# Forces in Fluids

## Chapter Planning Guide

### Objectives

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| **Section 1** | Fluids and Pressure | - Describe how fluids exert pressure.  
- Analyze how atmospheric pressure varies with depth.  
- Explain how depth and density affect water pressure.  
- Give examples of fluids flowing from high to low pressure. |
| **Section 2** | Buoyant Force | - Explain the relationship between fluid pressure and buoyant force.  
- Predict whether an object will float or sink in a fluid.  
- Analyze the role of density in an object’s ability to float.  
- Explain how the overall density of an object can be changed. |
| **Section 3** | Fluids and Motion | - Describe the relationship between pressure and fluid speed.  
- Analyze the roles of lift, thrust, and wing size in flight.  
- Describe drag, and explain how it affects lift.  
- Explain Pascal’s principle. |

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### Online and Technology Resources

Visit go.hrw.com for access to Holt Online Learning, or enter the keyword HP7 Home for a variety of free online resources.

This CD-ROM package includes:

- ExamView® Test Generator
- Interactive Teacher’s Edition
- Holt PuzzlePro®
- Holt PowerPoint® Resources
### SKILLS DEVELOPMENT RESOURCES

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| SE Math Focus Finding Density, p. 188 | General |
| TE Support for English Language Learners, p. 189 |

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| TE Reteaching, p. 190 | Basic |
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### CORRELATIONS

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**National Science Education Standards**

SAI 1, 2; ST 2

**SAI 1; ST 2; PS 1a**

**SAI 1; ST 2; HNS 3; PS 1a, 2c**

**Chapter Lab:** SAI 1; LabBook: SAI 1

**UCP 5; SAI 1; ST 2; SPSP 5; HNS 3**

**KEY**

<table>
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* Also on One-Stop Planner
- Requires advance prep
- Also available in Spanish

**SCIlinks.org**

Maintained by the National Science Teachers Association. See Chapter Enrichment pages that follow for a complete list of topics.

Check out Current Science articles and activities by visiting the HRW Web site at go.hrw.com. Just type in the keyword HPSCS07T.

**Classroom Videos**

- Lab Videos demonstrate the chapter lab.
- Brain Food Video Quizzes help students review the chapter material.

**Classroom CD-ROMs**

- Guided Reading Audio CD (Also in Spanish)
- Interactive Explorations
- Virtual Investigations
- Visual Concepts
- Science Tutor

**Holt Lab Generator CD-ROM**

- Search for any lab by topic, standard, difficulty level, or time. Edit any lab to fit your needs, or create your own labs. Use the Lab Materials QuickList software to customize your lab materials list.

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Chapter 7 • Forces in Fluids

Imagine... 

Write the story of the deep-sea fisher who recently discovered a new species of fish. The fish lives in water so deep that the pressure is 1,000 times greater than the pressure at the surface of the ocean. How does this pressure affect the fish's behavior? How does it affect the fish's ability to breathe and swim? Describe the adaptations that this fish may have developed to survive in such a hostile environment.

Section: Fluids and Pressure 

Answer the following questions: 

1. What is the difference between pressure and force? 
2. How does the pressure inside a balloon change as you blow it up? 
3. Why do divers wear special equipment underwater? 
4. What is the effect of depth on the pressure of water? 

Section: Buoyant Force 

Identify which of the following objects will float in water: a rock, an orange, a sponge, a quarter, a candle, a plastic-drain "plunger," and a sand-filled seaweed. 

Write a hypothesis in your science journal to explain why an object will float in water.

Check out the CD-ROM

This CD-ROM includes all of the resources shown here and the following time-saving tools:

• Lab Materials QuickList Software
• Customizable lesson plans
• Holt Calendar Planner
• The powerful ExamView® Test Generator
Chapter Enrichment

This Chapter Enrichment provides relevant and interesting information to expand and enhance your presentation of the chapter material.

Section 1

Fluids and Pressure

Refresher on Gas Laws

• Nearly all materials expand when they are heated and contract when they are cooled. Gases are not an exception. A gas expands as it gets hotter because the kinetic energy of its particles increases. When the kinetic energy increases, the particles move faster and bounce against each other harder. This movement causes the gas particles to move farther apart, and the gas expands. If the pressure does not change, the volume of the gas will increase as the temperature increases. This property of gases is known as Charles’s law.

• The air pressure inside the tires of an automobile can be much greater than the pressure outside the tires. The pressure can be greater inside an enclosed container because air, like all gases, is compressible. If the temperature does not change, the pressure of a gas will increase as the volume decreases. This property of gases is known as Boyle’s law.

Section 2

Buoyant Force

Archimedes (287–212 BCE)

• Archimedes, a Greek mathematician, inventor, and physicist, lived in the ancient city of Syracuse from 287 to 212 BCE. He is famous for his work in geometry, physics, mechanics, and water pressure.

Diving and Water Pressure

• Scuba diving relies in part on the principles of buoyancy and fluid pressure. Some of the effects of water pressure can be felt even in a swimming pool. Just a few meters under water, your ears begin to hurt from the pressure of the water on your eardrums.

• As a diver descends deeper into the water with scuba gear, the diver’s lungs hold more air because the air is compressed by the water pressure. As a diver rises to the surface, the air expands again. Under certain circumstances, the air in a diver’s lungs could expand enough to rupture the air sacs in the diver’s lungs.

Is That a Fact!

• Humans have built underwater vessels for hundreds of years. In 1620, the Dutch inventor Cornelis Drebbel built what is thought to be the first submarine. His vessel was not much more than a rowboat covered with greased leather. It traveled at a depth of 4 to 5 m under water in the Thames River, in London, England. King James I of England is said to have taken a short ride in this vessel.

Neutral Buoyancy

• Scuba divers use weights to compensate for the buoyancy of their body and diving gear. When a diver weighs exactly the same as an equal volume of the surrounding water, the diver can swim to any depth and remain there effortlessly. This state is called neutral buoyancy.

Is That a Fact!

• The water pressure at the bottom of a small, deep pond is greater than the pressure at the bottom of a large, shallow lake because water pressure is determined by the depth of the water, not the volume of the water.
Section 3

Fluids and Motion

Daniel Bernoulli (1700–1782)

- Daniel Bernoulli was born in the Netherlands in 1700. For most of his life, he lived in Basel, Switzerland.

- Bernoulli was born into a family distinguished for accomplishments in science and mathematics. His father, Johann, was famous for his work in calculus, trigonometry, and the study of geodesics. Bernoulli’s uncle Jacob was integral in the development of calculus. Bernoulli’s brothers, Nicolaus and Johann II, were also noted mathematicians and physicists.

- Bernoulli’s greatest work was *Hydrodynamica*, which was published in 1738. It included the concept now known as Bernoulli’s principle. He also made important contributions to probability theory and studied astronomy, botany, physiology, gravity, and magnetism.

Examples of Bernoulli’s Principle

- Even on a calm night, air moves across the top of a chimney. This air movement causes the pressure at the top of the chimney to be lower than the pressure in the house. According to Bernoulli’s principle, the smoke in the fireplace is pushed up the chimney by the greater air pressure in the house.

- Bernoulli’s principle also explains why a soft convertible top on a car bulges when the car travels at high speeds. The air moving over the top causes an area of low pressure, and the higher pressure inside the car pushes the soft top up.

Is That a Fact!

- Water flowing in a stream speeds up when it flows through a narrow part of the stream bed. According to Bernoulli’s principle, the water pressure decreases as the speed increases.

Blaise Pascal

- Blaise Pascal (1623–1662) was a famous French scientist, mathematician, philosopher, and writer of prose. He had no formal schooling but pursued his interests under his father’s guidance. Pascal’s father forbade him to study mathematics until he was 15 years old, but Pascal’s curiosity led him to begin studying geometry in secret at the age of 12. By the time he was 14, Pascal was regularly attending sessions with the leading geometers of his time. Pascal presented his first mathematics paper at the age of 16. The SI unit for pressure, the pascal, is named after Blaise Pascal.

