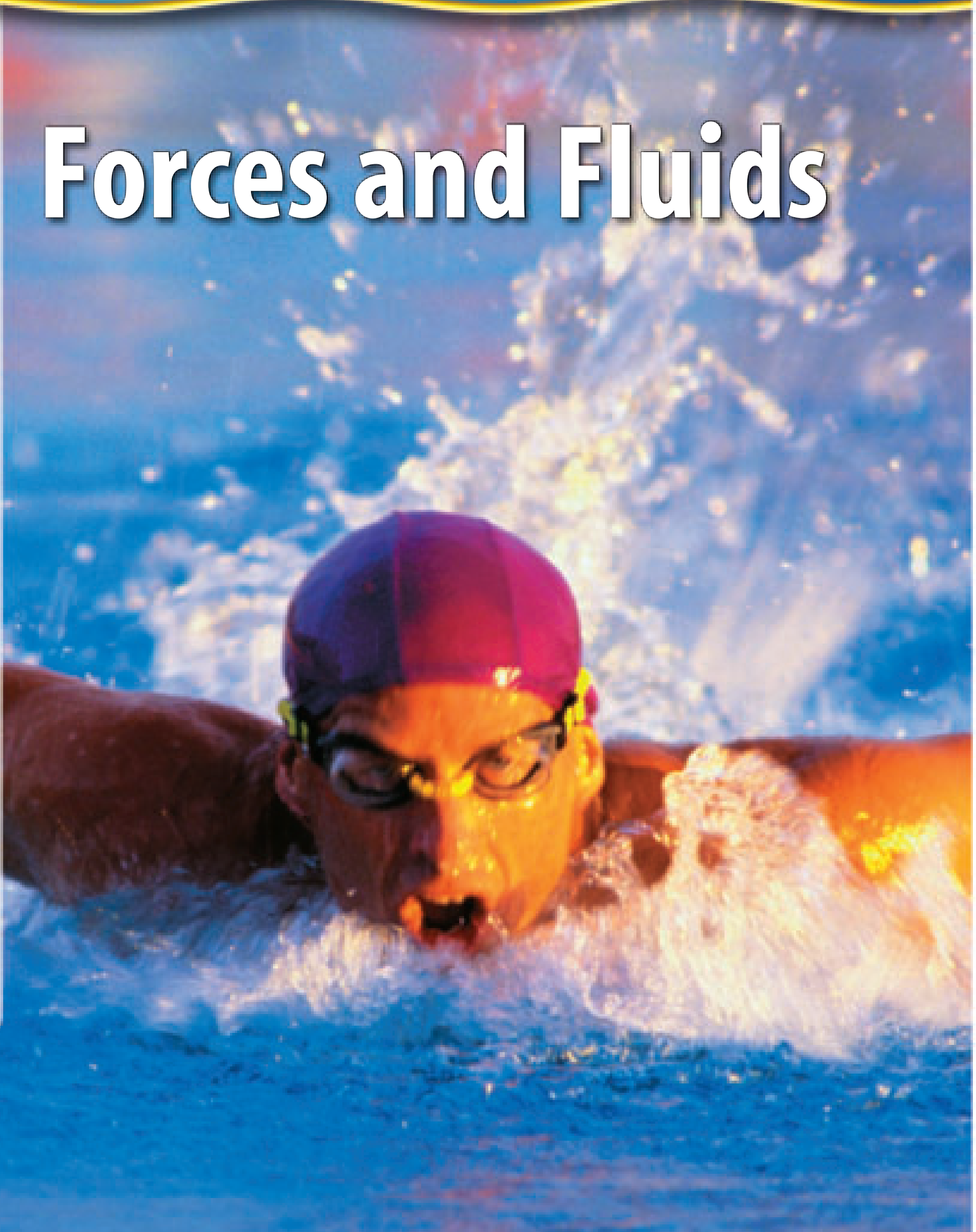
chapter 3

Forces and Fluids



The BIG Idea

A fluid exerts forces on an object in the fluid.

SECTION 1
Pressure
Main Idea The pressure exerted by a fluid increases as depth increases.

SECTION 2
Why do objects float?
Main Idea A fluid exerts an upward buoyant force on any object placed in the fluid.

SECTION 3
Doing Work with Fluids
Main Idea Fluids can be made to exert forces that do useful work.

A Very Fluid Situation

This swimmer seems to be defying gravity as he skims over the water. Even though the swimmer floats, a rock with the same mass would sink to the bottom of the pool. What forces cause something to float? Why does a swimmer float, while a rock sinks?

Science Journal Compare and contrast five objects that float with five objects that sink.

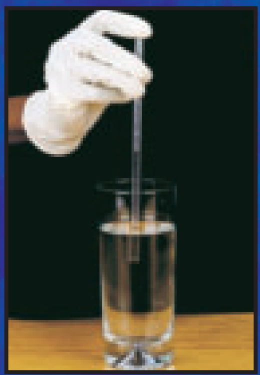
(bkgd.)Hughes Martin/CORBIS

Start-Up Activities

Launch LAB

Forces Exerted by Air

When you are lying down, something is pushing down on you with a force equal to the weight of several small cars. What is the substance that is applying all this pressure on you? It's air, a fluid that exerts forces on everything it is in contact with.

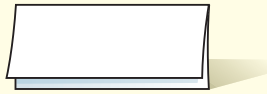


1. Suck water into a straw. Try to keep the straw completely filled with water.
2. Quickly cap the top of the straw with your finger and observe what happens to the water.
3. Release your finger from the top of the straw for an instant and replace it as quickly as possible. Observe what happens to the water.
4. Release your finger from the top of the straw and observe.
5. **Think Critically** Write a paragraph describing your observations of the water in the straw. When were the forces acting on the water in the straw balanced and when were they unbalanced?

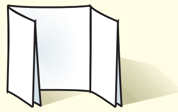
FOLDABLES™ Study Organizer

Fluids Make the following Foldable to compare and contrast the characteristics of two types of fluids—liquids and gases.

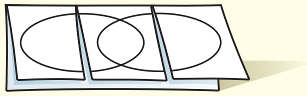
STEP 1 **Fold** one sheet of paper lengthwise.



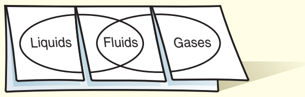
STEP 2 **Fold** into thirds.



STEP 3 **Unfold and draw** overlapping ovals. **Cut** the top sheet along the folds.



STEP 4 **Label** the ovals as shown.



Construct a Venn Diagram As you read the chapter, list the characteristics of liquids under the left tab, those characteristics of gases under the right tab, and those characteristics common to both under the middle tab.

Science Online

Preview this chapter's content and activities at bookm.msscience.com

(bkgd.)Hughes Martin/CORBIS, (inset)Matt Meadows

Get Ready to Read

Make Inferences

1 Learn It! When you make inferences, you draw conclusions that are not directly stated in the text. This means you "read between the lines." You interpret clues and draw upon prior knowledge. Authors rely on a reader's ability to infer because all the details are not always given.

2 Practice It! Read the excerpt below and pay attention to highlighted words as you make inferences. Use this Think-Through chart to help you make inferences.

> The buoyant force pushes an object in a fluid upward, but **gravity pulls the object downward**. If the **weight of the object** is greater than the buoyant force, the **net force** on the object is downward and it sinks.
>
> — *from page 75*

Text	Question	Inferences
Gravity pulls the object downward	What is gravity?	A downward force on the object?
Weight of the object	Is weight a force?	Weight is downward pull due to gravity?
Net force	What is the net force?	Combination of all forces on an object?

3 Apply It! As you read this chapter, practice your skill at making inferences by making connections and asking questions.

Reading Tip

Sometimes you make inferences by using other reading skills, such as questioning and predicting.

Target Your Reading

Use this to focus on the main ideas as you read the chapter.

1. **Before you read** the chapter, respond to the statements below on your worksheet or on a numbered sheet of paper.
   - Write an **A** if you **agree** with the statement.
   - Write a **D** if you **disagree** with the statement.

2. **After you read** the chapter, look back to this page to see if you've changed your mind about any of the statements.
   - If any of your answers changed, explain why.
   - Change any false statements into true statements.
   - Use your revised statements as a study guide.

Before You Read A or D	Statement	After You Read A or D
	1 The pressure due to a force depends on the area over which a force is exerted.	
	2 Fluids are substances that can flow.	
	3 The pressure exerted by water depends on the shape of its container.	
	4 The pressure in a fluid decreases with depth.	
	5 A rock sinks in water because the rock's weight is less than the upward force exerted by the water.	
	6 A metal boat floats in water because the density of the boat is less than the density of water.	
	7 Squeezing on a closed plastic water bottle causes the pressure in the water to decrease.	
	8 The pressure exerted by fluid decreases as the speed of the fluid increases.	
	9 The lift on a wing depends on the size of the wing.	

Science Online
Print out a worksheet of this page at bookm.msscience.com

section 1

Pressure

as you read

What You'll Learn

- **Define and calculate** pressure.
- **Model** how pressure varies in a fluid.

Why It's Important

Some of the processes that help keep you alive, such as inhaling and exhaling, depend on differences in pressure.

Review Vocabulary
weight: on Earth, the gravitational force between an object and Earth

New Vocabulary
- pressure
- fluid

What is pressure?

What happens when you walk in deep, soft snow or dry sand? Your feet sink into the snow or sand and walking can be difficult. If you rode a bicycle with narrow tires over these surfaces, the tires would sink even deeper than your feet.

How deep you sink depends on your weight as well as the area over which you make contact with the sand or snow. Like the person in **Figure 1,** when you stand on two feet, you make contact with the sand over the area covered by your feet. However, if you were to stand on a large piece of wood, your weight would be distributed over the area covered by the wood.

In both cases, your weight exerted a downward force on the sand. What changed was the area of contact between you and the sand. By changing the area of contact, you changed the pressure you exerted on the sand due to your weight. **Pressure** is the force per unit area that is applied on the surface of an object. When you stood on the board, the area of contact increased, so that the same force was applied over a larger area. As a result, the pressure that was exerted on the sand decreased and you didn't sink as deep.

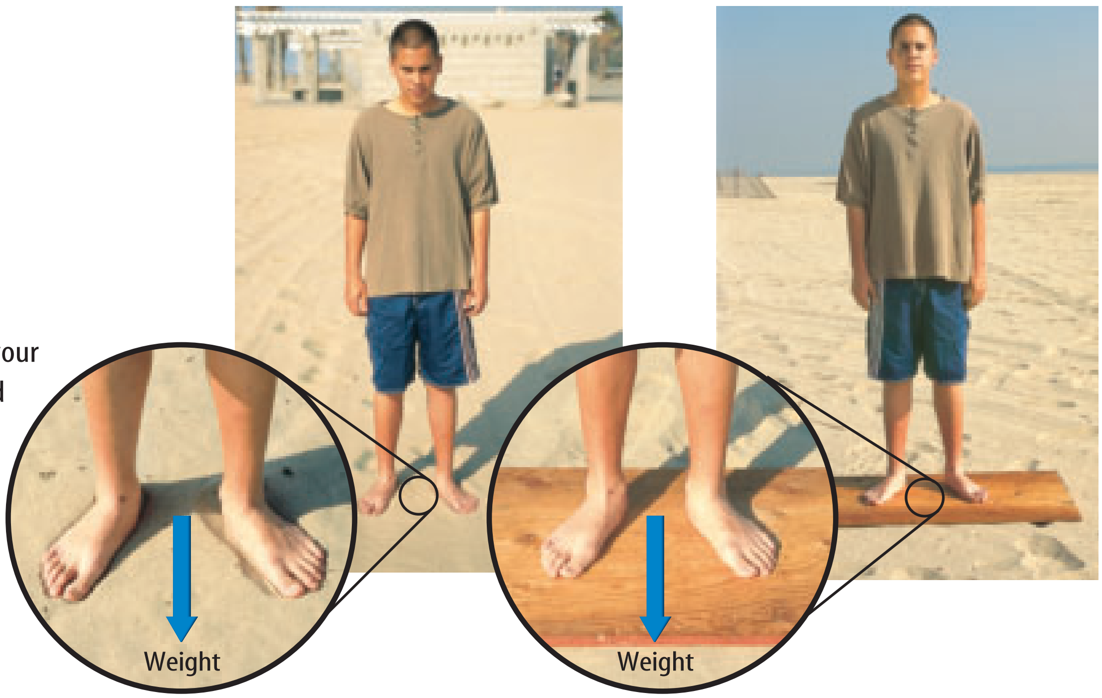


Figure 1 When your weight is distributed over a larger area, the pressure you exert on the sand decreases.

