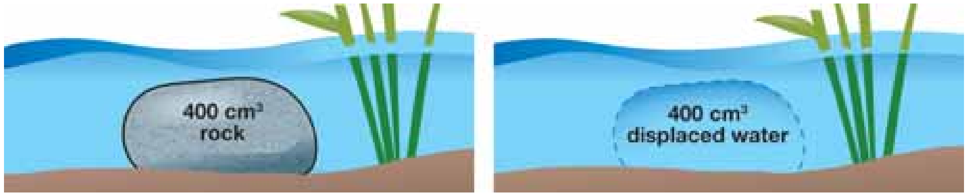
Several ways to help people float better in the water

Figure 5.4: *A foam life preserver, a life vest, and a raft all help people float!*

Sinking and buoyant force

A 400 cm^3 rock displaces 400 cm^3 of water

The illustration below shows a 400 cm^3 rock that has sunk to the bottom of a pond. When the rock is completely underwater, it displaces (pushes aside) an amount of water that is equal to its volume. The rock displaces 400 cm^3 of water.

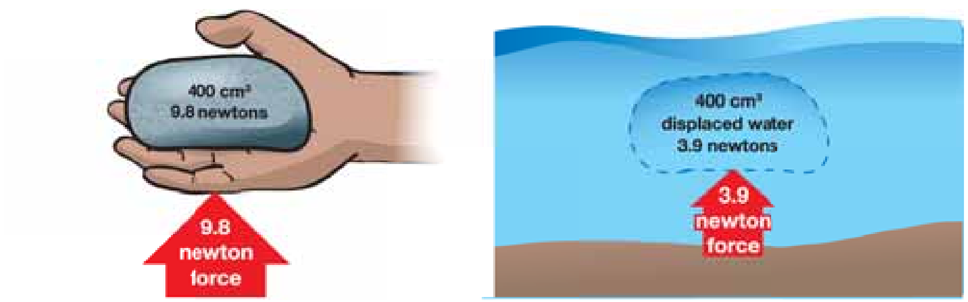


The rock weighs 9.8 newtons

On Earth, this 400 cm^3 rock weighs 9.8 newtons. This means that if you are holding the rock, you use 9.8 newtons of force to support it so it doesn't fall to the ground.

The water weighs 3.9 newtons

On Earth, the 400 cm^3 of water displaced by the rock weighs 3.9 newtons. This means that it takes 3.9 newtons of force to support the displaced water.



The water pushes on the rock with a 3.9 newton force

When the rock is dropped into water, the water pushes back on the rock with a force *equal to the weight* of the displaced water. The upward force shown in Figure 5.5 is called **buoyant force**. The buoyant force is always equal to the weight of the displaced fluid.

Why does the rock sink?

The rock sinks because its weight is greater than the displaced water's weight. The 9.8-newton downward force acting on the rock is greater than the water's 3.9-newton upward force.

VOCABULARY

buoyant force - an upward lifting force that acts on an object when it pushes aside a fluid.

Figure 5.5: *The buoyant force of the water displaced by this rock is not enough to support it so that it floats. Therefore, the rock sinks!*

Floating

A beach ball

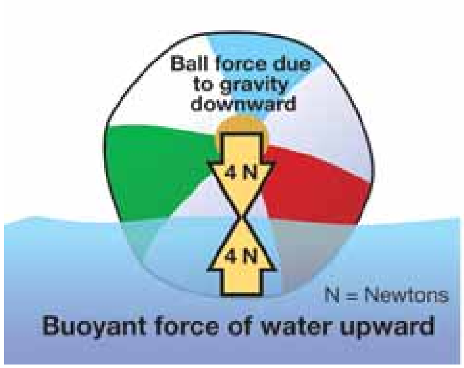
It is nearly impossible to get on top of a floating beach ball in a swimming pool. It takes a lot of weight to push it underwater. Why do you need to work so hard to push a beach ball underwater?