SciLinks

SciLinks is maintained by the National Science Teachers Association to provide you and your students with interesting, up-to-date links that will enrich your classroom presentation of the chapter. Visit www.sci-links.org and enter the SciLinks code for more information about the topic listed.

- Topic: Fluids and Pressure  SciLinks code: HSM0586
- Topic: Bernoulli’s Principle  SciLinks code: HSM0143
- Topic: Buoyant Force  SciLinks code: HSM0202
Overview
Tell students that this chapter will help them learn about fluids and the forces caused by fluids, including buoyant force, lift, and drag. Students also learn about pressure and the factors that affect flight.

Assessing Prior Knowledge
Students should be familiar with the following topics:
- forces and net force
- motion and speed
- SI units

Identifying Misconceptions
As students learn the material in this chapter, some of them may have difficulties understanding that gases, such as oxygen and air, are fluids. This confusion may result from the common usage of the word fluid. In everyday language, fluids usually refer to liquids only.

Overview
The following codes indicate the National Science Education Standards that correlate to this chapter. The full text of the standards is at the front of the book.

Chapter Opener
SAI 1, 2; ST 2

Section 1 Fluids and Pressure
SAI 1; ST 2; PS 1a

Section 2 Buoyant Force
SAI 1; ST 2; HNS 3; PS 1a, 2c; LabBook: SAI 1

Section 3 Fluids and Motion
UCP 5; SAI 1; ST 2; SPSP 5; HNS 3; LabBook: SAI 1

Chapter Lab
SAI 1

Chapter Review
SAI 1

Science in Action
SPSP 5

PRE-READING
Before you read the chapter, create the FoldNote entitled “Booklet” described in the Study Skills section of the Appendix. Label each page of the booklet with a main idea from the chapter. As you read the chapter, write what you learn about each main idea on the appropriate page of the booklet.

Overview
As you race downhill on your bicycle, the air around you pushes on your body and slows you down. "What a drag!" you say. Well, actually, it is a drag. When designing bicycle gear and clothing, manufacturers consider more than just looks and comfort. They also try to decrease drag, a fluid force that opposes motion. This photo shows cyclists riding their bikes in a wind tunnel in a study of how a fluid—air—affects their ride.
Taking Flight

In this activity, you will build a model airplane to learn how wing size affects flight.

Procedure

1. Fold a sheet of paper in half lengthwise. Then, open it. Fold the top corners toward the center crease. Keep the corners folded down, and fold the entire sheet in half along the center crease.
2. With the plane on its side, fold the top front edge down so that it meets the bottom edge. Fold the top edge down again so that it meets the bottom edge. Turn the plane over, and repeat.
3. Raise the wings so that they are perpendicular to the body.
4. Point the plane slightly upward, and gently throw it. Repeat several times. Describe what you see.
5. Make the wings smaller by folding them one more time. Gently throw the plane. Repeat several times. Describe what you see.
6. Using the smaller wings, try to achieve the same flight path you saw when the wings were bigger.

Analysis

1. What happened to the plane’s flight when you reduced the size of its wings? What did you have to do to achieve the same flight path as when the wings were bigger?
2. What gave your plane its forward motion?

Teacher’s Notes: Tell students that this activity is an exception to the usual rules about flying paper planes in class.

Answers

1. Sample answer: The plane did not stay in the air as long. To get a longer flight, I had to throw much harder.
2. Sample answer: I gave the plane its forward motion when I threw the plane.

MATERIALS

For Each Student
- paper, sheet

For Each Group

Teacher’s Notes:
- Tell students that this activity is an exception to the usual rules about flying paper planes in class.

Answers

1. Sample answer: The plane did not stay in the air as long. To get a longer flight, I had to throw much harder.
2. Sample answer: I gave the plane its forward motion when I threw the plane.

Forces in Fluids

Imagine . . .

Imagine a scenario in which a new underwater vehicle is designed to explore deep ocean areas. The vehicle’s design includes a streamlined shape to reduce drag and a powerful propeller to provide thrust. As the vehicle descends into the ocean depths, it encounters increasing pressure, which affects its performance.

Chapter Starter Transparency

Use this transparency to help students begin thinking about fluids and pressure.

CHAPTER RESOURCES

Technology

- Transparencies
- Student Edition on CD-ROM
- Guided Reading Audio CD
- Classroom Videos

Workbooks

- Science Puzzlers, Twisters & Teasers

Chapter 7 • Forces in Fluids
Fluids and Pressure

What does a dolphin have in common with a sea gull? What does a dog have in common with a fly? What do you have in common with all these living things?

One answer to these questions is that you and all these other living things spend a lifetime moving through fluids. A fluid is any material that can flow and that takes the shape of its container. Fluids include liquids and gases. Fluids can flow because the particles in fluids move easily past each other.

Fluids Exert Pressure

You probably have heard the terms air pressure and water pressure. Air and water are fluids. All fluids exert pressure. So, what is pressure? Think about this example. When you pump up a bicycle tire, you push air into the tire. And like all matter, air is made of tiny particles that are constantly moving.

Look at Figure 1. Inside the tire, the air particles collide with each other and with the walls of the tire. Together, these collisions create a force on the tire. The amount of force exerted on a given area is pressure.

Calculating Pressure

Pressure can be calculated by using the following equation:

\[ \text{pressure} = \frac{\text{force}}{\text{area}} \]

The SI unit for pressure is the pascal. One pascal (1 Pa) is the force of one newton exerted over an area of one square meter (1 N/m²).

Brainstorming

The key idea of this section is pressure. Brainstorm words and phrases related to pressure.
Pressure, Force, and Area  What is the pressure exerted by a book that has an area of 0.2 m² and a weight of 10 N?

**Step 1:** Write the equation for pressure.

\[ \text{pressure} = \frac{\text{force}}{\text{area}} \]

**Step 2:** Replace force and area with the values given, and solve. (Hint: Weight is a measure of gravitational force.)

\[ \text{pressure} = \frac{10 \text{ N}}{0.2 \text{ m}^2} = 50 \text{ N/m}^2 = 50 \text{ Pa} \]

Pressure and Bubbles

When you blow a soap bubble, you blow in only one direction. So, why does the bubble get rounder instead of longer as you blow? The shape of the bubble partly depends on an important property of fluids: Fluids exert pressure evenly in all directions. The air you blow into the bubble exerts pressure evenly in all directions. So, the bubble expands in all directions to create a sphere.

Atmospheric Pressure

The atmosphere is the layer of nitrogen, oxygen, and other gases that surrounds Earth. Earth’s atmosphere is held in place by gravity, which pulls the gases toward Earth. The pressure caused by the weight of the atmosphere is called atmospheric pressure.

Atmospheric pressure is exerted on everything on Earth, including you. At sea level, the atmosphere exerts a pressure of about 101,300 N on every square meter, or 101,300 Pa. So, there is a weight of about 10 N (about 2 lbs) on every square centimeter of your body. Why don’t you feel this crushing pressure? Like the air inside a balloon, the fluids inside your body exert pressure. Figure 2 can help you understand why you don’t feel the pressure.

**Reading Check**  Name two gases in the atmosphere.  (See the Appendix for answers to Reading Checks.)

**Answer to Math Focus**

1. \( \text{pressure} = \frac{3,000 \text{ N}}{2 \text{ m}^2} = 1,500 \text{ Pa} \)
2. \( \text{force} = 250 \text{ Pa} \times 10 \text{ m}^2 = 2,500 \text{ N} \)

**Answer to Reading Check**

Two gases in the atmosphere are nitrogen and oxygen.

**Figure 2** The air inside a balloon exerts pressure that keeps the balloon inflated against atmospheric pressure. Similarly, fluid inside your body exerts pressure that works against atmospheric pressure.