David Young-Wolff/PhotoEdit, Inc.

Calculating Pressure What would happen to the pressure exerted by your feet if your weight increased? You might expect that you would sink deeper in the sand, so the pressure also would increase. Pressure increases if the force applied increases, and decreases if the area of contact increases. Pressure can be calculated from this formula.

Pressure Equation

$$\textbf{Pressure} \text{ (in pascals)} = \frac{\textbf{force} \text{ (in newtons)}}{\textbf{area} \text{ (in meters squared)}}$$

$$P = \frac{F}{A}$$

The unit of pressure in the SI system is the pascal, abbreviated Pa. One pascal is equal to a force of 1 N applied over an area of 1 m^2, or 1 Pa = 1 N/m^2. The weight of a dollar bill resting completely flat on a table exerts a pressure of about 1 Pa on the table. Because 1 Pa is a small unit of pressure, pressure sometimes is expressed in units of kPa, which is 1,000 Pa.

Science Online

Topic: Snowshoes

Visit bookm.msscience.com for Web links to information about the history and use of snowshoes. These devices have been used for centuries in cold, snowy climates.

Activity Use simple materials, such as pipe cleaners, string, or paper, to make a model of a snowshoe.

Applying Math

Solve One-Step Equations

CALCULATING PRESSURE A water glass sitting on a table weighs 4 N. The bottom of the water glass has a surface area of 0.003 m^2. Calculate the pressure the water glass exerts on the table.

Solution

1. *This is what you know:*
   - force: $F = 4$ N
   - area: $A = 0.003$ m^2
2. *This is what you need to find out:*
   - pressure: $P = ?$ Pa
3. *This is the procedure you need to use:*
   Substitute the known values for force and area into the pressure equation and calculate the pressure:
   $$P = \frac{F}{A} = \frac{(4\text{ N})}{(0.003\text{ m}^2)}$$
   $$= 1{,}333\text{ N/m}^2 = 1{,}333\text{ Pa}$$
4. *Check your answer:*
   Multiply pressure by the given area. You should get the force that was given.

Practice Problems

1. A student weighs 600 N. The student's shoes are in contact with the floor over a surface area of 0.012 m^2. Calculate the pressure exerted by the student on the floor.
2. A box that weighs 250 N is at rest on the floor. If the pressure exerted by the box on the floor is 25,000 Pa, over what area is the box in contact with the floor?

Science Online

For more practice, visit bookm.msscience.com/math_practice

Mini LAB

Interpreting Footprints

Procedure

1. Go outside to **an area of dirt, sand, or snow** where you can make footprints. Smooth the surface.
2. Make tracks in several different ways. Possible choices include walking forward, walking backward, running, jumping a short or long distance, walking carrying a load, and tiptoeing.

Analysis

1. Measure the depth of each type of track at two points: the ball of the foot and the heel. Compare the depths of the different tracks.
2. The depth of the track corresponds to the pressure on the ground. In your **Science Journal,** explain how different means of motion put pressure on different parts of the sole.
3. Have one person make a track while the other looks away. Then have the second person determine what the motion was.

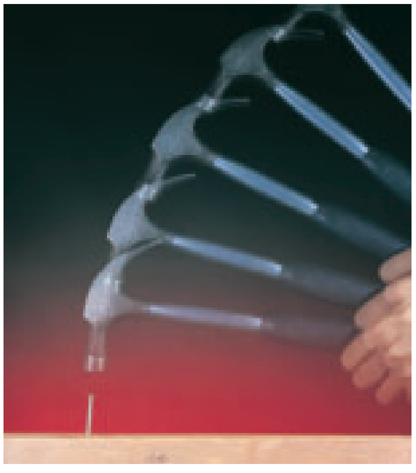
Pressure and Weight To calculate the pressure that is exerted on a surface, you need to know the force and the area over which it is applied. Sometimes the force that is exerted is the weight of an object, such as when you are standing on sand, snow, or a floor. Suppose you are holding a 2-kg book in the palm of your hand. To find out how much pressure is being exerted on your hand, you first must know the force that the book is exerting on your hand—its weight.

$$\text{Weight} = \text{mass} \times \text{acceleration due to gravity}$$
$$W = (2\ \text{kg}) \times (9.8\ \text{m/s}^2)$$
$$W = 19.6\ \text{N}$$

If the area of contact between your hand and the book is $0.003\ \text{m}^2$, the pressure that is exerted on your hand by the book is:

$$P = \frac{F}{A}$$
$$P = \frac{(19.6\ \text{N})}{(0.003\ \text{m}^2)}$$
$$P = 6{,}533\ \text{Pa} = 6.53\ \text{kPa}$$

Pressure and Area One way to change the pressure that is exerted on an object is to change the area over which the force is applied. Imagine trying to drive a nail into a piece of wood, as shown in **Figure 2.** Why is the tip of a nail pointed instead of flat? When you hit the nail with a hammer, the force you apply is transmitted through the nail from the head to the tip. The tip of the nail comes to a point and is in contact with the wood over a small area. Because the contact area is so small, the pressure that is exerted by the nail on the wood is large—large enough to push the wood fibers apart. This allows the nail to move downward into the wood.



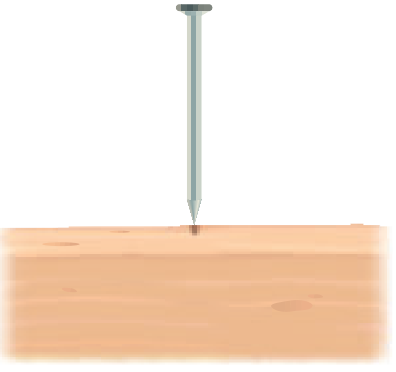


Figure 2 The force applied to the head of the nail by the hammer is the same as the force that the tip of the nail applies to the wood. However, because the area of the tip is small, the pressure applied to the wood is large.

Runk/Schoenberger from Grant Heilman

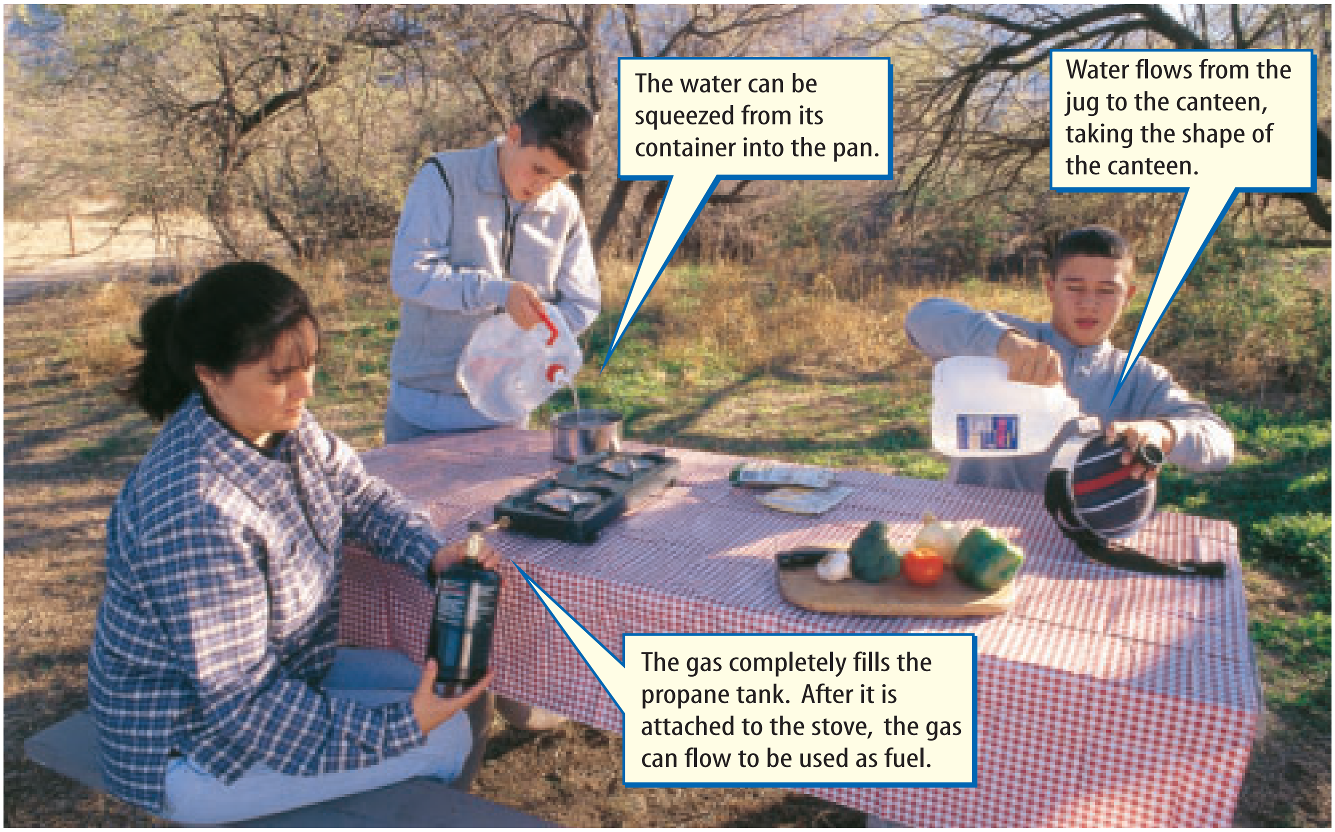


Figure 3 Fluids all have the ability to flow and take the shape of their containers.
Classify *What are some other examples of fluids?*

Fluids

What do the substances in **Figure 3** have in common? Each takes the shape of its container and can flow from one place to another. A **fluid** is any substance that has no definite shape and has the ability to flow. You might think of a fluid as being a liquid, such as water or motor oil. But gases are also fluids. When you are outside on a windy day, you can feel the air flowing past you. Because air can flow and has no definite shape, air is a fluid. Gases, liquids, and the state of matter called plasma, which is found in the Sun and other stars, are fluids and can flow.

Pressure in a Fluid

Suppose you placed an empty glass on a table. The weight of the glass exerts pressure on the table. If you fill the glass with water, the weight of the water and glass together exert a force on the table. So the pressure exerted on the table increases.

Because the water has weight, the water itself also exerts pressure on the bottom of the glass. This pressure is the weight of the water divided by the area of the glass bottom. If you pour more water into the glass, the height of the water in the glass increases and the weight of the water increases. As a result, the pressure exerted by the water increases.

INTEGRATE Astronomy

Plasma The Sun is a star with a core temperature of about 16 million°C. At this temperature, the particles in the Sun move at tremendous speeds, crashing into each other in violent collisions that tear atoms apart. As a result, the Sun is made of a type of fluid called a plasma. A plasma is a gas made of electrically charged particles.