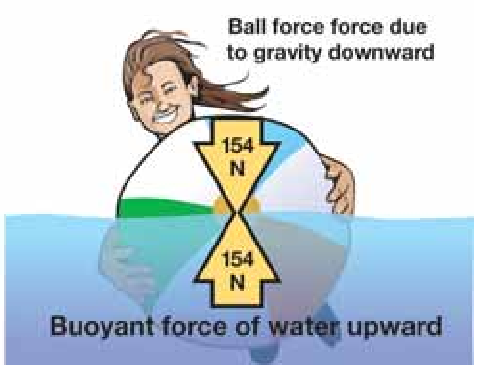
Why does a beach ball float?

A beach ball seems to float on top of the water. In other words, it does not displace a lot of water. Why? The answer is easy. The weight of the ball is small. Therefore, the amount of water that needs to be displaced (to provide enough upward buoyant force to keep it afloat) is also small.

How do you get a beach ball underwater?

If you pushed a large beach ball completely underwater, it would displace a volume of water equal to about 30,000 cm^3! This amount of water weighs 294 newtons. If the beach ball weighs only 4 newtons, you need to push down with at least 290 newtons (about 65 pounds) of your weight to get the ball underwater! In the example below, the girl is pushing down with only 150 newtons of weight so the beach ball is still partially above water. Keep in mind that any object or material floats if it pushes aside enough water to give an upward buoyant force that supports its weight.

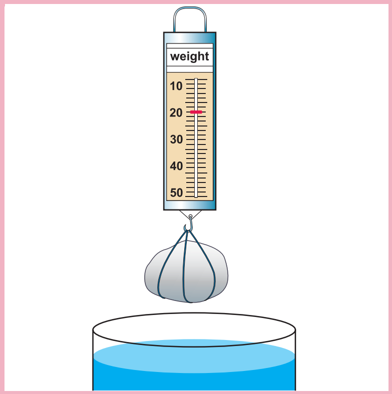




CHALLENGE

Try this!

1. Tie a piece of string around a rock and hang it from a spring scale.



2. Record the weight of the rock.

3. Lower the rock (still attached to the spring scale) into a container of water. Make sure the rock is underwater, but not touching the sides or bottom of the container.

4. Now, record the weight of the rock.

5. Compare the two weight measurements.

What happened? Explain why the scale reads differently when the rock is in the water. Use the term **buoyant force** in your answer.

Buoyancy and density

Review floating and sinking

What determines whether an object will float or sink? Look back at the beach ball and rock examples. What happens to an object depends on the object's weight and how much fluid it displaces.

The density connection

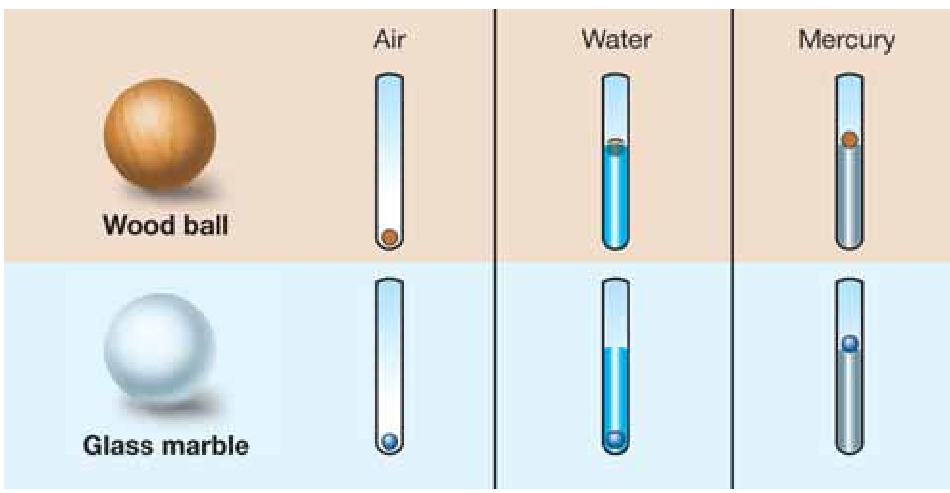
The amount of fluid pushed aside by an object (buoyancy) depends on the space an object takes up (its volume). You already know that density depends on mass and volume (D = m/V), so there must be a connection between buoyancy and density.