**Math Focus**

**Demonstrate** — **General**

**Safety Caution:** Have students wear protective goggles during this demonstration.

**Building Pressure**  Place two plastic soda bottles filled halfway with water in front of the classroom. Add some fizzing powder or crushed fizzing tablets to each bottle. Immediately, place a cork snugly in one of the bottles. Stretch the mouth of a balloon over the other bottle, sealing the opening of the bottle. Have the class observe what happens. Ask students to explain what happened in each bottle. (Sample answer: The fizzing tablet created gas. The gas created pressure inside the bottle with the cork, and the pressure forced the cork off. The balloon on the other bottle was filled by the gas created by the tablet.)

**Teach**

**Language Arts** — **General**

**Fluid Poem**  Have students write a short poem describing something about fluids. Some possible topics include water, mixing liquids, air, steam, clouds, or fog.

**Logical**

**Comparing Pressure**  Have students calculate the pressure exerted by their bodies on the floor. Students should estimate the area of their feet as a rectangle. Ask students to compare the pressure exerted when their feet are flat on the floor with the pressure exerted when students are standing on their toes.

**Logical**

**Surface Area-to-Volume Ratio**  Use the teaching transparency titled “Math Focus: Surface Area-to-Volume Ratio” to help students understand how objects, including the human body, can withstand atmospheric pressure.

**Verbal**
The atmosphere stretches about 15,000 km above Earth’s surface. However, about 80% of the atmosphere’s gases are found within 10 km of Earth’s surface. At the top of the atmosphere, pressure is almost nonexistent. The pressure is close to 0 Pa because the gas particles are far apart and rarely collide. Mount Everest in south-central Asia is the highest point on Earth. At the top of Mount Everest, atmospheric pressure is about 33,000 Pa, or 33 kilopascals (33 kPa). (Remember that the prefix kilo- means 1,000. So, 1 kPa is equal to 1,000 Pa.) At sea level, atmospheric pressure is about 101 kPa.

Atmospheric Pressure and Depth

Take a look at Figure 3. Notice how atmospheric pressure changes as you travel through the atmosphere. The further down through the atmosphere you go, the greater the pressure is. In other words, the pressure increases as the atmosphere gets “deeper.” An important point to remember about fluids is that pressure varies depending on depth. At lower levels of the atmosphere, there is more fluid above that is being pulled by Earth’s gravitational force. So, there is more pressure at lower levels of the atmosphere.

Pressure Changes and Your Body

So, what happens to your body when atmospheric pressure changes? If you travel to higher or lower points in the atmosphere, the fluids in your body have to adjust to maintain equal pressure. You may have experienced this adjustment if your ears have “popped” when you were in a plane taking off or in a car traveling down a steep mountain road. The “pop” happens because of pressure changes in pockets of air behind your eardrums.

Variation of Air Density

The relationship between pressure and depth in the atmosphere is not the same as in the ocean. Air is less dense at higher altitudes. So, the pressure in the upper atmosphere varies less with depth than pressure in the lower atmosphere does. But water density in the ocean remains approximately constant with depth. So, the rate of change in pressure remains relatively constant as you go deeper underwater.
Water Pressure

Water is a fluid. So, it exerts pressure like the atmosphere does. Water pressure also increases as depth increases, as shown in Figure 4. The deeper a diver goes in the water, the greater the pressure is. The pressure increases because more water above the diver is being pulled by Earth’s gravitational force. In addition, the atmosphere presses down on the water, so the total pressure on the diver includes water pressure and atmospheric pressure.

Water Pressure and Depth

Like atmospheric pressure, water pressure depends on depth. Water pressure does not depend on the total amount of fluid present. A swimmer would feel the same pressure swimming at 3 m below the surface of a small pond and at 3 m below the surface of an ocean. Even though there is more water in the ocean than in the pond, the pressure on the swimmer in the pond would be the same as the pressure on the swimmer in the ocean.

Density Making a Difference

Water is about 1,000 times more dense than air. Density is the amount of matter in a given volume, or mass per unit volume. Because water is more dense than air, a certain volume of water has more mass—and weighs more—than the same volume of air. So, water exerts more pressure than air.

For example, if you climb a 10 m tree, the decrease in atmospheric pressure is too small to notice. But if you dive 10 m underwater, the pressure on you increases to 201 kPa, which is almost twice the atmospheric pressure at the surface.

In 1960, the Trieste descended to the deepest part of the ocean (11,000 m), where the pressure is 110,000 kPa.

Pressure exerted on a diver 10 m below the water’s surface is twice the pressure at the surface.

At 500 m below the surface, pressure is about 5,000 kPa. Divers at or below this level must wear special suits to survive the pressure.

The wreck of the Titanic is 3,660 m below the surface. The water pressure at this depth is 36,600 kPa.

The viper fish lives 8,000 m below the ocean’s surface. No fish are found below this level. The water pressure at this depth is 80,000 kPa.

CONNECTION to Real World

Real World

Pressure and Diving

The pressure on a diver’s body increases as the diver goes deeper underwater. The increased pressure on the diver’s chest makes breathing more difficult. Scuba divers use a pressure regulator to solve this problem. As they go deeper, the regulator increases the pressure of the air released from the diver’s air tanks. The pressure of the released air equals the pressure of the water on the diver, making breathing easier.

Cultural Awareness

Pearl Diving

Have students research Japanese pearl divers. Students should investigate the techniques these deep divers use to cope with the effects of water pressure. Ask students to make a poster that illustrates what they learn.

Inclusion Strategies

• Attention Deficit Disorder
• Developmentally Delayed
• Hearing Impaired

Many students benefit from hands-on activities. Give students a hands-on opportunity to clarify the meaning of the word density. Working in small groups, have students gather a kilogram of each of the following items: marshmallows, popcorn kernels, and measuring masses (the metal “weights” used with two-pan balances). Have each student handle the items to feel their masses and compare their volumes. Ask each group to write a paragraph comparing the volumes and masses of the different items and indicating the order of the items from highest to lowest.

Support for English Language Learners

Pressure and Depth

To check comprehension of the relationship between air pressure and depth as well as water pressure and depth, ask students to summarize what they have learned after reading the text and the graphics on these pages. Have students write a brief summary explaining how pressure changes with depth and what that means for the human body in each environment. Evaluate the summaries based on accuracy of information, clarity of organization, and grammar and spelling.
Pressure Differences and Fluid Flow

When you drink through a straw, you remove some of the air in the straw. Because there is less air inside the straw, the pressure in the straw is reduced. But the atmospheric pressure on the surface of the liquid remains the same. Thus, there is a difference between the pressure inside the straw and the pressure outside the straw. The outside pressure forces the liquid up the straw and into your mouth. So, just by drinking through a straw, you can observe an important property of fluids: Fluids flow from areas of high pressure to areas of low pressure.

**Answer to Reading Check**

You decrease pressure inside a straw by removing some of the air inside the straw.
A fluid is any material that flows and takes the shape of its container.
Pressure is force exerted on a given area.
Moving particles of matter create pressure by colliding with one another and with the walls of their container.
The pressure caused by the weight of the atmosphere is called atmospheric pressure.
Fluid pressure increases as depth increases.
As depth increases, water pressure increases faster than atmospheric pressure does because water is denser than air.
Fluids flow from areas of high pressure to areas of low pressure.

Using Key Terms
1. In your own words, write a definition for each of the following terms: fluid and atmospheric pressure.
2. Use the following terms in the same sentence: pressure and pascal.

Understanding Key Ideas
3. Which of the following statements about fluids is true?
   a. Fluids rarely take the shape of their container.
   b. Fluids include liquids and gases.
   c. Fluids flow from low pressure to high pressure.
   d. Fluids exert the most pressure in the downward direction.
4. How do fluids exert pressure on a container?
5. Why are you not crushed by atmospheric pressure?
6. Explain why atmospheric pressure changes as depth changes.
7. Give three examples of fluids flowing from high pressure to low pressure in everyday life.
8. The water in a glass has a weight of 2.4 N. The bottom of the glass has an area of 0.012 m². What is the pressure exerted by the water on the bottom of the glass?