Dominic Oldershaw

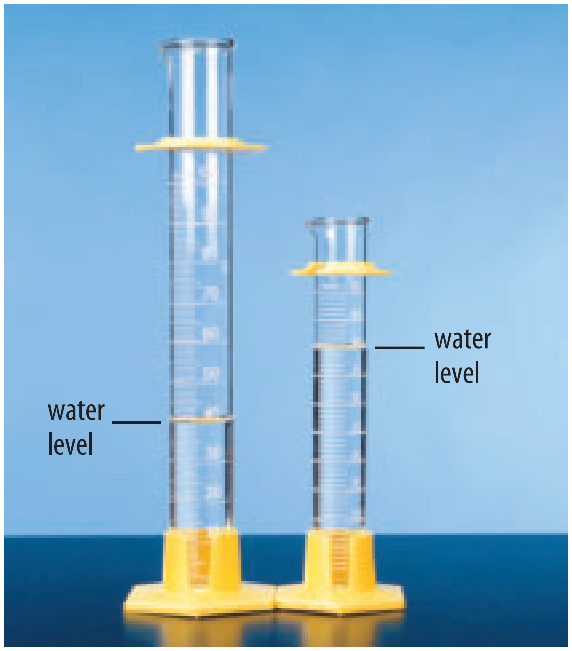


Figure 4 Even though each graduated cylinder contains the same volume of water, the pressure exerted by the higher column of water is greater.
Infer *how the pressure exerted by a water column would change as the column becomes narrower.*

Pressure and Fluid Height Suppose you poured the same amount of water into a small and a large graduated cylinder, as shown in **Figure 4.** Notice that the height of the water in the small cylinder is greater than in the large cylinder. Is the water pressure the same at the bottom of each cylinder? The weight of the water in each cylinder is the same, but the contact area at the bottom of the small cylinder is smaller. Therefore, the pressure is greater at the bottom of the small cylinder.

The height of the water can increase if more water is added to a container or if the same amount of water is added to a narrower container. In either case, when the height of the fluid is greater, the pressure at the bottom of the container is greater. This is always true for any fluid or any container. The greater the height of a fluid above a surface, the greater the pressure exerted by the fluid on that surface. The pressure exerted at the bottom of a container doesn't depend on the shape of the container, but only on the height of the fluid above the bottom, as **Figure 5** shows.

Pressure Increases with Depth If you swim underwater, you might notice that you can feel pressure in your ears. As you go deeper, you can feel this pressure increase. This pressure is exerted by the weight of the water above you. As you go deeper in a fluid, the height of the fluid above you increases. As the height of the fluid above you increases, the weight of the fluid above you also increases. As a result, the pressure exerted by the fluid increases with depth.

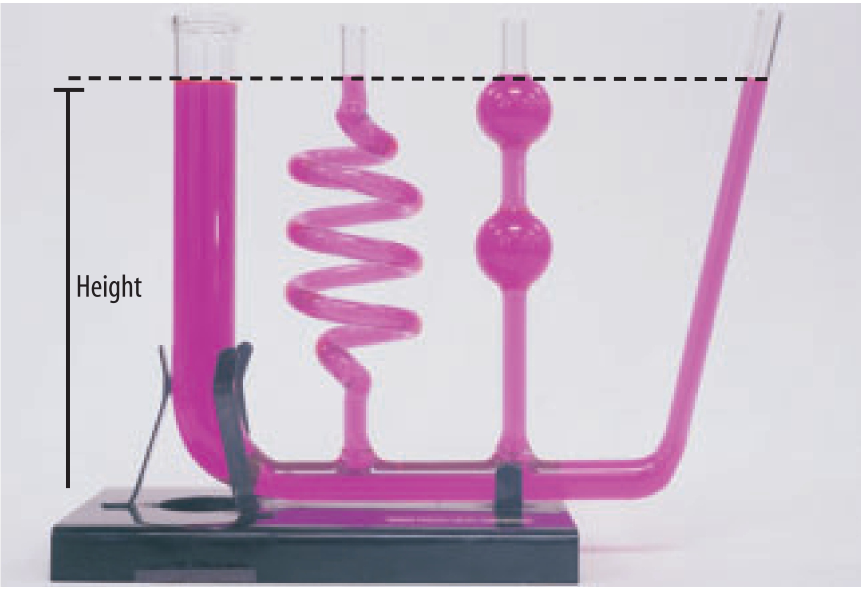


Figure 5 Pressure depends only on the height of the fluid above a surface, not on the shape of the container. The pressure at the bottom of each section of the tube is the same.

(t)Matt Meadows, (b)Tom Pantages

Pressure in All Directions If the pressure that is exerted by a fluid is due to the weight of the fluid, is the pressure in a fluid exerted only downward? **Figure 6** shows a small, solid cube in a fluid. The fluid exerts a pressure on each side of this cube, not just on the top. The pressure on each side is perpendicular to the surface, and the amount of pressure depends only on the depth in the fluid. As shown in **Figure 6,** this is true for any object in a fluid, no matter how complicated the shape. The pressure at any point on the object is perpendicular to the surface of the object at that point.

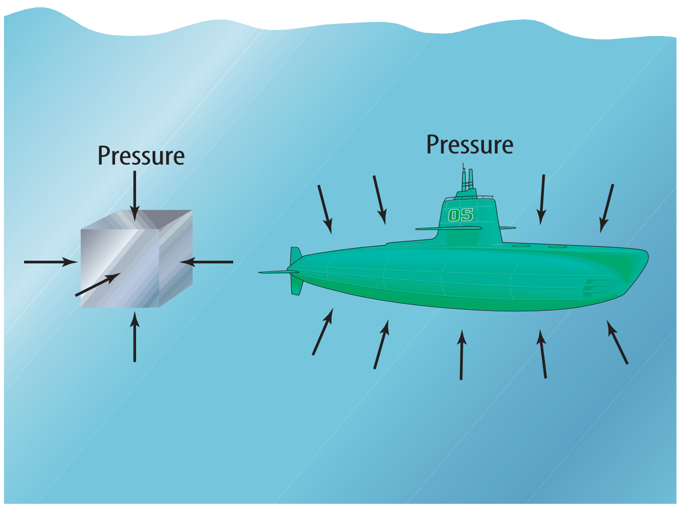


Figure 6 The pressure on all objects in a fluid is exerted on all sides, perpendicular to the surface of the object, no matter what its shape.

Reading Check *In what direction is pressure exerted by a fluid on a surface?*

Atmospheric Pressure

Even though you don't feel it, you are surrounded by a fluid that exerts pressure on you constantly. That fluid is the atmosphere. The atmosphere at Earth's surface is only about one-thousandth as dense as water. However, the thickness of the atmosphere is large enough to exert a large pressure on objects at Earth's surface. For example, look at **Figure 7.** When you are sitting down, the force pushing down on your body due to atmospheric pressure can be equal to the weight of several small cars. Atmospheric pressure is approximately 100,000 Pa at sea level. This means that the weight of Earth's atmosphere exerts about 100,000 N of force over every square meter on Earth.

Why doesn't this pressure cause you to be crushed? Your body is filled with fluids such as blood that also exert pressure. The pressure exerted outward by the fluids inside your body balances the pressure exerted by the atmosphere.

Going Higher As you go higher in the atmosphere, atmospheric pressure decreases as the amount of air above you decreases. The same is true in an ocean, lake, or pond. The water pressure is highest at the ocean floor and decreases as you go upward. The changes in pressure at varying heights in the atmosphere and depths in the ocean are illustrated in **Figure 8.**

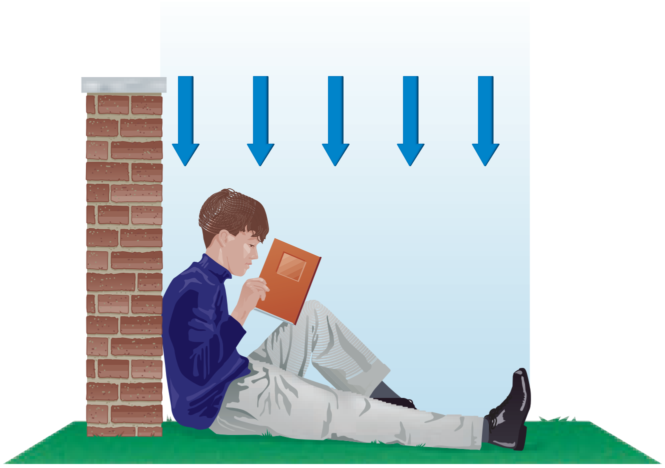


Figure 7 Atmospheric pressure on your body is a result of the weight of the atmosphere exerting force on your body.
Infer *Why don't you feel the pressure exerted by the atmosphere?*

VISUALIZING PRESSURE AT VARYING ELEVATIONS

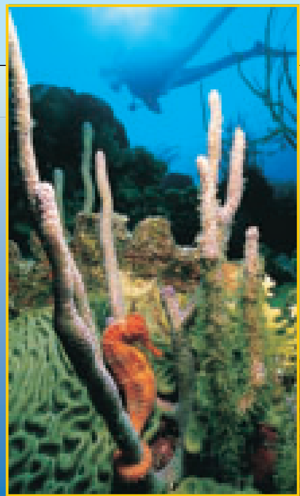
NATIONAL GEOGRAPHIC

Figure 8

No matter where you are on Earth, you're under pressure. Air and water have weight and therefore exert pressure on your body. The amount of pressure depends on your location above or below sea level and how much air or water—or both—are exerting force on you.

▲ **HIGH ELEVATION** With increasing elevation, the amount of air above you decreases, and so does air pressure. At the 8,850-m summit of Mt. Everest, air pressure is a mere 33 kPa—about one third of the air pressure at sea level.

▲ **SEA LEVEL** Air pressure is pressure exerted by the weight of the atmosphere above you. At sea level the atmosphere exerts a pressure of about 100,000 N on every square meter of area. Called one atmosphere (atm), this pressure is also equal to 100 kPa.



▶ **REEF LEVEL** When you descend below the sea surface, pressure increases by about 1 atm every 10 meters. At 20 meters depth, you'd experience 2 atm of water pressure and 1 atm of air pressure, a total of 3 atm of pressure on your body.

▶ **VERY LOW ELEVATION** The deeper you dive, the greater the pressure. The water pressure on a submersible at a depth of 2,200 m is about 220 times greater than atmospheric pressure at sea level.

8,000 m
7,000 m
6,000 m
5,000 m
4,000 m
3,000 m
2,000 m
1,000 m
0 m
1,000 m
2,000 m
3,000 m
4,000 m
5,000 m
6,000 m
7,000 m
8,000 m
9,000 m

(t)Bobby Model/National Geographic Image Collection, (cl)Richard Nowitz/National Geographic Image Collection, (cr)George Grall/National Geographic Image Collection, (bl)Ralph White/CORBIS, (br)CORBIS

Barometer An instrument called a barometer is used to measure atmospheric pressure. A barometer has something in common with a drinking straw. When you drink through a straw, it seems like you pull your drink up through the straw. But actually, atmospheric pressure pushes your drink up the straw. By removing air from the straw, you reduce the air pressure in the straw. Meanwhile, the atmosphere is pushing down on the surface of your drink. When you pull the air from the straw, the pressure in the straw is less than the pressure pushing down on the liquid, so atmospheric pressure pushes the drink up the straw.

One type of barometer works in a similar way, as shown in **Figure 9.** The space at the top of the tube is a vacuum. Atmospheric pressure pushes liquid up a tube. The liquid reaches a height where the pressure at the bottom of the column of liquid balances the pressure of the atmosphere. As the atmospheric pressure changes, the force pushing on the surface of the liquid changes. As a result, the height of the liquid in the tube increases as the atmospheric pressure increases.