Floating, sinking, and density

Examine each test tube in the graphic below to determine whether the object sank or floated. Density values for wood, glass, water, and mercury are listed in Figure 5.6. Complete these sentences to make two rules that use density to predict floating or sinking.

1. When an object is *less dense* than the fluid it is in, the object will __________ (sink/float).

2. When an object is *more dense* than the fluid it is in, the object will __________ (sink/float).



	Density (g/cm^3)
air	0.001
wood	0.9
water	1.0
glass	2.3
mercury	11.0

Figure 5.6: *Density values for common materials*

STUDY SKILLS

Draw your own diagrams!

If you have a lot of information to keep track of in a problem, it helps to make a drawing to organize your thoughts.

For example, make your own sketch of the diagram at the left. Label each object and fluid on your sketch with the density values from Table 5.2. This will make it easier for you to compare the objects and fluids, and complete the two rules.

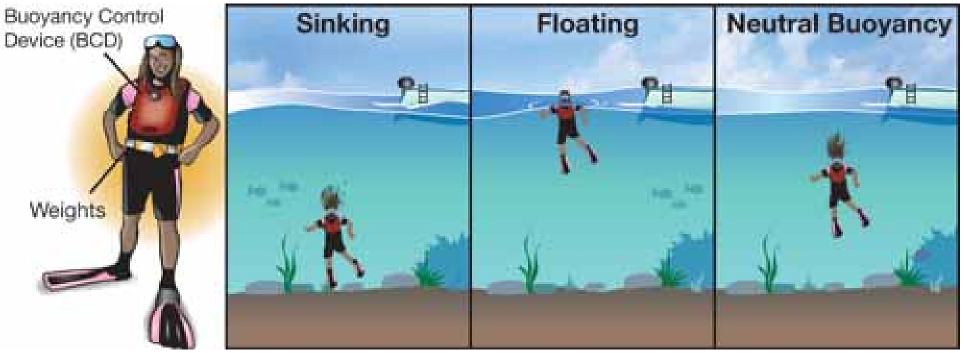
Rules for floating and sinking

What happened? Low-density objects have a *large volume* for their mass. If a low-density object is placed in a higher-density fluid, it will be able to push aside enough fluid so it can float. High-density objects have a *small volume* for their mass. If a high-density object is placed in a lower-density fluid, it will not be able to push aside enough fluid to float.

The rules When an object is:

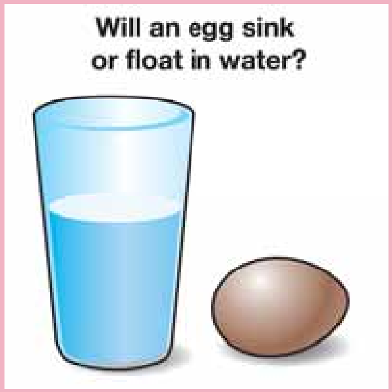
1. *less dense* than the fluid it is in, the object will **float**.
2. *more dense* than the fluid it is in, the object will **sink**.

Neutral buoyancy A scuba diver uses a buoyancy control device (BCD) to sink or float in water. To sink, a scuba diver releases air from the BCD to decrease her volume. This *reduces* her buoyant force and makes her *more dense*. To rise to the water's surface, she has to become *less dense* by *increasing* her buoyant force. So, she increases her volume by filling her BCD with air from her scuba tank. She can stay in one place underwater if she has *neutral buoyancy*. This means she has the same density as the water around her! She can be neutrally buoyant by controlling the amount of air in her BCD.



CHALLENGE

An "Eggs-periment"



1. Place a egg (uncooked and in its shell) in a wide-mouth glass containing $1^{1}/_{4}$ cup of warm* tap water.
2. Does the egg sink or float?
3. Remove the egg and add three tablespoons of salt to the warm tap water. Stir until the salt has dissolved.
4. Place the egg back into the glass of water.
5. Does the egg sink or float?