Critical Thinking
9. Identifying Relationships
   Mercury is a liquid that has a density of 13.5 g/mL. Water has a density of 1.0 g/mL. Equal volumes of mercury and water are in identical containers. Explain why the pressures exerted on the bottoms of the containers are different.
10. Making Inferences
    Why do airplanes need to be pressurized for passenger safety when flying high in the atmosphere?

Math Skills

For a variety of links related to this chapter, go to www.scilinks.org
Topic: Fluids and Pressure
SciLinks code: HSM0586

CHAPTER RESOURCES

Chapter Resource File
- Section Quiz
- Section Review
- Vocabulary and Section Summary
- Datasheet for Quick Lab

Technology
- Transparencies
  - P24 Exhaling, Pressure, and Fluid Flow
**Overview**
This section describes how differences in fluid pressure create buoyant force. Students are introduced to Archimedes’ principle and learn how to find the buoyant force on an object. Finally, students learn the factors that determine whether an object floats or sinks in a fluid.

**Bellringer**
Ask your students to identify which of the following objects will float in water: a rock, an orange, a screw, a quarter, a candle, a plastic-foam “peanut,” and a chalkboard eraser. Ask students to write a hypothesis about why an aircraft carrier, which weighs thousands of tons, does not sink.

**Motivate**

**Demonstration** — GENERAL
Density Layers Layer 20 mL each of corn syrup, water, and cooking oil in a 100 mL graduated cylinder. Have students observe as you drop in objects that will float on the different layers. You might also try adding droplets of alcohol. Use the results of the demonstration to launch a discussion about buoyant force.

**Reading Strategy**
**Reading Strategy**
**What You Will Learn**
- Explain the relationship between fluid pressure and buoyant force.
- Predict whether an object will float or sink in a fluid.
- Analyze the role of density in an object’s ability to float.
- Explain how the overall density of an object can be changed.

**Vocabulary**
- buoyant force
- Archimedes’ principle

**Discussion**
Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

**Buoyant Force**

Why does an ice cube float on water? Why doesn’t it sink to the bottom of your glass?

Imagine that you use a straw to push an ice cube under water. Then, you release the cube. A force pushes the ice back to the water’s surface. The force, called buoyant force (BOY uhnt FAWS), is the upward force that fluids exert on all matter.

**Buoyant Force and Fluid Pressure**

Look at Figure 1. Water exerts fluid pressure on all sides of an object. The pressure exerted horizontally on one side of the object is equal to the pressure exerted on the opposite side. These equal pressures cancel one another. So, the only fluid pressures affecting the net force on the object are at the top and at the bottom. Pressure increases as depth increases. So, the pressure at the bottom of the object is greater than the pressure at the top. The water exerts a net upward force on the object. This upward force is buoyant force.

**Determining Buoyant Force**

Archimedes (AR kuh MEE DEEZ), a Greek mathematician who lived in the third century BCE, discovered how to determine buoyant force. Archimedes’ principle states that the buoyant force on an object in a fluid is an upward force equal to the weight of the fluid that the object takes the place of, or displaces. Suppose the object in Figure 1 displaces 250 mL of water. The weight of that volume of displaced water is about 2.5 N. So, the buoyant force on the object is 2.5 N. Notice that only the weight of the displaced fluid determines the buoyant force on an object. The weight of the object does not affect buoyant force.

**Figure 1**
There is more pressure at the bottom of an object because pressure increases with depth. This results in an upward buoyant force on the object.
Weight Versus Buoyant Force
An object in a fluid will sink if its weight is greater than the buoyant force (the weight of the fluid it displaces). An object floats only when the buoyant force on the object is equal to the object’s weight.

Sinking
The rock in Figure 2 weighs 75 N. It displaces 5 L of water. Archimedes’ principle says that the buoyant force is equal to the weight of the displaced water—about 50 N. The rock’s weight is greater than the buoyant force. So, the rock sinks.

Floating
The fish in Figure 2 weighs 12 N. It displaces a volume of water that weighs 12 N. Because the fish’s weight is equal to the buoyant force, the fish floats in the water. In fact, the fish is suspended in the water as it floats. Now, look at the duck. The duck does not sink. So, the buoyant force on the duck must be equal to the duck’s weight. But the duck isn’t all the way underwater! Only the duck’s feet, legs, and stomach have to be underwater to displace 9 N of water, which is equal to the duck’s weight. So, the duck floats on the surface of the water.

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

Reading Check
What causes an object to buoy up? (See the Appendix for answers to Reading Checks.)

Determining Weight
Ask students to solve the following problem: “A force of 15 N is required to lift an object that is underwater. The object displaces 2 L of water (1 L of water weighs 10 N). What is the weight of the object out of water?” (force required to lift object in water = weight of object out of water – buoyant force)

15 N = weight of object out of water – 20 N

weight of object out of water = 20 N + 15 N = 35 N

Answer to Reading Check
An object is buoyed up if the buoyant force on the object is greater than the object’s weight.
Floating, Sinking, and Density

Think again about the rock in the lake. The rock displaces 5 L of water. But volumes of solids are measured in cubic centimeters (cm³). Because 1 mL is equal to 1 cm³, the volume of the rock is 5,000 cm³. But 5,000 cm³ of rock weighs more than an equal volume of water. So, the rock sinks.

Because mass is proportional to weight, you can say that the rock has more mass per volume than water has. Mass per unit volume is density. The rock sinks because it is more dense than water is. The duck floats because it is less dense than water is. The density of the fish is equal to the density of the water.

More Dense Than Air

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

Less Dense Than Air

One substance that is less dense than air is helium, a gas. In fact, helium has one-seventh the density of air under normal conditions. A given volume of helium displaces an equal volume of air that is much heavier than itself. So, helium floats in air. Because helium floats in air, it is used in parade balloons, such as the one shown in Figure 3.

✓ Reading Check
Name a substance that is less dense than air.

Figure 3 Helium in a balloon floats in air for the same reason an ice cube floats on water—helium is less dense than the surrounding fluid.

Finding Density
Find the density of a rock that has a mass of 10 g and a volume of 2 cm³.

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

\[ \text{density} = \frac{\text{mass}}{\text{volume}} \]

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

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

Now It’s Your Turn

1. What is the density of a 20 cm³ object that has a mass of 25 g?
2. A 546 g fish displaces 420 mL of water. What is the density of the fish? (Note: 1 mL = 1 cm³)
3. A beaker holds 50 mL of a slimy green liquid. The mass of the liquid is 163 g. What is the density of the liquid?

Is That a Fact!

Before plastics can be recycled, they must first be separated by type. Most containers display a number that identifies the type of plastic used. Containers that do not display number codes can be separated by density by being floated in liquids of different densities.
Changing Overall Density
Steel is almost 8 times denser than water. And yet huge steel ships cruise the oceans with ease. But hold on! You just learned that substances that are more dense than water will sink in water. So, how does a steel ship float?

Changing Shape
The secret of how a ship floats is in the shape of the ship. What if a ship were just a big block of steel, as shown in Figure 4? If you put that block into water, the block would sink because it is more dense than water. So, ships are built with a hollow shape. The amount of steel in the ship is the same as in the block. But the hollow shape increases the volume of the ship. Remember that density is mass per unit volume. So, an increase in the ship’s volume leads to a decrease in its density. Thus, ships made of steel float because their overall density is less than the density of water.

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

### Figure 4  Shape and Overall Density

A block of steel is more dense than water, so it sinks.

Shaping the steel into a hollow form increases the volume occupied by the same mass. The overall density of the ship is reduced. The ship is less dense than water, so the ship floats.

### Internet Activity

For another activity related to this chapter, go to go.hrw.com and type in the keyword HPSFLUW.

### CONNECTION TO GEOLOGY

**Floating Rocks** The rock that makes up Earth’s continents is about 15% less dense than the molten (melted) mantle rock below it. Because of this difference in density, the continents are floating on the mantle. Research the structure of Earth, and make a poster that shows Earth’s interior layers.