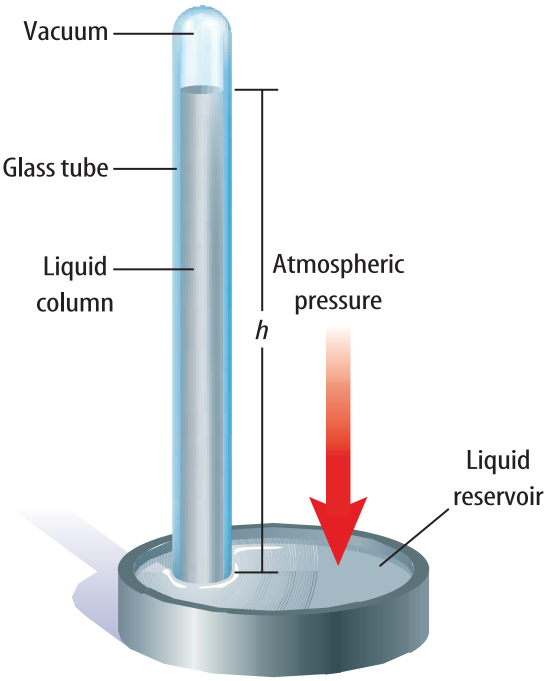


Figure 9 In this type of barometer, the height of the liquid column increases as the atmospheric pressure increases.

section 1 review

Summary

Pressure

- Pressure is the force exerted on a unit area of a surface. Pressure can be calculated from this equation:

$$P = \frac{F}{A}$$

- The SI unit for pressure is the pascal, abbreviated Pa.

Pressure in a Fluid

- The pressure exerted by a fluid depends on the depth below the fluid surface.
- The pressure exerted by a fluid on a surface is always perpendicular to the surface.

Atmospheric Pressure

- Earth's atmosphere exerts a pressure of about 100,000 Pa at sea level.
- A barometer is an instrument used to measure atmospheric pressure.

Self Check

1. **Compare** One column of water has twice the diameter as another water column. If the pressure at the bottom of each column is the same, how do the heights of the two columns compare?
2. **Explain** why the height of the liquid column in a barometer changes as atmospheric pressure changes.
3. **Classify** the following as fluids or solids: warm butter, liquid nitrogen, paper, neon gas, ice.
4. **Explain** how the pressure at the bottom of a container depends on the container shape and the fluid height.
5. **Think Critically** Explain how the diameter of a balloon changes as it rises higher in the atmosphere.

Applying Math

6. **Calculate Force** The palm of a person's hand has an area of 0.0135 m^2. If atmospheric pressure is 100,000 N/m^2, find the force exerted by the atmosphere on the person's palm.

section 2

Why do objects float?

as you read

What You'll Learn

- **Explain** how the pressure in a fluid produces a buoyant force.
- **Define** density.
- **Explain** floating and sinking using Archimedes' principle.

Why It's Important

Knowing how fluids exert forces helps you understand how boats can float.

Review Vocabulary

Newton's second law of motion: the acceleration of an object is in the direction of the total force and equals the total force divided by the object's mass

New Vocabulary

- buoyant force
- Archimedes' principle
- density

The Buoyant Force

Can you float? Think about the forces that are acting on you as you float motionless on the surface of a pool or lake. You are not moving, so according to Newton's second law of motion, the forces on you must be balanced. Earth's gravity is pulling you downward, so an upward force must be balancing your weight, as shown in **Figure 10.** This force is called the buoyant force. The **buoyant force** is an upward force that is exerted by a fluid on any object in the fluid.

What causes the buoyant force?

The buoyant force is caused by the pressure that is exerted by a fluid on an object in the fluid. **Figure 11** shows a cube-shaped object submerged in a glass of water. The water exerts pressure everywhere over the surface of the object. Recall that the pressure exerted by a fluid has two properties. One is that the direction of the pressure on a surface is always perpendicular to the surface. The other is that the pressure exerted by a fluid increases as you go deeper into the fluid.

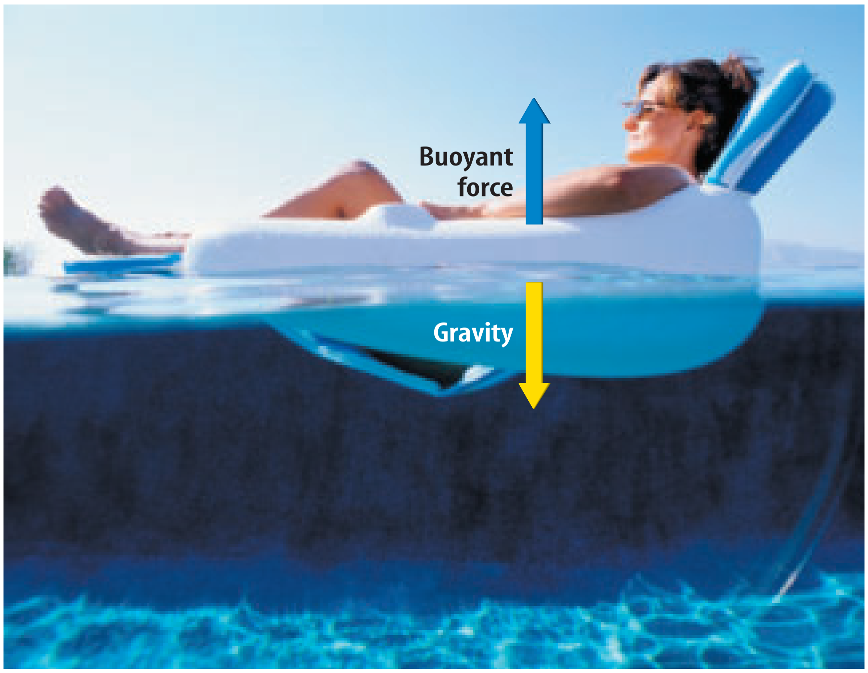


Figure 10 When you float, the forces on you are balanced. Gravity pulls you downward and is balanced by the buoyant force pushing you upward.
Infer *What is the acceleration of the person shown here?*

Ryan McVay/PhotoDisc

Buoyant Force and Unbalanced Pressure The pressure that is exerted by the water on the cube is shown in **Figure 11.** The bottom of the cube is deeper in the water. Therefore, the pressure that is exerted by the water at the bottom of the cube is greater than it is at the top of the cube. The higher pressure near the bottom means that the water exerts an upward force on the bottom of the cube that is greater than the downward force that is exerted at the top of the cube. As a result, the force that is exerted on the cube due to water pressure is not balanced, and a net upward force is acting on the cube due to the pressure of the water. This upward force is the buoyant force. A buoyant force acts on all objects that are placed in a fluid, whether they are floating or sinking.

Reading Check *When does the buoyant force act on an object?*

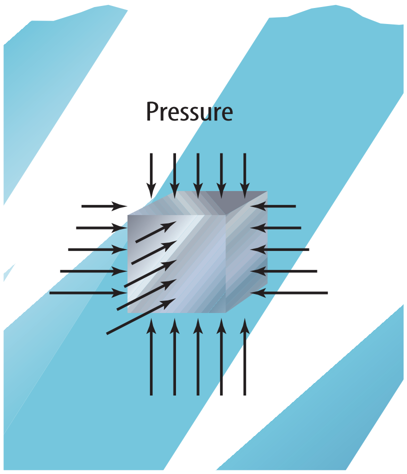


Figure 11 The pressure exerted on the bottom of the cube is greater than the pressure on the top. The fluid exerts a net upward force on the cube.

Sinking and Floating

If you drop a stone into a pool of water, it sinks. But if you toss a twig on the water, it floats. An upward buoyant force acts on the twig and the stone, so why does one float and one sink?

The buoyant force pushes an object in a fluid upward, but gravity pulls the object downward. If the weight of the object is greater than the buoyant force, the net force on the object is downward and it sinks. If the buoyant force is equal to the object's weight, the forces are balanced and the object floats. As shown in **Figure 12,** the fish floats because the buoyant force on it balances its weight. The rocks sink because the buoyant force acting on them is not large enough to balance their weight.

Figure 12 The weight of a rock is more than the buoyant force exerted by the water, so it sinks to the bottom.
Infer *Why do the fish float?*

CORBIS

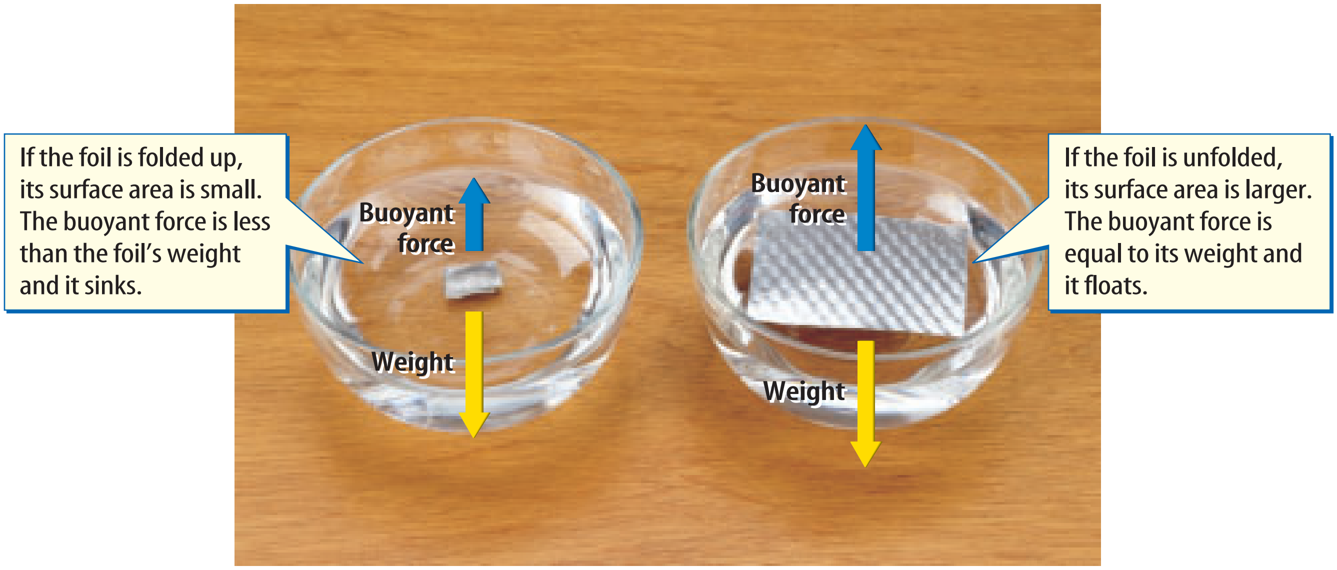


Figure 13 The buoyant force on a piece of aluminum foil increases as the surface area of the foil increases.

Changing the Buoyant Force

Whether an object sinks or floats depends on whether the buoyant force is smaller than its weight. The weight of an object depends only on the object's mass, which is the amount of matter the object contains. The weight does not change if the shape of the object changes. A piece of modeling clay contains the same amount of matter whether it's squeezed into a ball or pressed flat.

Buoyant Force and Shape Buoyant force does depend on the shape of the object. The fluid exerts upward pressure on the entire lower surface of the object that is in contact with the fluid. If this surface is made larger, then more upward pressure is exerted on the object and the buoyant force is greater. **Figure 13** shows how a piece of aluminum can be made to float. If the aluminum is crumpled, the buoyant force is less than the weight, so the aluminum sinks. When the aluminum is flattened into a thin, curved sheet, the buoyant force is large enough that the sheet floats. This is how large, metal ships, like the one in **Figure 14,** are able to float. The metal is formed into a curved sheet that is the hull of the ship. The contact area of the hull with the water is much greater than if the metal were a solid block. As a result, the buoyant force on the hull is greater than it would be on a metal block.

Figure 14 The hull of this oil tanker has a large surface area in contact with the water. As a result, the buoyant force is so large that the ship floats.

(t)Matt Meadows, (b)Vince Streano/Stone/Getty Images

The Buoyant Force Doesn't Change with Depth Suppose you drop a steel cube into the ocean. You might think that the cube would sink only to a depth where the buoyant force on the cube balances its weight. However, the steel sinks to the bottom, no matter how deep the ocean is.

The buoyant force on the cube is the difference between the downward force due to the water pressure on the top of the cube and the upward force due to water pressure on the bottom of the cube. **Figure 15** shows that when the cube is deeper, the pressure on the top surface increases, but the pressure on the bottom surface also increases by the same amount. As a result, the difference between the forces on the top and bottom surfaces is the same, no matter how deep the cube is submerged. The buoyant force on the submerged cube is the same at any depth.