Explain your results by using the density prediction rules for floating and sinking.

*Using warm water the salt dissolve in step 3.

5.2 Section Review

1. Define the term "fluid." Which of the follow substances are fluids?

a. light	b. concrete	c. water
d. air	e. orange juice	f. helium

2. Give an example of an object (solid, liquid, or gas) that floats on a fluid.
3. What is buoyancy? Against what other force does it act?
4. A 10-newton object displaces 12 newtons of water. Will this object sink or float?
5. Ben's model boat weighs 4 newtons. When he places it in the water it sinks! Explain what happened and what he can do to make it boat float.
6. What makes an object float rather than sink? Answer this question using the terms weight and buoyant force. Then, answer in terms of the density of the object and the density of the fluid.
7. A beach ball that is full of air floats in a swimming pool. However, a ball that is not inflated sinks to the bottom of the pool. Why?
8. In order for an object to have neutral buoyancy, what would the relationship between the density of the object and the density of the fluid have to be?
9. Research questions:
   a. If you went for a swim in the Dead Sea in Israel, you would discover that it is very easy to float! Find out why.
   b. What percent of an iceberg is below water and why?

SOLVE IT!

National Concrete Canoe Competition

Concrete is a heavy construction material made from sand, gravel, and stone. If you toss a piece of concrete into a pond, it sinks. So, how can you make concrete float? The American Society of Civil Engineers (ASCE) sponsors an annual contest for college-level engineering students. The goal is to build a concrete canoe that displaces enough water so that up to four adults can be in it without it sinking. The contestants race the canoes to win scholarships. To make concrete float, it must be shaped so that it pushes aside enough water to create enough buoyant force to support the boat's weight.

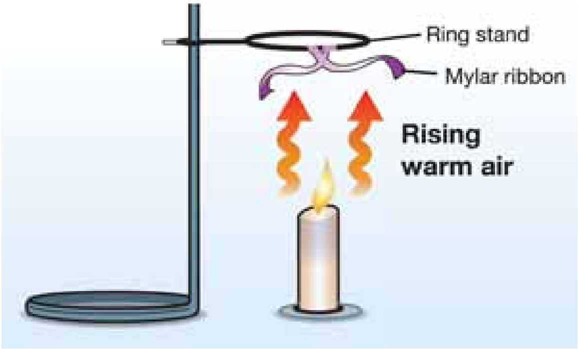
Make a sketch that explains why a block of concrete sinks, but a concrete canoe floats!

5.3 Heat Affects Density and Buoyancy

How does a hot-air balloon float? The word “hot” is important. See if you can explain how hot-air balloons can float after you read this section. Hint: Helium isn’t involved!

Warm air

Warm air from a candle Look at the picture of the candle below. As the candle burns, the ribbons of mylar (the shiny, thin material that is often used to make silvery birthday balloons) mysteriously flutter and move. If you try this experiment, make sure the mylar is placed far enough from the candle so it doesn’t burn!



A mystery Why do the mylar ribbons move when there is no breeze from an open window or a fan? The candle simply sits there, warming the air around it. Look at Figure 5.7. The carousel moves using only the heat from candles too. How?

Mystery solved—warm air rises The air above a candle feels warmer than the air below the table on which it has been placed. Therefore, warm air must move upward. Mystery solved! In the graphic above, the current of rising warm air causes the mylar ribbons to move. In Figure 5.7, the current of rising warm air causes the fan to move. The first mystery is solved, but now there is a new mystery—why does warm air rise?