### Support for English Language Learners

Sinking and Floating
A demonstration may help students understand the concept of density's effect on how an object sinks or floats. Fill a tall, transparent glass or jar about one-third full with water, and mark the water level. Add a golf ball to the glass, and ask students to describe what happens. (The ball sinks.) Mark the water level again. Next, add salt to the water until the golf ball floats. Call on students to explain these two occurrences in terms of density. Direct their attention to the explanations in the textbook if necessary.

### Using the Figure – GENERAL

Shape and Overall Density
Some students may have difficulty understanding how changing the shape of a steel block changes the overall density. Place the teaching transparency of Figure 4, “Shape and Overall Density,” on the overhead projector. Draw a line that connects the top edges of the two sides of the U-shaped steel. Explain to students that the volume of the ship includes the steel sides of the ship and the air inside the ship. Further explain that because air is much less dense than water, the overall density of the steel and the air is less than the density of water. So, the ship floats.
A submarine is a special kind of ship that can travel both on the surface of the water and underwater. Submarines have ballast tanks that can be opened to allow sea water to flow in. As water is added, the submarine's mass increases, but its volume stays the same. The submarine's overall density increases so that it can dive under the surface. Crew members control the amount of water taken in. In this way, they control how dense the submarine is and how deep it dives. Compressed air is used to blow the water out of the tanks so that the submarine can rise. Study Figure 5 to learn how ballast tanks work.

**Reading Check**

How do crew members control the density of a submarine?

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

**Changing Mass**

A submarine is a special kind of ship that can travel both on the surface of the water and underwater. Submarines have ballast tanks that can be opened to allow sea water to flow in. As water is added, the submarine's mass increases, but its volume stays the same. The submarine's overall density increases so that it can dive under the surface. Crew members control the amount of water taken in. In this way, they control how dense the submarine is and how deep it dives. Compressed air is used to blow the water out of the tanks so that the submarine can rise. Study Figure 5 to learn how ballast tanks work.

**MATERIALS**

**FOR EACH STUDENT**
- bowl or pail, medium, one for every two or three students
- clay, modeling, golf-ball-sized piece
- water

**Answer**

3. Forming the clay into a boat shape causes the clay to displace more water, which increases the buoyant force. The change in shape causes the overall density of the clay boat to decrease so that the clay boat is less dense than the water. Therefore, the clay boat floats.
Changing Volume
Like a submarine, some fish adjust their overall density to stay at a certain depth in the water. Most bony fishes have an organ called a swim bladder, shown in Figure 6. This swim bladder is filled with gases produced in a fish’s blood. The inflated swim bladder increases the fish’s volume and thereby decreases the fish’s overall density, which keeps the fish from sinking in the water. The fish’s nervous system controls the amount of gas in the bladder. Some fish, such as sharks, do not have a swim bladder. These fish must swim constantly to keep from sinking.

Summary
- All fluids exert an upward force called buoyant force.
- Buoyant force is caused by differences in fluid pressure.
- Archimedes’ principle states that the buoyant force on an object is equal to the weight of the fluid displaced by the object.
- Any object that is more dense than the surrounding fluid will sink.
- The overall density of an object can be changed by changing the object’s shape, mass, or volume.

Using Key Terms
1. Use the following terms in the same sentence: buoyant force and Archimedes’ principle.

Understanding Key Ideas
2. Which of the following changes increases the overall density of the object?
   a. A block of iron is formed into a hollow shape.
   b. A submarine fills its ballast tanks with water.
   c. A submarine fills its ballast tanks with air.
   d. A fish increases the amount of gas in its swim bladder.
3. Explain how differences in fluid pressure create buoyant force on an object.
4. How does an object’s density determine whether the object will sink or float in water?
5. Name three methods that can be used to change the overall density of an object.

Math Skills
6. What is the density of an object that has a mass of 184 g and a volume of 50 cm³?

Critical Thinking
7. Applying Concepts An object weighs 20 N. It displaces a volume of water that weighs 15 N.
   a. What is the buoyant force on the object?
   b. Will this object float or sink? Explain your answer.

8. Predicting Consequences Iron has a density of 7.9 g/cm³. Mercury is a liquid that has a density of 13.5 g/cm³. Will iron float or sink in mercury? Explain your answer.

9. Evaluating Hypotheses Imagine that your brother tells you that all heavy objects sink in water. Explain why you agree or disagree with his statement.

Answers to Section Review
1. Sample answer: Archimedes’ principle is about the relationship between the buoyant force of an object and the amount of water the object displaces.
2. b
3. Water pressure is exerted on all sides of an object. The pressures exerted horizontally on the sides cancel each other out. The pressure exerted at the bottom is greater than that exerted at the top because pressure increases with depth. This creates an overall upward force on the object—the buoyant force.
4. An object will float in water if its density is less than the density of water. An object will sink in water if its density is greater than the density of water.
5. The density of an object can be changed by changing the shape, mass, or volume of an object.
6. $184 \text{ g} \div 50 \text{ cm}^3 = 3.68 \text{ g/cm}^3$
7. a. 15 N
   b. It will sink because its weight is greater than the buoyant force acting on it.
8. Iron will float in mercury because iron is less dense than mercury.
9. Sample answer: I disagree with this statement because steel ships are heavy but they float in water. The ships float because the overall density of the steel and the air inside the ship is less than the density of water.
Overview
In this section, students learn about Bernoulli’s principle. They then explore how objects that are heavier than air can achieve flight. Students also learn about the basic aspects of flight. Finally, students learn about Pascal’s principle.

Bellringer
Pose the following problem to your students: “You have been asked to design two kites. One kite will be flown in areas where there is almost always a good breeze. The other kite will be flown in areas with very little wind.” What differences in design and materials are there between your two kites?

Motivate

Demonstration

Magic Water  Place a straw upright in a glass of water. Hold a second straw at a right angle at the top of the first so that the straws are just touching. Blow very hard through the horizontal straw. Water will rise up in the vertical straw and form a spray. Tell students they will learn why this occurs after reading this section. Visual

Fluids and Motion

Hold two sheets of paper so that the edges are hanging in front of your face about 4 cm apart. The flat faces of the paper should be parallel to each other. Now, blow as hard as you can between the two sheets of paper.

What’s going on? You can’t separate the sheets by blowing between them. In fact, the sheets move closer together the harder you blow. You may be surprised that the explanation for this unusual occurrence also includes how wings help birds and planes fly and how pitchers throw screwballs.

Fluid Speed and Pressure

The strange reaction of the paper is caused by a property of moving fluids. This property was first described in the 18th century by Daniel Bernoulli (ber NOO lee), a Swiss mathematician. Bernoulli’s principle states that as the speed of a moving fluid increases, the fluid’s pressure decreases. In the case of the paper, air speed between the two sheets increased when you blew air between them. Because air speed increased, the pressure between the sheets decreased. Thus, the higher pressure on the outside of the sheets pushed them together.

Science in a Sink

Bernoulli’s principle is at work in Figure 1. A table-tennis ball is attached to a string and swung into a stream of water. Instead of being pushed out of the water, the ball is held in the water. Why? The water is moving faster than the air around it, so the water has a lower pressure than the surrounding air. The higher air pressure pushes the ball into the area of lower pressure—the water stream. Try this at home to see for yourself!

Bernoulli’s principle  the principle that states that the pressure in a fluid decreases as the fluid’s velocity increases

Figure 1  This ball is pushed by the higher pressure of the air into an area of reduced pressure—the water stream.
Factors That Affect Flight

A common commercial airplane in the skies today is the Boeing 737 jet. Even without passengers, the plane weighs 350,000 N. How can something so big and heavy get off the ground and fly?

Wing shape plays a role in helping these big planes—as well as smaller planes and birds—achieve flight, as shown in Figure 2.