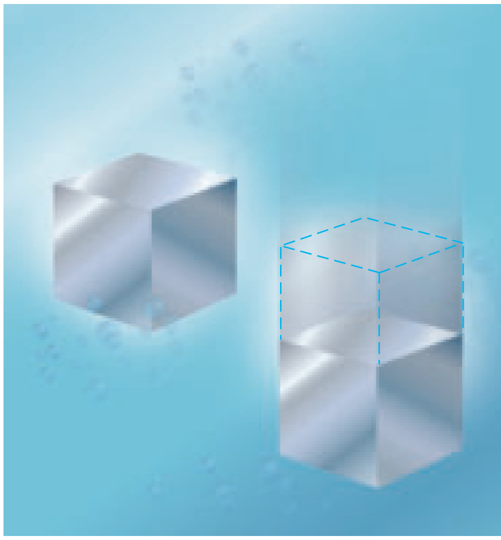


Figure 15 Because the cube on the right is deeper, the pressure on its upper surface is increased due to the weight of the water inside the dashed lines. The pressure on the bottom surface also increases by this amount.
Explain *how the buoyant force on the cube would change if it moved only to the left or right.*

Archimedes' Principle

A way of determining the buoyant force was given by the ancient Greek mathematician Archimedes(ar kuh MEE deez) more than 2,200 years ago. According to **Archimedes' principle,** the buoyant force on an object is equal to the weight of the fluid it displaces.

To understand Archimedes' principle, think about what happens if you drop an ice cube in a glass of water that's filled to the top. The ice cube takes the place of some of the water and causes this water to overflow, as shown in **Figure 16.** Another way to say this is that the ice cube displaced water that was in the glass.

Suppose you caught all the overflow water and weighed it. According to Archimedes' principle, the weight of the overflow, or displaced water, would be equal to the buoyant force on the ice cube. Because the ice cube is floating, the buoyant force is balanced by the weight of the ice cube. So the weight of the water that is displaced, or the buoyant force, is equal to the weight of the ice cube.

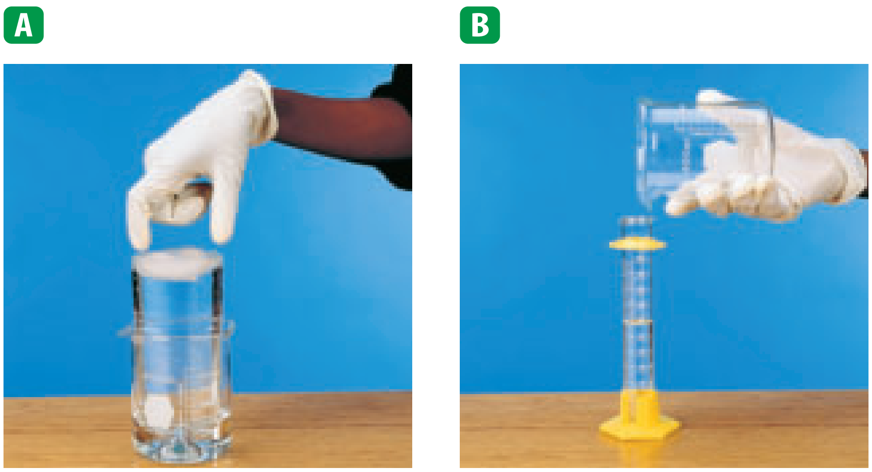


Figure 16 The buoyant force exerted on this ice cube is equal to the weight of the water displaced by the ice cube.

Matt Meadows

INTEGRATE Career

Naval Architect Naval architects design the ships and submarines for the U.S. Naval Fleet, Coast Guard, and Military Sealift Command. Naval architects need math, science, and English skills for designing and communicating design ideas to others.

Density Archimedes' principle leads to a way of determining whether an object placed in a fluid will float or sink. The answer depends on comparing the density of the fluid and the density of the object. The **density** of a fluid or an object is the mass of the object divided by the volume it occupies. Density can be calculated by the following formula:

Density Equation

$$\textbf{density}\ (\text{in g/cm}^3) = \frac{\textbf{mass}\ (\text{in g})}{\textbf{volume}\ (\text{in cm}^3)}$$

$$D = \frac{m}{V}$$

For example, water has a density of 1.0 g/cm^3. The mass of any volume of a substance can be calculated by multiplying both sides of the above equation by volume. This gives the equation

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

Then if the density and volume are known, the mass of the material can be calculated.

Applying Science

Layering Liquids

The density of an object or substance determines whether it will sink or float in a fluid. Just like solid objects, liquids also have different densities. If you pour vegetable oil into water, the oil doesn't mix. Instead, because the density of oil is less than the density of water, the oil floats on top of the water.

Identifying the Problem

In science class, a student is presented with five unknown liquids and their densities. He measures the volume of each and organizes his data into the table at the right. He decides to experiment with these liquids by carefully pouring them, one at a time, into a graduated cylinder.

Liquid Density and Volume

Liquid	Color	Density (g/cm^3)	Volume (cm^3)
A	red	2.40	32.0
B	blue	2.90	15.0
C	green	1.20	20.0
D	yellow	0.36	40.0
E	purple	0.78	19.0

Solving the Problem

1. Assuming the liquids don't mix with each other, draw a diagram and label the colors, illustrating how these liquids would look when poured into a graduated cylinder. If 30 cm^3 of water were added to the graduated cylinder, explain how your diagram would change.
2. Use the formula for density to calculate the mass of each of the unknown liquids in the chart.

Sinking and Density Suppose you place a copper block with a volume of 1,000 cm^3 into a container of water. This block weighs about 88 N. As the block sinks, it displaces water, and an upward buoyant force acts on it. If the block is completely submerged, the volume of water it has displaced is 1,000 cm^3—the same as its own volume. This is the maximum amount of water the block can displace. The weight of 1,000 cm^3 of water is about 10 N, and this is the maximum buoyant force that can act on the block. This buoyant force is less than the weight of the copper, so the copper block continues to sink.

The copper block and the displaced water had the same volume. Because the copper block had a greater density, the mass of the copper block was greater than the mass of the displaced water. As a result, the copper block weighed more than the displaced water because its density was greater. Any material with a density that is greater than the density of water will weigh more than the water that it displaces, and it will sink. This is true for any object and any fluid. Any object that has a density greater than the density of the fluid it is placed in will sink.

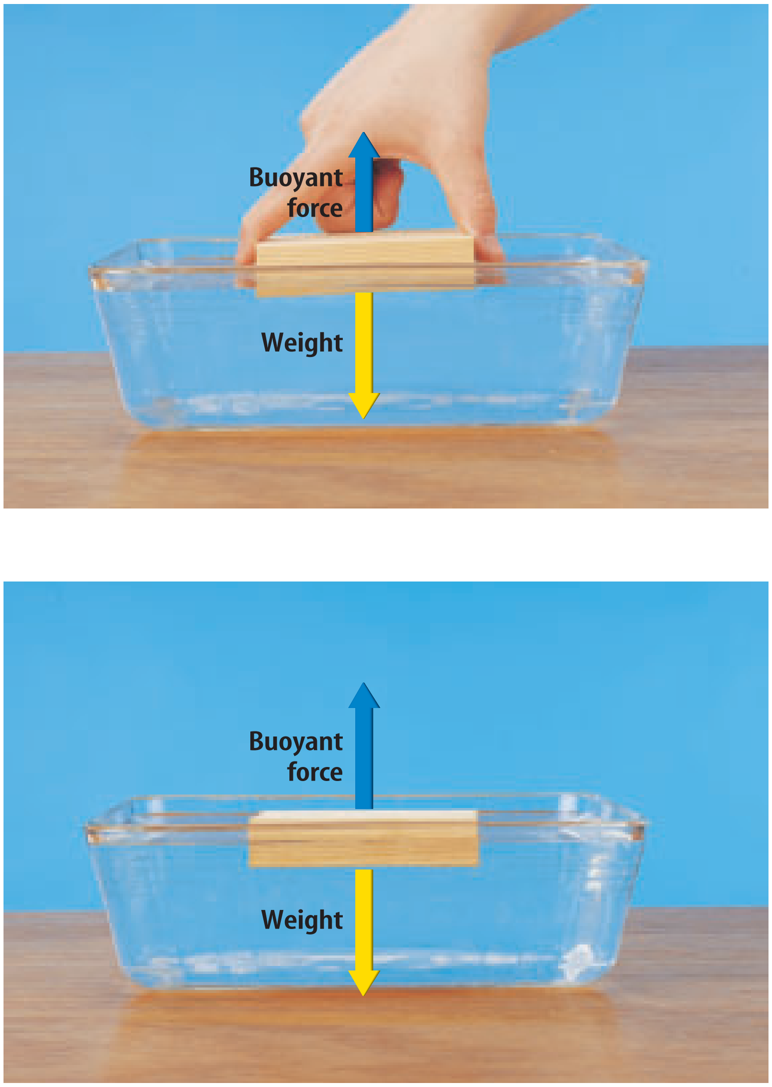


Figure 17 An object, such as this block of wood, will continue to sink in a fluid until it has displaced an amount of fluid that is equal to its mass. Then the buoyant force equals its weight.

Floating and Density Suppose you place a block of wood with a volume of 1,000 cm^3 into a container of water. This block weighs about 7 N. The block starts to sink and displaces water. However, it stops sinking and floats before it is completely submerged, as shown in **Figure 17.** The density of the wood was less than the density of the water. So the wood was able to displace an amount of water equal to its weight before it was completely submerged. It stopped sinking after it had displaced about 700 cm^3 of water. That much water has a weight of about 7 N, which is equal to the weight of the block. Any object with a density less than the fluid it is placed in will float.

Reading Check *How can you determine whether an object will float or sink?*

Matt Meadows

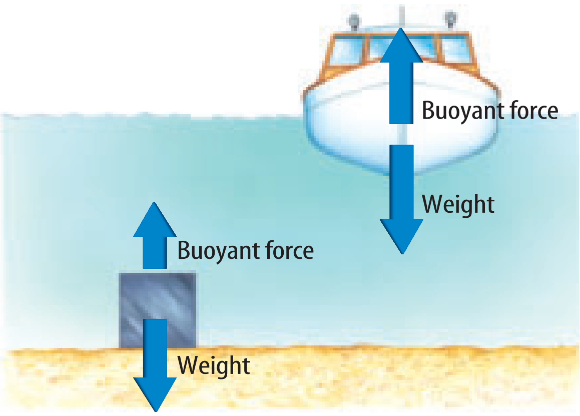


Figure 18 Even though the boat and the cube have the same mass, the boat displaces more water because of its shape. Therefore the boat floats, but the cube sinks.

Boats

Archimedes' principle provides another way to understand why boats that are made of metal can float. Look at **Figure 18.** By making a piece of steel into a boat that occupies a large volume, more water is displaced by the boat than by the piece of steel. According to Archimedes' principle, increasing the weight of the water that is displaced increases the buoyant force. By making the volume of the boat large enough, enough water can be displaced so that the buoyant force is greater than the weight of the steel.

How does the density of the boat compare to the density of the piece of steel? The steel now surrounds a volume that is filled with air that has little mass. The mass of the boat is nearly the same as the mass of the steel, but the volume of the boat is much larger. As a result, the density of the boat is much less than the density of the steel. The boat floats when its volume becomes large enough that its density is less than the density of water.

section 2 review

Summary

The Buoyant Force

- The buoyant force is an upward force that is exerted by a fluid on any object in the fluid.
- The buoyant force is caused by the increase in pressure with depth in a fluid.
- Increasing the surface area in contact with a fluid increases the buoyant force on an object.

Sinking and Floating

- An object sinks when the buoyant force on an object is less than the object's weight.
- An object floats when the buoyant force on an object equals the object's weight.

Archimedes' Principle

- Archimedes' principle states that the buoyant force on a object equals the weight of the fluid the object displaces.
- According to Archimedes' principle, an object will float in a fluid only if the density of the object is less than the density of the fluid.