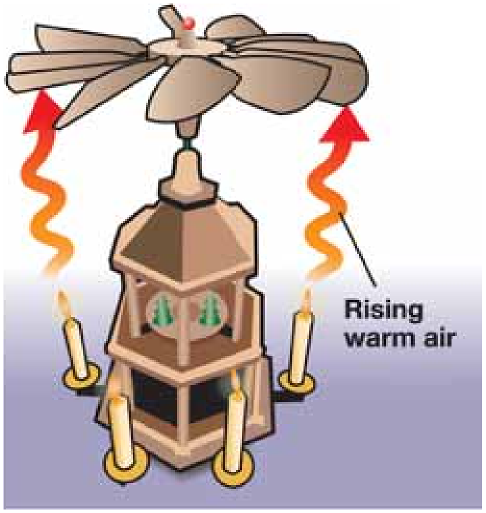


Figure 5.7: *How does a candle carousel work? The burning candles heat the air. The warmed air rises and encounters the wooden paddles of the fan. The fan turns. Since the base of the carousel is connected to the fan, it also turns, like a carousel or merry-go-round. Important: This type of decoration can never be left unattended!*

Why does warm air rise?

Warm air is less dense Since warm air rises, the warm air must float on top of the cooler air. Therefore, we know the density of warm air is *less than* the density of cool air.

Mass or volume? You know that density is the relationship between the mass and the volume of matter. In the examples on the previous page, the burning candle warmed the air around the flame so that the air became less dense than the cool air. To make the density of any material smaller, you would need to either make the mass smaller, or make the volume bigger. So, did the burning candle *decrease the mass* or *increase the volume* of the warm air so that it became less dense than the cool air?

Fast-moving warm air molecules Warm air molecules move faster than cool air molecules. Faster-moving warm molecules push against each other with more force than cold molecules. This causes warm molecules to be pushed farther apart. Warm molecules that have been pushed farther apart take up more space. We know that volume is the space that atoms take up so we now have the answer to our question. The burning candle *increased the volume* of the warm air, making it less dense. This is why warm air rises.

Earth's enormous energy We have just studied an example of heat affecting air density in a simple candle system. We studied it in detail because, as you will learn, this process is also at the heart of many important Earth systems. In our candle example, the energy source was a candle flame. On the surface of Earth, the Sun is the energy source and it can affect wind and weather. Below the surface, heat from the Earth's core drives the movement of large pieces of Earth's crust. These Earth systems are huge and involve enormous energy, but they work much like the simple candle system. The same rules of buoyancy, density, and heat energy apply!

Blimps: No Hot Air!

Have you ever seen a blimp in the sky, or have you seen one on television? Do you know how a blimp stays in the air? If you guessed that the blimp floats because the gas inside it is less dense than the surrounding air, you're right! Hot-air balloons heat up ordinary air molecules to make them less dense so the balloon can float. Blimps, however, don't use warm air. A blimp is filled with helium (a gaseous element)! Helium gas has the same volume, but less mass, than regular air. That's why helium floats in air.

5.3 Section Review

1. Which is less dense, warm air or cool air? What does your answer tell you about how warm air and cool air will move relative to each other?
2. An empty party balloon will float to the ceiling of a room once it is filled with helium.
   a. What does this tell you about the density of air in the room compared to the density of helium?
   b. For the balloon to float in air, what two factors might have changed about the balloon?
3. Why does a group of warmer atoms take up more volume than a group of cooler atoms?
4. Name the two energy sources for Earth's systems.
5. Write a paragraph that explains why hot-air balloons float.
   a. Once you have written your paragraph, compare it to the list of information on the right. How did you do?
   b. Use the list of steps at the right and your paragraph to make a poster that explains why hot-air balloons float. Your poster should be creative and easy to understand.

Why hot-air balloons float

Answer question 5a before you read this sidebar!

1. The hot-air balloon pilot allows the gas burner flame to heat the air inside the balloon.

2. The now-warm air molecules are traveling at a higher speed than they had been.

3. The warm air molecules collide with greater impact.

4. The warm air molecules push each other farther apart, taking up more space.

5. The volume of the air in the balloon increases. Some air is forced out of the opening at the bottom because the envelope of the balloon doesn't stretch very much.

6. The mass of the remaining air is less, but the volume is about the same. This makes the density of the balloon less.

7. Buoyancy says that less-dense objects (the warm air in the balloon) will float in more-dense fluids (the cool surrounding air). Therefore, the hot-air balloon floats high above the ground.