According to Bernoulli’s principle, the fast-moving air above the wing exerts less pressure than the slow-moving air below the wing. The greater pressure below the wing exerts an upward force. This upward force, known as lift, pushes the wings (and the rest of the airplane or bird) upward against the downward pull of gravity.

Reading Check

What is lift? (See the Appendix for answers to Reading Checks.)

MISCONCEPTION ALERT

More Than Bernoulli

When teaching about airplane flight, emphasize that there is more to understanding lift than can be explained by Bernoulli’s principle. Newton’s third law also plays a part. A tilted wing deflects horizontal airflow downward (the action force exerted by the wing on the air). The reaction force is the upward force the air exerts on the wing. This force also contributes to lift.

Activity

Pressure Analogy

Before you discuss Bernoulli’s principle, it may help some students to imagine the pressure of a fluid as the combined pressure of many particles striking a surface. Have students imagine a swarm of bees trapped in a short section of a long piece of pipe. As the bees fly around inside the pipe, they bounce off each other and off the walls of the pipe, creating pressure. Then, have students imagine that the bees are suddenly able to fly the entire length of the pipe. Explain that, because the bees have more room, they bounce against the walls of the pipe much less frequently, creating less pressure inside the pipe.

Wing Shape

Ask students to examine the wing shape shown in Figure 2. Have students use their knowledge of Bernoulli’s principle to hypothesize about what type of wings might work in flight. Does the wing have to be curved? Is flight possible without wings?

Demonstration

Flying Ball

Point the airflow of a portable hair dryer straight up, and suspend a table-tennis ball in the airstream. Change the direction of the airflow slightly to maneuver the ball. Have students speculate on the forces that are at work in this demonstration.

Answer to Reading Check

Lift is an upward force on an object that is moving in a fluid.
The amount of lift created by a plane’s wing is determined partly by the speed at which air travels around the wing. The speed of a plane is determined mostly by its thrust. Thrust is the forward force produced by the plane’s engine. In general, a plane with a large amount of thrust moves faster than a plane that has less thrust does. This faster speed means air travels around the wing at a higher speed, which increases lift.

The amount of lift also depends partly on the size of a plane’s wings. Look at the jet plane in Figure 3. This plane can fly with a relatively small wing size because its engine gives a large amount of thrust. This thrust pushes the plane through the sky at great speeds. So, the jet creates a large amount of lift with small wings by moving quickly through the air. Smaller wings keep a plane’s weight low, which also helps it move faster.

Compared with the jet, the glider in Figure 3 has a large wing area. A glider is an engineless plane. It rides rising air currents to stay in flight. Without engines, gliders produce no thrust and move more slowly than many other kinds of planes. Thus, a glider must have large wings to create the lift it needs to stay in the air.

Bernoulli and Birds

Birds don’t have engines, so birds must flap their wings to push themselves through the air. A small bird must flap its wings at a fast pace to stay in the air. But a hawk flaps its wings only occasionally because it has larger wings than the small bird has. A hawk uses its large wings to fly with very little effort. Fully extended, a hawk’s wings allow the hawk to glide on wind currents and still have enough lift to stay in the air.

**Thrust and Lift**

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**Wing Size, Speed, and Lift**

The amount of lift also depends partly on the size of a plane’s wings. Look at the jet plane in Figure 3. This plane can fly with a relatively small wing size because its engine gives a large amount of thrust. This thrust pushes the plane through the sky at great speeds. So, the jet creates a large amount of lift with small wings by moving quickly through the air. Smaller wings keep a plane’s weight low, which also helps it move faster.

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**Boomerangs**

More than 8,000 years ago, Australian aborigines discovered the aerodynamic qualities of a type of hunting stick called a boomerang. Have students research boomerangs and compare a boomerang’s flight with an airplane’s flight. Ask students to present their findings in a poster.
Bernoulli and Baseball

You don’t have to look up at a bird or a plane flying through the sky to see Bernoulli’s principle in your world. Any time fluids are moving, Bernoulli’s principle is at work. Figure 4 shows how a baseball pitcher can take advantage of Bernoulli’s principle to throw a confusing screwball that is difficult for a batter to hit.

Drag and Motion in Fluids

Have you ever walked into a strong wind and noticed that the wind seemed to slow you down? It may have felt like the wind was pushing you backward. Fluids exert a force that opposes the motion of objects moving through the fluids. The force that opposes or restricts motion in a fluid is called drag.

In a strong wind, air “drags” on your body and makes it difficult for you to move forward. Drag also works against the forward motion of a plane or bird in flight. Drag is usually caused by an irregular flow of air. An irregular or unpredictable flow of fluids is known as turbulence.

Answer to Reading Check

What is turbulence?

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**English Language Learners**

**Specialized Vocabulary** As students read through this section they will encounter new specialized scientific meanings for words they may have learned before. Ask them to keep a running list of words they do not understand. When they have finished reading the section, ask them to read it again with a partner, using context and the partner’s knowledge to help them define the new terms in their lists in their own words. After the partner reading, if there are still some terms left undefined, allow students to fill in the definitions using a dictionary. In addition, have them look up the terms they defined through context to verify their definitions. The words may include: reaction, property, lift, force, thrust, and drag. Check students’ definitions for accuracy and language usage. Have students make corrections if necessary.
Turbulence and Lift

Lift is often reduced when turbulence causes drag. Drag can be a serious problem for airplanes moving at high speeds. So, airplanes are equipped with ways to reduce turbulence as much as possible when in flight. For example, flaps like those shown in Figure 5 can be used to change the shape or area of a wing. This change can reduce drag and increase lift. Similarly, birds can adjust their wing feathers in response to turbulence.

✓ ✓

Reading Check
How do airplanes reduce turbulence?

Pascal’s Principle

Imagine that the water-pumping station in your town increases the water pressure by 20 Pa. Will the water pressure be increased more at a store two blocks away or at a home 2 km away?

Believe it or not, the increase in water pressure will be the same at both locations. This equal change in water pressure is explained by Pascal’s principle. Pascal’s principle states that a change in pressure at any point in an enclosed fluid will be transmitted equally to all parts of that fluid. This principle was discovered by the 17th-century French scientist Blaise Pascal.

Pascal’s Principle and Motion

Hydraulic devices use Pascal’s principle to move or lift objects. Liquids are used in hydraulic devices because liquids cannot be easily compressed, or squeezed, into a smaller space. Cranes, forklifts, and bulldozers have hydraulic devices that help them lift heavy objects.

Hydraulic devices can multiply forces. Car brakes are a good example. In Figure 6, a driver’s foot exerts pressure on a cylinder of liquid. This pressure is transmitted to all parts of the liquid-filled brake system. The liquid moves the brake pads. The pads press against the wheels, and friction stops the car. The force is multiplied because the pistons that push the brake pads are larger than the piston that is pushed by the brake pedal.

Answer to Reading Check
Airplanes can reduce turbulence by changing the shape or area of the wings.
For each pair of terms, explain how the meanings of the terms differ.

1. Bernoulli’s principle and Pascal’s principle

2. thrust and drag

3. The shape of an airplane’s wing helps it gain
   a. drag,   c. thrust.
   b. lift,   d. turbulence.

4. What is the relationship between pressure and fluid speed?

5. What is Pascal’s principle?

6. What force opposes motion through a fluid? How does this force affect lift?

7. How do thrust and lift help an airplane achieve flight?

8. Applying Concepts Air moving around a speeding race car can create lift. Upside-down wings, or spoilers, are mounted on the rear of race cars. Use Bernoulli’s principle to explain how spoilers reduce the danger of accidents.

9. Making Inferences When you squeeze a balloon, where is the pressure inside the balloon increased the most? Explain.

10. Look at the image below. When the space through which a fluid flows becomes narrow, fluid speed increases. Using this information, explain how the two boats could collide.

Sample answer: Air traveling around the spoiler produces a downward force. This downward force pushes down on the rear of the car and helps keep the rear wheels of the cars in contact with the road. The cars travel more safely because the rear wheels stay in contact with the road.