Self Check

1. **Explain** whether the buoyant force on a submerged object depends on the weight of the object.
2. **Determine** whether an object will float or sink in water if it has a density of 1.5 g/cm^3. Explain.
3. **Compare** the buoyant force on an object when it is partially submerged and when it's completely submerged.
4. **Explain** how the buoyant force acting on an object placed in water can be measured.
5. **Think Critically** A submarine changes its mass by adding or removing seawater from tanks inside the sub. Explain how this can enable the sub to dive or rise to the surface.

Applying Math

6. **Calculate Buoyant Force** A ship displaces 80,000 L of water. One liter of water weighs 9.8 N. What is the buoyant force on the ship?
7. **Density** The density of 14k gold is 13.7 g/cm^3. What is the density of a ring with a mass of 7.21 g and a volume of 0.65 cm^3. Is it made from 14k gold?

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Measuring Buoyant Force

The total force on an object in a fluid is the difference between the object's weight and the buoyant force. In this lab, you will measure the buoyant force on an object and compare it to the weight of the water displaced.

Real-World Question

How is the buoyant force related to the weight of the water that an object displaces?

Goals

- **Measure** the buoyant force on an object.
- **Compare** the buoyant force to the weight of the water displaced by the object.

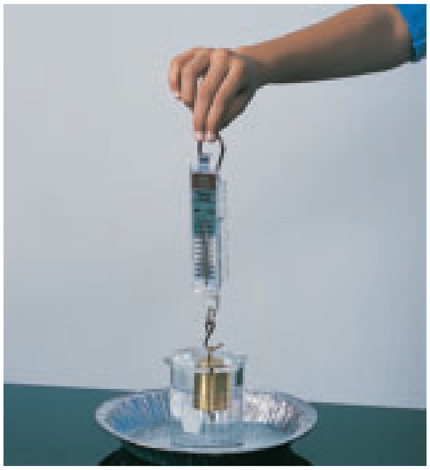
Materials

aluminum pan
spring scale
500-mL beaker
graduated cylinder
funnel
metal object

Safety Precautions

Procedure

1. Place the beaker in the aluminum pan and fill the beaker to the brim with water.
2. Hang the object from the spring scale and record its weight.
3. With the object hanging from the spring scale, completely submerge the object in the water. The object should not be touching the bottom or the sides of the beaker.
4. **Record** the reading on the spring scale while the object is in the water. Calculate the buoyant force by subtracting this reading from the object's weight.



5. Use the funnel to carefully pour the water from the pan into the graduated cylinder. Record the volume of this water in cm^3.
6. **Calculate** the weight of the water displaced by multiplying the volume of water by 0.0098 N.

Conclude and Apply

1. **Explain** how the total force on the object changed when it was submerged in water.
2. **Compare** the weight of the water that is displaced with the buoyant force.
3. **Explain** how the buoyant force would change if the object were submersed halfway in water.

Communicating Your Data

Make a poster of an empty ship, a heavily loaded ship, and an overloaded, sinking ship. Explain how Archimedes' principle applies in each case. **For more help, refer to the Science Skill Handbook.**

John Evans

section 3

Doing Work with Fluids

as you read

What You'll Learn

- **Explain** how forces are transmitted through fluids.
- **Describe** how a hydraulic system increases force.
- **Describe** Bernoulli's principle.

Why It's Important

Fluids can exert forces that lift heavy objects and enable aircraft to fly.

Review Vocabulary

work: the product of the force applied to an object and the distance the object moves in the direction of the force

New Vocabulary

- Pascal's principle
- hydraulic system
- Bernoulli's principle

Using Fluid Forces

You might have watched a hydraulic lift raise a car off the ground. It might surprise you to learn that the force pushing the car upward is being exerted by a fluid. When a huge jetliner soars through the air, a fluid exerts the force that holds it up. Fluids at rest and fluids in motion can be made to exert forces that do useful work, such as pumping water from a well, making cars stop, and carrying people long distances through the air. How are these forces produced by fluids?

Pushing on a Fluid The pressure in a fluid can be increased by pushing on the fluid. Suppose a watertight, movable cover, or piston, is sitting on top of a column of fluid in a container. If you push on the piston, the fluid can't escape past the piston, so the height of the fluid in the container doesn't change. As a result, the piston doesn't move. But now the force exerted on the bottom of the container is the weight of the fluid plus the force pushing the piston down. Because the force exerted by the fluid at the bottom of the container has increased, the pressure exerted by the fluid also has increased. **Figure 19** shows how the force exerted on a brake pedal is transmitted to a fluid.

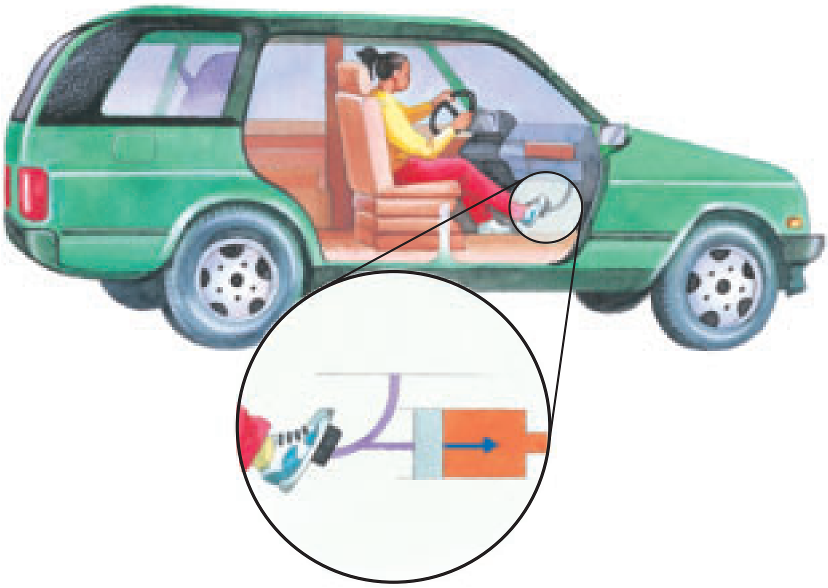


Figure 19 Because the fluid in this piston can't escape, it transmits the force you apply throughout the fluid.

Pascal's Principle

Suppose you fill a plastic bottle with water and screw the cap back on. If you poke a hole in the bottle near the top, water will leak out of the hole. However, if you squeeze the bottle near the bottom, as shown in **Figure 20,** water will shoot out of the hole. When you squeezed the bottle, you applied a force on the fluid. This increased the pressure in the fluid and pushed the water out of the hole faster.

No matter where you poke the hole in the bottle, squeezing the bottle will cause the water to flow faster out of the hole. The force you exert on the fluid by squeezing has been transmitted to every part of the bottle. This is an example of Pascal's principle. According to **Pascal's principle,** when a force is applied to a fluid in a closed container, the pressure in the fluid increases everywhere by the same amount.

Figure 20 When you squeeze the bottle, the pressure you apply is distributed throughout the fluid, forcing the water out the hole.

Hydraulic Systems

Pascal's principle is used in building hydraulic systems like the ones used by car lifts. A **hydraulic system** uses a fluid to increase an input force. The fluid enclosed in a hydraulic system transfers pressure from one piston to another. An example is shown in **Figure 21.** An input force that is applied to the small piston increases the pressure in the fluid. This pressure increase is transmitted throughout the fluid and acts on the large piston. The force the fluid exerts on the large piston is the pressure in the fluid times the area of the piston. Because the area of the large piston is greater than the area of the small piston, the output force exerted on the large piston is greater than the input force exerted on the small piston.

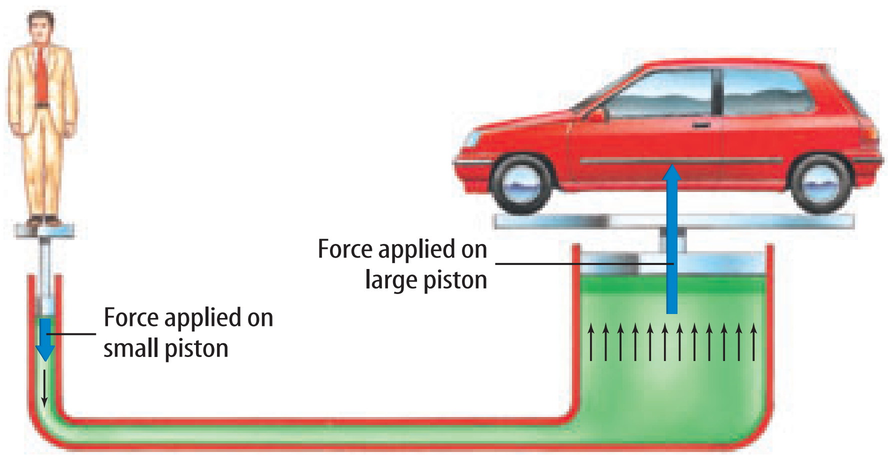


Figure 21 A hydraulic system uses Pascal's principle to make the output force applied on the large piston greater than the input force applied on the small piston.
Infer *how the force on the large piston would change if its area increased.*

KS Studios

Science Online

Topic: Hydraulic Systems

Visit bookm.msscience.com for Web links to information about hydraulic systems.

Activity Draw a diagram showing how one of the hydraulic systems that you find works. Share your diagram with the class.

Increasing Force What is the force pushing upward on the larger piston? For example, suppose that the area of the small piston is 1 m^2 and the area of the large piston is 2 m^2. If you push on the small piston with a force of 10 N, the increase in pressure at the bottom of the small piston is

$$\begin{aligned} P &= F/A \\ &= (10\text{ N})/(1\text{ m}^2) \\ &= 10\text{ Pa} \end{aligned}$$

According to Pascal's principle, this increase in pressure is transmitted throughout the fluid. This causes the force exerted by the fluid on the larger piston to increase. The increase in the force on the larger piston can be calculated by multiplying both sides of the above formula by *A*.

$$\begin{aligned} F &= P \times A \\ &= 10\text{ Pa} \times 2\text{ m}^2 \\ &= 20\text{ N} \end{aligned}$$

The force pushing upward on the larger piston is twice as large as the force pushing downward on the smaller piston. What happens if the larger piston increases in size? Look at the calculation above. If the area of the larger piston increases to 5 m^2, the force pushing up on this piston increases to 50 N. So a small force pushing down on the left piston as in **Figure 21** can be made much larger by increasing the size of the piston on the right.

Reading Check *How does a hydraulic system increase force?*

Figure 22 By blowing on one side of the can, you decrease the air pressure on that side. Because the pressure on the opposite side is now greater, the can moves toward the side you're blowing on.

Pressure in a Moving Fluid

What happens to the pressure in a fluid if the fluid is moving? Try the following experiment. Place an empty soda can on the desktop and blow to the right of the can, as shown in **Figure 22.** In which direction will the can move?

When you blow to the right of the can, the can moves to the right, toward the moving air. The air pressure exerted on the right side of the can, where the air is moving, is less than the air pressure on the left side of the can, where the air is not moving. As a result, the force exerted by the air pressure on the left side is greater than the force exerted on the right side, and the can is pushed to the right. What would happen if you blew between two empty cans?

Dominic Oldershaw

Bernoulli's Principle

The reason for the surprising behavior of the can in **Figure 22** was discovered by the Swiss scientist Daniel Bernoulli in the eighteenth century. It is an example of Bernoulli's principle. According to **Bernoulli's principle,** when the speed of a fluid increases, the pressure exerted by the fluid decreases. When you blew across the side of the can, the pressure exerted by the air on that side of the can decreased because the air was moving faster than it was on the other side. As a result, the can was pushed toward the side you blew across.

Chimneys and Bernoulli's Principle In a fireplace the hotter, less dense air above the fire is pushed upward by the cooler, denser air in the room. Wind outside of the house can increase the rate at which the smoke rises. Look at **Figure 23.** Air moving across the top of the chimney causes the air pressure above the chimney to decrease according to Bernoulli's principle. As a result, more smoke is pushed upward by the higher pressure of the air in the room.