PHYSICS CONNECTION

Full of Hot Air

Do you know what the oldest form of aircraft is? You may think it is the airplane flown by the Wright brothers in 1903. The hot-air balloon dates back much earlier than the Wright brothers. In 1783, the first passengers in a hot-air balloon were a duck, rooster, and a sheep.

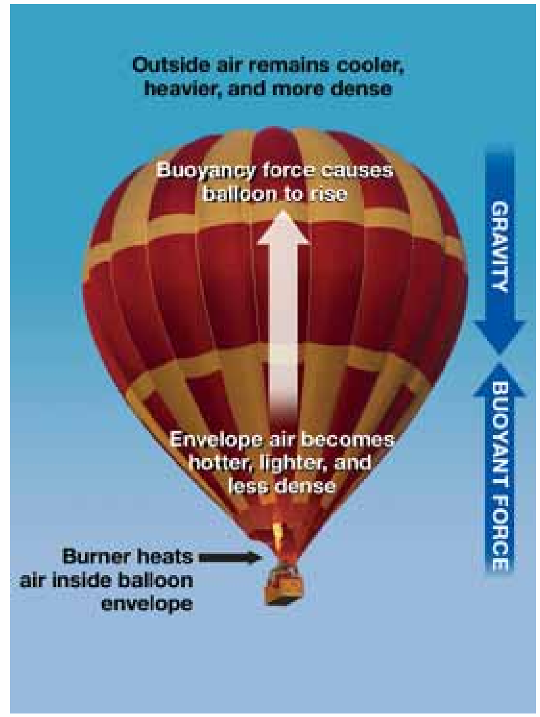
Several months later, the Montgolfier brothers of France made a balloon of paper and silk. This flight carried two men for 25 minutes across 5½ miles. Ballooning has come a long way since that historic flight. Balloons are used to forecast weather, explore space, perform science experiments, and flying in them is considered a sport.

The science behind hot-air balloons

Hot-air balloons have three major parts: envelope, basket, and burner. The envelope is the colorful part of the balloon. It is made of heat resistant nylon with a special liner to hold in the heat. The basket is made of strong wicker that will not crack upon landing. Before takeoff, inflator fans are used to fill the envelope with air. Once the envelope is filled with air, burners heat the air. Just as smoke rises, the heated air makes the balloon rise.

An increase in the temperature of a gas causes an increase in the movement of gas molecules. A molecule is a tiny particle in motion. When molecules move around more, they move further apart. Gas molecules that are farther apart decrease gas density.

In a hot-air balloon, the heat from the burners makes the envelope air less dense. The air inside the envelope is now lighter than the air outside. These temperature and density differences create a force called buoyancy. Buoyancy is an upward force.



When you are in a swimming pool, buoyancy helps you to float. For hot-air balloons, buoyancy pushes the lighter, hotter air up. The result is the hot-air balloon rises.

Hot-air balloons depend on the wind to travel. The pilot controls the burner to raise or lower the balloon to catch these winds. Balloons move wherever the wind blows!

Hot-air balloons used for science

The National Scientific Balloon Facility in Palestine, Texas is a National Aeronautics and Space Administration (NASA) facility. NASA launches about 25 science balloons each year. Science balloons do not carry people, but carry a "payload." The payload carries equipment for experiments and may weigh up to 8,000 pounds. These experiments help scientists study earth and space. Airplanes usually fly five to six miles above the ground. Science balloons fly up to 26 miles high!

NASA is developing an Ultra-Long Duration Balloon (ULDB). The ULDB envelope is made of a material that is as thin as sandwich wrap. Scientists hope the ULDB will be able to fly up to 100 days. Longer balloon flights will let scientists carry out more advanced science experiments.

Steve Fossett

Steve Fossett is the first person to fly solo around the world in a hot-air balloon. He is an adventurer who worked 10 years to achieve this goal. On June 19, 2002, Fossett completed his trip. His journey lasted 14 days, 19 hours, and 51 minutes. Fossett did run into problems during his great balloon adventure. At one point, he had to fly as low as 500 feet to avoid very high winds.