The pressure inside the balloon increases equally in all directions. Squeezing a balloon demonstrates Pascal’s principle.

As the fluid speed between the boats increases, the fluid pressure decreases. The pressure on the outer sides of the boats then becomes greater than the pressure between them. This increased pressure from the outside can push the boats together, causing them to collide.
**Teacher’s Notes**

**Time Required**
One to two 45-minute class periods

**Lab Ratings**
Teacher Prep  
Student Set-Up ☻☻  
Concept Level ☻☻☻  
Clean Up ☻☻

**Materials**
The supplies listed are for one group of 3–4 students. The tank or tub should have vertical sides. A small or medium-sized tub works best because changes in volume can be observed easily. Masses should be added near the center of the baking pan. A fish tank or aquarium works well for this activity.

**Preparation Notes**
If you use a tub or pan without vertical sides, the buoyant force and the weight of the pan and masses will not be equal. In most cases, the buoyant force will be greater than the weight. Have students measure the side of the baking pan and mark the one-quarter, one-half, and three-quarter levels. Analyze the results.

**Lab Notes**
Volumes of liquids are usually expressed in milliliters (mL). Here, the volume measurements for the water displaced are based on a rectangular container (the tank or tub), so cubic centimeters (cm³) are used.

**Procedure**

1. Copy the table shown below.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Trial 1</th>
<th>Trial 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (l), cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Width (w), cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial height (h₁), cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial volume (V₁), cm³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New height (h₂), cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New total volume (V₂), cm³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Displaced volume (∆V), cm³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass of displaced water, g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight of displaced water, N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight of pan and masses, N</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Fill the tub half full with water. Measure (in centimeters) the length, width, and initial height of the water. Record your measurements in the table.

3. Using the equation given in the table, determine the initial volume of water in the tub. Record your results in the table.

4. Place the pan in the water, and place masses in the pan, as shown on the next page. Keep adding masses until the pan sinks to about three-quarters of its height. Record the new height of the water in the table. Then, use this value to determine and record the new total volume of water plus the volume of water displaced by the pan.

**Skills Practice Lab**

**Fluids, Force, and Floating**

Why do some objects sink in fluids but others float? In this lab, you’ll get a sinking feeling as you determine that an object floats when its weight equals the buoyant force exerted by the surrounding fluid.

**Objectives**

- Calculate the buoyant force on an object.
- Compare the buoyant force on an object with its weight.

**Materials**
- balance
- mass set
- pan, rectangular baking
- paper towels
- ruler, metric
- tub, plastic, large rectangular
- water
5 Determine the volume of the water that was displaced by the pan and masses, and record this value in the table. The displaced volume is equal to the new total volume minus the initial volume.

6 Determine the mass of the displaced water by multiplying the displaced volume by its density (1 g/cm³). Record the mass in the table.

7 Divide the mass by 100. The value you get is the weight of the displaced water in newtons (N). This is equal to the buoyant force. Record the weight of the displaced water in the table.

8 Remove the pan and masses, and determine their total mass (in grams) using the balance. Convert the mass to weight (N), as you did in step 7. Record the weight of the masses and pan in the table.

9 Place the empty pan back in the tub. Perform a second trial by repeating steps 4–8. This time, add masses until the pan is just about to sink.

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**Analyze the Results**

1 **Identifying Patterns** Compare the buoyant force (the weight of the displaced water) with the weight of the pan and masses for both trials.

2 **Examining Data** How did the buoyant force differ between the two trials? Explain.

**Draw Conclusions**

3 **Drawing Conclusions** Based on your observations, what would happen if you were to add even more mass to the pan than you did in the second trial? Explain your answer in terms of the buoyant force.

4 **Making Predictions** What would happen if you put the masses in the water without the pan? What difference does the pan’s shape make?

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**Holt Lab Generator CD-ROM**

Search for any lab by topic, standard, difficulty level, or time. Edit any lab to fit your needs, or create your own labs. Use the Lab Materials QuickList software to customize your lab materials list.

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**Chapter 7 • Chapter Lab 199**

**Chapter Resources**

**Workbooks**

- Whiz-Bang Demonstrations
  - The Rise and Fall of Raisins
  - Going Against the Flow
- EcoLabs & Field Activities
  - What’s the Flap All About?
- Long-Term Projects & Research Ideas
  - Scuba Dive

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**Sharon L. Woolf**

Langston Hughes Middle School

Reston, Virginia
In each of the following sentences, replace the incorrect term with the correct term from the word bank.

- thrust pressure
- drag lift
- buoyant force fluid
- Pascal’s principle
- Bernoulli’s principle

1. Lift increases with the depth of a fluid.
2. A plane’s engines produce drag to push the plane forward.
3. A pascal can be a liquid or a gas.
4. A hydraulic device uses Archimedes’ principle to lift or move objects.
5. Atmospheric pressure is the upward force exerted on objects by fluids.

**Multiple Choice**

6. The design of a wing
   a. causes the air above the wing to travel faster than the air below the wing.
   b. helps create lift.
   c. creates a low-pressure zone above the wing.
   d. All of the above
7. Fluid pressure is always directed
   a. up.
   b. down.
   c. sideways.
   d. in all directions.

8. An object surrounded by a fluid will displace a volume of fluid that is
   a. equal to its own volume.
   b. less than its own volume.
   c. greater than its own volume.
   d. denser than itself.
9. If an object weighing 50 N displaces a volume of water that weighs 10 N, what is the buoyant force on the object?
   a. 60 N
   b. 50 N
   c. 40 N
   d. 10 N
10. A helium-filled balloon will float in air because
    a. there is more air than helium.
    b. helium is less dense than air.
    c. helium is as dense as air.
    d. helium is more dense than air.
11. Materials that can flow to fit their containers include
    a. gases.
    b. liquids.
    c. both gases and liquids.
    d. gases, liquids, and solids.
**Short Answer**

12. Where is water pressure greater, at a depth of 1 m in a large lake or at a depth of 2 m in a small pond? Explain your answer.

13. Why are bubbles round?

14. Why are tornadoes like giant vacuum cleaners?

**Math Skills**

15. Calculate the area of a 1500 N object that exerts a pressure of 500 Pa (500 N/m²). Then, calculate the pressure exerted by the same object over twice that area.

**CRITICAL THINKING**

16. Concept Mapping Use the following terms to create a concept map: fluid, pressure, depth, density, and buoyant force.

17. Forming Hypotheses Gases can be easily compressed into smaller spaces. Why would this property of gases make gases less useful than liquids in hydraulic brakes?

18. Making Comparisons Will a ship loaded with beach balls float higher or lower in the water than an empty ship? Explain your reasoning.

19. Applying Concepts Inside all vacuum cleaners is a high-speed fan. Explain how this fan causes the vacuum cleaner to pick up dirt.

**Evaluating Hypotheses** A 600 N girl on stilts says to two 600 N boys sitting on the ground, “I am exerting over twice as much pressure as the two of you are exerting together!” Could this statement be true? Explain your reasoning.

20. Yes, the statement could be true. Pressure is equal to force divided by area. The girl on stilts is exerting force over a much smaller area than the two boys on the ground are. Therefore, it is possible that the girl is exerting twice as much pressure as the two boys are.

**Interpreting Graphics**

21. c

22. a

23. Ice is less dense than water.

24. Only a small portion of an iceberg floats above water, as shown in the image. A ship may actually be closer to running into a massive block of ice underwater than it would appear on the surface. If the ship is not turned or stopped in time, it could collide with the iceberg.