Damage from High Winds You might have seen photographs of people preparing for a hurricane by closing shutters over windows or nailing boards across the outside of windows. In a hurricane, the high winds blowing outside the house cause the pressure outside the house to be less than the pressure inside. This difference in pressure can be large enough to cause windows to be pushed out and to shatter.

Hurricanes and other high winds sometimes can blow roofs from houses. When wind blows across the roof of a house, the pressure outside the roof decreases. If the wind outside is blowing fast enough, the outside pressure can become so low that the roof can be pushed off the house by the higher pressure of the still air inside.

Wings and Flight

You might have placed your hand outside the open window of a moving car and felt the push on it from the air streaming past. If you angled your hand so it tilted upward into the moving air, you would have felt your hand pushed upward. If you increased the tilt of your hand, you felt the upward push increase. You might not have realized it, but your hand was behaving like an airplane wing. The force that lifted your hand was provided by a fluid—the air.

Mini LAB

Observing Bernoulli's Principle

Procedure

1. Tie a piece of **string** to the handle of a **plastic spoon.**
2. Turn on a faucet to make a stream of water.
3. Holding the string, bring the spoon close to the stream of water.

Analysis

Use Bernoulli's principle to explain the motion of the spoon.

Try at Home

Figure 23 The air moving past the chimney lowers the air pressure above the chimney. As a result, smoke is forced up the chimney faster than when air above the chimney is still.

Producing Lift How is the upward force, or lift, on an airplane wing produced? A jet engine pushes the plane forward, or a propeller pulls the plane forward. Air flows over the wings as the plane moves. The wings are tilted upward into the airflow, just like your hand was tilted outside the car window. **Figure 24** shows how the tilt of the wing causes air that has flowed over the wing's upper and lower surfaces to be directed downward.

Lift is created by making the air flow downward. To understand this, remember that air is made of different types of molecules. The motion of these molecules is changed only when a force acts on them. When the air is directed downward, a force is being exerted on the air molecules by the wing.

However, according to Newton's third law of motion, for every action force there is an equal but opposite reaction force. The wing exerts a downward action force on the air. So the air must exert an upward reaction force on the wing. This reaction force is the lift that enables paper airplanes and jet airliners to fly.

Airplane Wings Airplanes have different wing shapes, depending on how the airplane is used. The lift on a wing depends on the amount of air that the wing deflects downward and how fast that air is moving. Lift can be increased by increasing the size or surface area of the wing. A larger wing is able to deflect more air downward.

Look at the planes in **Figure 25.** A plane designed to fly at high speeds, such as a jet fighter, can have small wings. A large cargo plane that carries heavy loads needs large wings to provide a great deal of lift. A glider flies at low speeds and uses long wings that have a large surface area to provide the lift it needs.

Reading Check *How can a wing's lift be increased?*

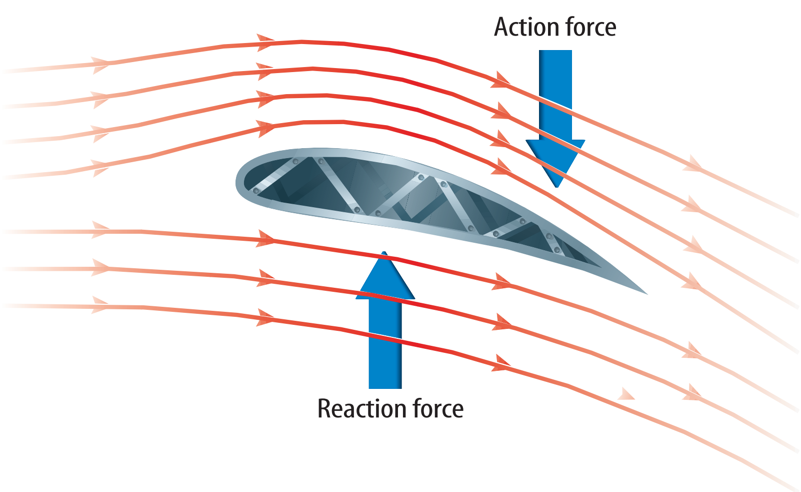


Figure 24 An airplane wing forces air to be directed downward. As a result, the air exerts an upward reaction force on the wing, producing lift.

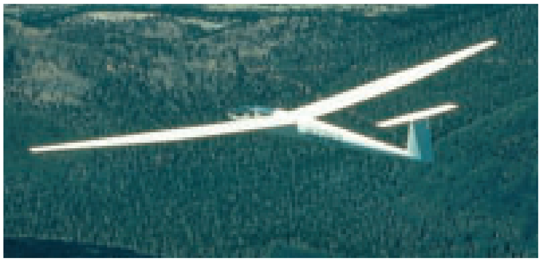


Figure 25 Different wing shapes are used for different types of planes. Larger wings provide more lift.

INTEGRATE Life Science

Birds' Wings A bird's wing provides lift in the same way that an airplane wing does. The wings also act as propellers that pull the bird forward when it flaps its wings up and down. Bird wings also have different shapes depending on the type of flight. Seabirds have long, narrow wings, like the wings of a glider, that help them glide long distances. Forest and field birds, such as pheasants, have short, rounded wings that enable them to take off quickly and make sharp turns. Swallows, swifts, and falcons, which fly at high speeds, have small, narrow, tapered wings like those on a jet fighter.

section 3 review

Summary

Pascal's Principle

- Pascal's principle states that when a force is applied to a fluid in a closed container, the pressure in the fluid increases by the same amount everywhere in the fluid.
- Hydraulic systems use Pascal's principle to produce an output force that is greater than an applied input force.
- Increasing the surface area in contact with a fluid increases the buoyant force on an object.

Bernoulli's Principle

- Bernoulli's principle states that when the speed of a fluid increases, the pressure exerted by the fluid decreases.

Wings and Flight

- An airplane wing exerts a force on air and deflects it downward. By Newton's third law, the air exerts an upward reaction force.

Self Check

1. **Explain** why making an airplane wing larger enables the wing to produce more lift.
2. **Infer** If you squeeze a plastic water-filled bottle, where is the pressure change in the water the greatest?
3. **Explain** Use Bernoulli's principle to explain why a car passing a truck tends to be pushed toward the truck.
4. **Infer** why a sheet of paper rises when you blow across the top of the paper.
5. **Think Critically** Explain why the following statement is false: In a hydraulic system, because the increase in the pressure on both pistons is the same, the increase in the force on both pistons is the same.

Applying Math

6. **Calculate Force** The small piston of a hydraulic lift, has an area of 0.01 m^2. If a force of 250 N is applied to the small piston, find the force on the large piston if it has an area of 0.05 m^2.

Science Online bookm.msscience.com/self_check_quiz

(t)Michael Collier/Stock Boston, (bl)George Hall/CORBIS, (br)Dean Conger/CORBIS

LAB

Use the Internet

Barometric Pressure and Weather

Goals

- **Collect** barometric pressure and other weather data.
- **Compare** barometric pressure to weather conditions.
- **Predict** weather patterns based on barometric pressure, wind speed and direction, and visual conditions.

Data Source

Science Online

Visit bookm.msscience.com/internet_lab for more information about barometric pressure, weather information, and data collected by other students.

Real-World Question

What is the current barometric pressure where you are? How would you describe the weather today where you are? What is the weather like in the region to the west of you? To the east of you? What will your weather be like tomorrow? The atmosphere is a fluid and flows from one place to another as weather patterns change. Changing weather conditions also cause the atmospheric pressure to change. By collecting barometric pressure data and observing weather conditions, you will be able to make a prediction about the next day's weather.

Make a Plan

1. Visit the Web site on the left for links to information about weather in the region where you live.
2. Find and record the current barometric pressure and whether the pressure is rising, falling, or remaining steady. Also record the wind speed and direction.
3. **Observe and record** other weather conditions, such as whether rain is falling, the Sun is shining, or the sky is cloudy.
4. Based on the data you collect and your observations, predict what you think tomorrow's weather will be. Record your prediction.
5. Repeat the data collection and observation for a total of five days.

Steve McCutcheon/Visuals Unlimited

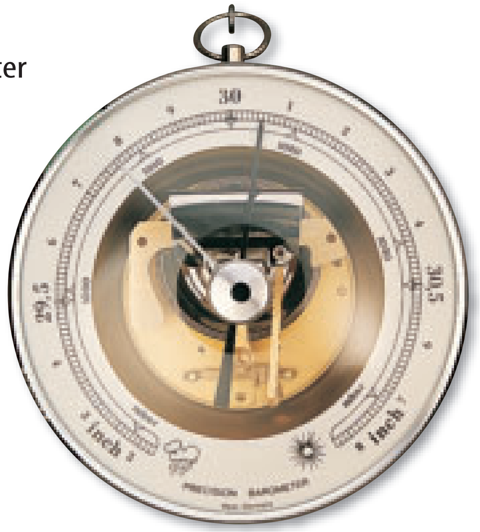
Barometric Pressure Weather Data	
Location of weather station	
Barometric pressure	
Status of barometric pressure	
Wind speed	Do not write in this book.
Wind direction	
Current weather conditions	
Predictions of tomorrow's weather conditions	

Follow Your Plan

1. Make sure your teacher approves your plan before you start.
2. Visit the link below to post your data.

Analyze Your Data

1. **Analyze** Look at your data. What was the weather the day after the barometric pressure increased? The day after the barometric pressure decreased? The day after the barometric pressure was steady?
2. **Draw Conclusions** How accurate were your weather predictions?



Conclude and Apply

1. **Infer** What is the weather to the west of you today? How will that affect the weather in your area tomorrow?
2. **Compare** What was the weather to the east of you today? How does that compare to the weather in your area yesterday?
3. **Evaluate** How does increasing, decreasing, or steady barometric pressure affect the weather?

Communicating Your Data

Find this lab using the link below. Use the data on the Web site to predict the weather where you are two days from now.

Science Online

bookm.msscience.com/internet_lab

Runk/Schoenberger from Grant Heilman

Science and Language Arts

"Hurricane"

by John Balaban

Near dawn our old live oak sagged over
then crashed on the tool shed
rocketing off rakes paintcans flower pots.

All night, rain slashed the shutters until
it finally quit and day arrived in queer light,
silence, and ozoned air. Then voices calling

as neighbors crept out to see the snapped trees,
leaf mash and lawn chairs driven in heaps
with roof bits, siding, sodden birds, dead snakes.

For days, bulldozers clanked by our houses
in sickening August heat as heavy cranes
scraped the rotting tonnage from the streets.

Then our friend Elling drove in from Sarasota
in his old . . . van packed with candles, with
dog food, cat food, flashlights and batteries . . . .

Understanding Literature

Sense Impressions In this poem, John Balaban uses sense impressions to place the reader directly into the poem's environment. For example, the words *rotting tonnage* evoke the sense of smell. Give examples of other sense impressions mentioned.

Respond to the Reading

1. What kinds of damage did the hurricane cause?
2. Why do you think the poet felt relief when his friend, Elling, arrived?
3. **Linking Science and Writing** Write a poem describing a natural phenomenon involving forces and fluids. Use words that evoke at least one of the five sense impressions.

INTEGRATE Physics

In the poem, bits of roofs and siding from houses are part of the debris that is everywhere in heaps. According to Bernoulli's principle, the high winds in a hurricane blowing past a house causes the air pressure outside the house to be less than the air pressure inside. In some cases, the forces exerted by the air inside causes the roof to be pushed off the house, and the walls to be blown outward.

AP/Wide World Photos/Ray Fairall

Reviewing Main Ideas

Section 1 Pressure

1. Pressure equals force divided by area.
2. Liquids and gases are fluids that flow.
3. Pressure increases with depth and decreases with elevation in a fluid.
4. The pressure exerted by a fluid on a surface is always perpendicular to the surface.