Although Fossett was alone in the balloon, he did not work alone to complete the trip. He had a team that included meteorologists, engineers, scientists, and balloonists. Fossett's balloon was equipped with computers, telephone, radio, and almost 20 pounds of maps. He also had oxygen available for high altitudes. The air at high altitudes is very thin and does not have enough oxygen for normal breathing.

Balloon festivals

In the United States, there are more than 4,000 balloon pilots. Pilots from around the world love to gather, race, and fly. The Albuquerque International Balloon Fiesta in New Mexico has been held annually for over 30 years. This fiesta is the largest balloon festival in the world with over 500 balloons. The Helen to the Atlantic Balloon Race and Festival in Georgia is the oldest in the south. It is also the only long distance hot-air balloon race in the United States.

Imagine floating above some of the most spectacular views from coast to coast. Ballooning in New Hampshire offers views of the White Mountains. The Sonoma County Hot-air Balloon Classic, held in Windsor, California offers balloonists early morning rides over the vineyards of Northern California. hot-air ballooning is not just full of hot-air. The wind welcomes the balloonists and provides an experience unlike any other of its kind.

Questions:

1. How does heat affect air density?
2. Describe buoyancy and its effect on a hot-air balloon.
3. How do you steer a hot-air balloon?

CHAPTER ACTIVITY

Observing Density Effects

The density of water changes depending on its temperature and how salty it might be. In this activity you will observe how these two variables—temperature and saltiness—affect the density and movement of water.

Materials

- Clear plastic cups and foam cups
- Table salt
- Red and blue food coloring
- Eye dropper
- Cool and hot water

What you will do

Part 1: Creating an underwater waterfall

1. Fill a clear plastic cup nearly full with cool water.
2. Fill a foam cup half-full with hot water. Add a pinch of salt. Add 6 drops of red food coloring. Stir until the salt dissolves.
3. Place the eyedropper into the hot red water to warm it up. After a minute, fill the dropper barrel with the water.
4. Hold the dropper so that it lies at a flat angle at the surface of the clear water with the tip just under the surface. Gently squeeze out a layer of hot red water onto the surface of the clear water.

5. After a short cooling time, the red layer will form little waterfalls that sink through the clear water. They may even form little smoke-ring-like structures as they fall. If this does not happen within a few minutes, add a little more salt to the hot red water, stir, and try again.

Part 2: Observing underwater springs

6. Fill a clear cup three-quarters full with cool water. Add a heaping teaspoon of salt to the water. Stir until the salt dissolves.
7. Fill a foam cup half-full with cool water. Add 6 drops of blue food coloring. Stir to mix.
8. Fill the eyedropper with cool blue water.
9. Gently lower the dropper into the salt water so that the tip is near the bottom. Gently squeeze the dropper so that a small stream of blue water is released.

Applying your knowledge

For part 1:

a. Explain why the red water floats at first.
b. Explain why the red water eventually sinks.

For part 2:

c. Where did the blue water go? Why?
d. In this model, the blue water was less salty than the surrounding water. Think of another way you could cause the results seen in this activity. Write your own procedure, test it, and explain what happened.

Vocabulary

Select the correct term to complete the sentences.

fluid	density	buoyant force

Section 5.1 and Section 5.2

1. Matter that can flow is called a _____.
2. An object which has a weight (downward force) of 20 newtons displaces a volume of water that weighs 8 newtons. This object will sink because the _____ is not enough to help it float.
3. The _____ of a wooden ball is less than water so it floats.

Concepts

Section 5.1

1. Fill in the blanks using the terms *mass* or *weight*:
   a. Your _____ is always the same regardless of gravity.
   b. Your _____ on Earth is different than on the moon because of the moon's weaker gravitational force.
   c. On Earth the _____ of an object is 10 newtons.
   d. On Jupiter the _____ of an elephant would be greater than it is on Earth, but its _____ would be the same.
2. Describe how you would find the volume of these two objects: (a) A cardboard box, and (b) A marble.
3. Density is the ratio between which two properties an object (see box below)? Write the formula for density.

mass	temperature	weight
heat energy	volume	buoyant force

4. The _____ (mass, weight, or density) of a material is the same no matter how much of the material you have.

Section 5.2

5. Define the term fluid and give three examples of fluids.
6. When talking about buoyant force, why is the weight of an object talked about instead of its mass?
7. If the weight of an object was 500 newtons and the buoyant force was 75 newtons, would the object sink or float?
8. Why is it so easy to float in the very salty Dead Sea?
9. True or false? This is an example of a gas floating on another gas—warm air rising above cooler air because it is less dense.
10. True or false? You can increase the volume of a balloon by heating up the air inside.