Section 2 Why do objects float?

1. A buoyant force is an upward force exerted on all objects placed in a fluid.
2. The buoyant force depends on the shape of the object.
3. According to Archimedes' principle, the buoyant force on the object is equal to the weight of the fluid displaced by the object.
4. An object floats when the buoyant force exerted by the fluid is equal to the object's weight.
5. An object will float if it is less dense than the fluid it is placed in.

Section 3 Doing Work with Fluids

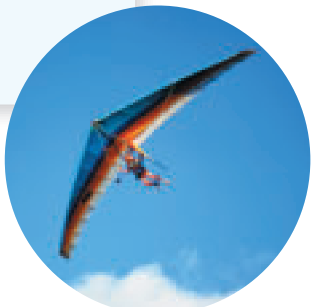
1. Pascal's principle states that the pressure applied at any point to a confined fluid is transmitted unchanged throughout the fluid.
2. Bernoulli's principle states that when the velocity of a fluid increases, the pressure exerted by the fluid decreases.
3. A wing provides lift by forcing air downward.

Visualizing Main Ideas

Copy and complete the following table.

Relationships Among Forces and Fluids

Idea	What does it relate?	How?
Density	mass and volume	
Pressure		force/area
Archimedes' principle	buoyant force and weight of fluid that is displaced	
Bernoulli's principle		velocity increases, pressure decreases
Pascal's principle	pressure applied to enclosed fluid at one point and pressure at other points in a fluid	



(l)D.R. & T.L. Schrichte/Stone/Getty Images, (r)CORBIS

Using Vocabulary

Archimedes' principle p. 77	fluid p. 69
Bernoulli's principle p. 85	hydraulic system p. 83
buoyant force p. 74	Pascal's principle p. 83
density p. 78	pressure p. 66

Answer each of the following questions using complete sentences that include vocabulary from the list above.

1. How would you describe a substance that can flow?
2. When the area over which a force is applied decreases, what increases?
3. What principle relates the weight of displaced fluid to the buoyant force?
4. How is a fluid used to lift heavy objects?
5. If you increase an object's mass but not its volume, what have you changed?
6. How is a log able to float in a river?
7. What principle explains why hurricanes can blow the roof off of a house?

Checking Concepts

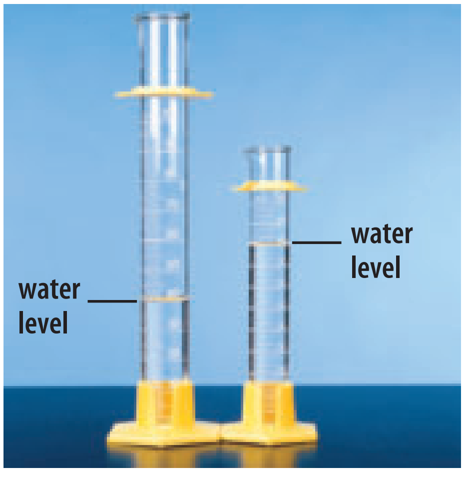
Choose the word or phrase that best answers the question.

8. Which always equals the weight of the fluid displaced by an object?
   A) the weight of the object
   B) the force of gravity on the object
   C) the buoyant force on the object
   D) the net force on the object

9. What is the net force on a rock that weighs 500 N if the weight of the water it displaces is 300 N?
   A) 200 N downward **C)** 800 N downward
   B) 200 N upward **D)** 800 N upward

10. The pressure exerted by a fluid on a surface is always in which direction?
   A) upward
   B) downward
   C) parallel to the surface
   D) perpendicular to the surface

Use the photo below to answer question 11.



11. Each graduated cylinder contains the same amount of water. Which of the following statements is true?
   A) The pressure is greater at the bottom of the large cylinder.
   B) The pressure is greater at the bottom of the small cylinder.
   C) The pressure is equal at the bottom of both cylinders.
   D) There is zero pressure at the bottom of both cylinders.

12. Which would increase the lift provided by an airplane wing?
   A) decreasing the volume of the wing
   B) increasing the area of the wing
   C) decreasing the length of the wing
   D) increasing the mass of the wing

13. An airplane wing produces lift by forcing air in which direction?
   A) upward **C)** under the wing
   B) downward **D)** over the wing

Matt Meadows
Science Online bookm.msscience.com/vocabulary_puzzlemaker

Thinking Critically

14. **Explain** A sandbag is dropped from a hot-air balloon and the balloon rises. Explain why this happens.

15. **Determine** whether or not this statement is true: Heavy objects sink, and light objects float. Explain your answer.

16. **Explain** why a leaking boat sinks.

17. **Explain** why the direction of the buoyant force on a submerged cube is upward and not left or right.

18. **Recognizing Cause and Effect** A steel tank and a balloon are the same size and contain the same amount of helium. Explain why the balloon rises and the steel tank doesn't.

19. **Make and Use Graphs** Graph the pressure exerted by a 75-kg person wearing different shoes with areas of 0.01 m^2, 0.02 m^2, 0.03 m^2, 0.04 m^2, and 0.05 m^2. Plot pressure on the vertical axis and area on the horizontal axis.

20. **Explain** why it is easier to lift an object that is underwater, than it is to lift the object when it is out of the water.

21. **Infer** Two objects with identical shapes are placed in water. One object floats and the other object sinks. Infer the difference between the two objects that causes one to sink and the other to float.

22. **Compare** Two containers with different diameters are filled with water to the same height. Compare the force exerted by the fluid on the bottom of the two containers.

Performance Activities

23. **Oral Presentation** Research the different wing designs in birds or aircraft. Present your results to the class.

24. **Experiment** Partially fill a plastic dropper with water until it floats just below the surface of the water in a bowl or beaker. Place the dropper inside a plastic bottle, fill the bottle with water, and seal the top. Now squeeze the bottle. What happens to the water pressure in the bottle? How does the water level in the dropper change? How does the density of the dropper change? Use your answers to these questions to explain how the dropper moves when you squeeze the bottle.

Applying Math

25. **Buoyant Force** A rock is attached to a spring scale that reads 10 N. If the rock is submerged in water, the scale reads 6 N. What is the buoyant force on the submerged rock?

26. **Hydraulic Force** A hydraulic lift with a large piston area of 0.04 m^2 exerts a force of 5,000 N. If the smaller piston has an area of 0.01 m^2, what is the force on it?

Use the table below to answer questions 27 and 28.

Material Density

Substance	Density (g/cm^3)
Ice	0.92
Lead	11.34
Balsa wood	0.12
Sugar	1.59

27. **Density** Classify which of the above substances will and will not float in water.

28. **Volume** Find the volumes of each material, if each has a mass of 25 g.

29. **Pressure** What is the pressure due to a force of 100 N on an area 4 m^2?

30. **Pressure** A bottle of lemonade sitting on a table weighs 6 N. The bottom of the bottle has a surface area of 0.025 m^2. Calculate the pressure the bottle of lemonade exerts on the table.

chapter 3 Standardized Test Practice

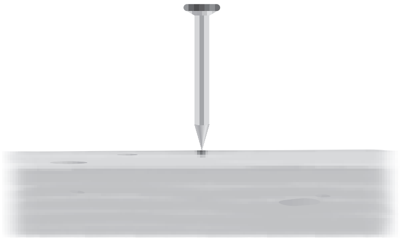
Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

1. A force of 15 N is exerted on an area of 0.1 m^2. What is the pressure?

A. 150 N
B. 150 Pa
C. 1.5 Pa
D. 0.007 Pa

Use the illustration below to answer questions 2 and 3.



2. Which statement is TRUE?

A. The contact area between the board and the nail tip is large.
B. The contact area between the nail tip and the board is greater than the contact area between the nail head and the hammer head.
C. The nail exerts no pressure on the board because its weight is so small.
D. The pressure exerted by the nail is large because the contact area between the nail tip and the board is small.

3. Which increases the pressure exerted by the nail tip on the board?

A. increasing the area of the nail tip
B. decreasing the area of the nail tip
C. increasing the length of the nail
D. decreasing the length of the nail

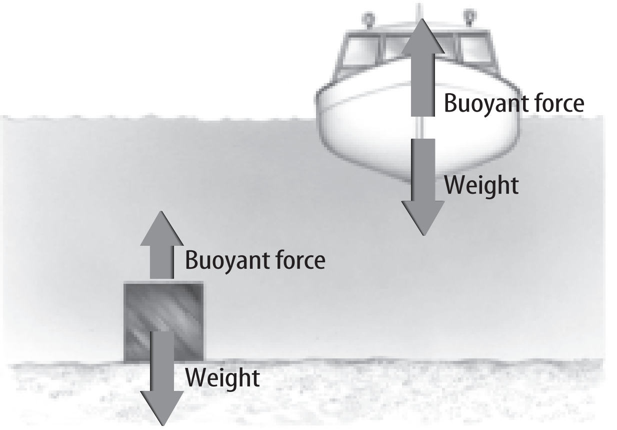
Test-Taking Tip

Check the Answer Number For each question, double check that you are filling in the correct answer bubble for the question number you are working on.

4. A 15-g block of aluminum has a volume of 5.5 cm^3. What is the density?

A. 2.7 g/cm^3
B. 82.5 g/cm^3
C. 0.37 g/cm^3
D. 2.7 cm^3/g

Use the illustration below to answer questions 5 and 6.



5. Assume the boat and cube have the same mass. Which of these is correct?

A. The boat displaces less water than the cube.
B. The densities of the boat and cube are equal.
C. The density of the boat is less than the density of the cube.
D. The density of the boat is greater than the density of the water.

6. Which of the following would make the cube more likely to float?

A. increasing its volume
B. increasing its density
C. increasing its weight
D. decreasing its volume

7. Which of the following instruments is used to measure atmospheric pressure?

A. altimeter
B. hygrometer
C. barometer
D. anemometer

Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

8. Explain why wearing snowshoes makes it easier to walk over deep, soft snow.

9. Why is a gas, such as air condidered to be a fluid?

10. Explain why the pressure exerted by the atmosphere does not crush your body.

Use the illustration below to answer questions 11 and 12.

11. How does the buoyant force on the boat change if the boat is loaded so that it floats lower in the water?

12. What changes in the properties of this boat could cause it to sink?

13. People sometimes prepare for a coming hurricane by nailing boards over the outside of windows. How can high winds damage windows?

14. What factors influence the amount of lift on an airplane wing?

15. The pressure inside the fluid of a hydraulic system is increased by 1,000 Pa. What is the increase in the force exerted on a piston that has an area of 0.05 m^2?

Part 3 Open Ended

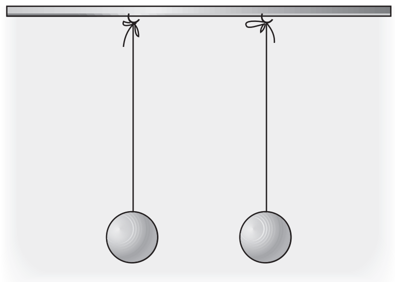
Record your answers on a sheet of paper.

16. Explain why the interior of an airplane is pressurized when flying at high altitude. If a hole were punctured in an exterior wall, what would happen to the air pressure inside the plane?

17. In an experiment, you design small boats using aluminum foil. You add pennies to each boat until it sinks. Sketch several different shapes you might create. Which will likely hold the most pennies? Why?

18. You squeeze a round, air-filled balloon slightly, changing its shape. Describe how the pressure inside the balloon changes.

Use the illustration below to answer questions 19 and 20.



19. Describe the motion of the table tennis balls when air is blown between the two balls. Explain.

20. Describe the motion of the table tennis balls if air blown to the left of the ball on the left and to the right of the ball on the right at the same time. Explain.

21. Compare the pressure you exert on a floor when you are standing on the floor and when you are lying on the floor.

22. In order to drink a milk shake through a straw, how must the air pressure inside the straw change, compared with the air pressure outside the straw?

Vince Streano/Stone/Getty Images