Section 5.3

11. You want to heat a cold room. You place a space heater in a corner. Using what you know about the density of warm air versus cool air, explain what happens in the room when the space heater is turned on.
12. What are two ways to make the density of an object smaller? Give your own example.

Math and Writing Skills

Section 5.1

1. The moon's gravity is one sixth that of the gravity experienced on Earth, If an object's weight on Earth is 1,200 newtons, what would be its weight on the moon?
2. The volume of a solid 4 cm × 6 cm × 10 cm is:

   a. 24 cm   c. 240 cm^3
   b. 240 cm   d. 100 cm^3

3. What is the volume of a box that measures 10 meters long by 5 meters wide by 2 meters high?
4. You know that a box can contain 150 cm^3 of water. Give an example of what the dimensions of the box might be.
5. The volume of a 20-gram object is 5 cm^3. What is its density?

Section 5.2

6. If an object has a buoyant force acting on it of 320 newtons, would the weight of the object have to be more or less than 320 newtons in order to float?
7. An object weighs 135 newtons. What would the buoyant force have to be in order for the object to have neutral buoyancy?

Section 5.3

8. If you have a hot-air balloon, how does heating up the air inside decrease the density of the hot air balloon? Explain using the concepts of volume and mass.
9. At the top of the highest mountain on Earth, the force of gravity is a little less than it is at sea level. Would your weight be a little greater or a little less at the top of the highest mountain on Earth?
10. The density of water is 1.0 g/cm^3 and the density of wax is 0.9 g/cm^3. Would wax float or sink in water?

Chapter Project—How Do Animals Float?

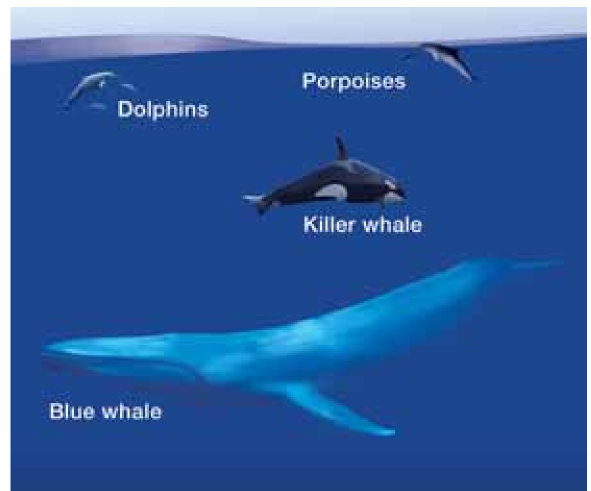
Marine mammals live in water all the time. Have you ever wondered how these animals stay afloat? Why don't they sink to the bottom of the ocean? Especially, why doesn't a 150-metric ton animal like the blue whale sink?

For this project, pick any marine animal. Then, research facts about this animal to find out why this animal doesn't sink. Do an oral presentation in front of your class to describe what you learn from your research.

Here are some questions to guide your research:

- What is the name of your marine mammal?
- What is the mass of the animal in kilograms or metric tons (one metric ton = 1,000 kilograms)?
- What are the dimensions of this animal? Use these dimensions to estimate the volume of this animal.
- See if you can use the mass and volume of the animal to calculate the density of this animal.

  Note: The density of salt water is 1,028 kg/m^3. The density of pure water is 1,000 kg/m^3.
- Why does this animal float instead of sink?
- What does this animal do when it sleeps?



Why don't large marine mammals sink?