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**Chapter Resources**

**Chapter Resource File**

- Chapter Review
- Chapter Test A
general
- Chapter Test B
general
- Chapter Test C
special needs
- Vocabulary Activity

**Workbooks**

- Study Guide
  - Study Guide is also available in Spanish.
Reading

Passage 1

The Mariana Trench is about 11 km deep—that’s deep enough to swallow Mount Everest, the tallest mountain in the world. Fewer than a dozen undersea vessels have ever ventured this deep into the ocean. Why? Water exerts tremendous pressure at this depth. A revolutionary new undersea vessel, Deep Flight, has a hull made of an extremely strong ceramic material that can withstand such pressure. Although Deep Flight has not made it to the bottom of the Mariana Trench, some scientists think this type of undersea vessel will one day be used routinely to explore the ocean floor.

1. What is the meaning of the word revolutionary in this passage?
   A strange
   B overthrowing the government
   C radically different
   D disgusting

2. Based on the name of the undersea vessel described in this passage, what does the vessel look like?
   F a robot
   G a house
   H a car
   I an airplane

3. Based on the passage, which of the following statements is a fact?
   A Scientists hope to fly Deep Flight to the top of Mount Everest.
   B Deep Flight can withstand very high pressures.
   C Scientists cannot explore the ocean without using Deep Flight.
   D Deep Flight has gone to the bottom of the Mariana Trench a dozen times.

Passage 2

Buoyancy is an object’s ability to float. An object will float if the water it displaces has a mass greater than the object’s mass. It will sink if the water it displaces has a mass less than its own mass. But if an object displaces its own mass in water, it will neither float nor sink. Instead, it will remain suspended in the water because of what is called neutral buoyancy.

A goldfish has neutral buoyancy. A goldfish has a sac in its body called a swim bladder. Gases from blood vessels can diffuse into and out of the swim bladder. When the goldfish needs to rise in the water, for example, gases diffuse into the swim bladder and cause it to inflate. The swim bladder helps the goldfish maintain neutral buoyancy.

1. What is the purpose of this passage?
   A to explain how a goldfish maintains neutral buoyancy
   B to explain how to change the buoyancy of an object
   C to convince people to buy goldfish
   D to describe objects that float and sink

2. What is the meaning of the word suspended in this passage?
   F not allowed to attend school
   G stopped for a period of time
   H weighed down
   I supported from sinking

3. What is buoyancy?
   A a sac in a goldfish’s body
   B the ability to float
   C the mass of an object
   D an inflated balloon

Question 1: Although “overthrowing the government” is a meaning of the word revolutionary, it is not the correct meaning of the word in the passage. There is no mention of government in the passage. “Radically different” is also a meaning of the word revolutionary and is the correct answer.

Question 2: Answer choices F, G, and I are all correct meanings of the word suspended. However, both answer choices F and G can be eliminated because the passage does not discuss school attendance or mention stopping any activity for a period of time. The passage does discuss sinking and floating, and I is the correct answer.
1. What is the pressure on the object when it is 100 m underwater?
   - A 1.0 MPa
   - B 1.1 MPa
   - C 1.5 MPa
   - D 2.0 MPa

2. Based on the data in the graph, which of the following is the best estimate of the pressure at 250 m below the surface of the ocean?
   - F 1.7 MPa
   - G 2.2 MPa
   - H 2.6 MPa
   - I 5.0 MPa

3. Which of the following statements best describes the relationship between the water pressure on an object and the depth of the object in the ocean?
   - A Water pressure increases as the depth increases.
   - B Water pressure decreases as the depth increases.
   - C Water pressure does not change as the depth increases.
   - D Water pressure has no predictable relationship to the depth.

4. Javi filled a container halfway full with water. The container measures 2 m wide, 3 m long, and 1 m high. How many cubic meters of water are in the container?
   - F 2 m³
   - G 3 m³
   - H 5 m³
   - I 6 m³

5. Pressure is equal to force divided by area. Jenny pushes a door with a force of 12 N. The area of her hand is 96 cm². What is the pressure exerted by Jenny’s hand on the door?
   - A 0.125 N/cm
   - B 0.125 N/cm²
   - C 8 N/cm
   - D 8 N/cm²

Question 2: To answer this question, students must extrapolate (or imagine) that the line in the graph continues up and to the right. Students should determine that the extrapolated line will cross the 250 m point somewhere just above 2.5 MPa. The only answer choice that is above and close to 2.5 MPa is H.

Question 4: Students may be tempted to multiply the dimensions of the container to find the total volume of the container. However, the problem clearly states that the container is only halfway full with water. Therefore, students must multiply 2 m, 3 m, and 0.5 m to find the number of cubic meters in the container. The correct choice is G.
Science, Technology, and Society

Teaching Strategy—GENERAL
Go to an open area with your students. Have students throw a Frisbee® with different amounts of thrust, or have them vary the angle of attack when they throw their disk. Discuss Bernoulli’s principle and other aspects of lift. Have students attempt to throw a Frisbee without any spin (eliminating the angular momentum that gives the disk stability in flight). Compare a spinning Frisbee with a spinning top or a moving bicycle.

Science Fiction

Background
Sports and science fiction may seem like an unlikely combination, but Jack C. Haldeman II enjoys both. He has written science fiction stories, sports stories, and stories such as “Wet Behind the Ears,” which is a bit of both! Before becoming a writer, Haldeman received a college degree in life science and worked as a research assistant, a medical technician, a statistician, a photographer, and an apprentice in a print shop.

Stayin’ Aloft—The Story of the Frisbee®
In the late 1800s, a few fun-loving college students invented a game that involved tossing an empty tin pie plate. The pie plate was stamped with the name of a bakery: Frisbie’s Pies. So, the game of Frisbie was created. Unfortunately, the metal pie plates tended to develop sharp edges that caused injuries. In 1947, plastic disks were made to replace the metal pie plates. These plastic disks were called Frisbees. How do Frisbees stay in the air? When you throw a Frisbee, you give it thrust. And as it moves through the air, lift is created because of Bernoulli’s principle. But you don’t have to think about the science behind Frisbees to have fun with them!

Science, Technology, and Society

Math Activity
A Frisbee landed 10 m away from where it is thrown. The Frisbee was in the air for 2.5 s. What was the average speed of the Frisbee?

Answer to Math Activity
The equation for average speed is:
\[
\text{average speed} = \frac{\text{distance}}{\text{time}}
\]
\[
\text{average speed} = \frac{10 \text{ m}}{2.5 \text{ s}} = 4 \text{ m/s}
\]

Science Fiction

“Wet Behind the Ears” by Jack C. Haldeman II
Willie Joe Thomas cheated to get a swimming scholarship. Now, he is faced with a major swim meet, and his coach told him that he has to swim or be kicked off the team. Willie Joe could lose his scholarship.

One day, Willie Joe’s roommate, Frank, announces that he has developed a new “sliding compound.” And Frank also said something about using the compound to make ships go faster. So, Willie Joe thought, if it works for ships, it might work for swimming.

See what happens when Willie Joe tries to save his scholarship by using Frank’s compound at the swim meet. Read “Wet Behind the Ears,” by Jack C. Haldeman II in the Holt Anthology of Science Fiction.

Language Arts Activity
Analyze the story structure of “Wet Behind the Ears.” In your analysis, identify the introduction, the rising action, the climax, and the denouement. Summarize your analysis in a chart.

Answer to Language Arts Activity
Accept all reasonable answers. Students should make a chart that analyzes the story structure of “Wet Behind the Ears.” The first column of their chart should list the parts of the story (introduction, rising action, climax, and denouement). The second column should have a brief summary of what occurred in each part of the story.
Scuba divers and other underwater explorers sometimes investigate shipwrecks on the bottom of the ocean. Research the exploration of a specific shipwreck. Make a poster showing what artifacts were retrieved from the shipwreck and what was learned from the exploration.

Answer to Social Studies Activity
Accept all reasonable answers. All students’ posters should identify a shipwreck, list or show some of the artifacts collected from the shipwreck, and summarize what was learned by the exploration of the shipwreck.

Careers

Background
The word *scuba* is an acronym that stands for *self-contained underwater breathing apparatus*. The first scuba breathing device, known as the aqualung, was invented by Jacques Cousteau and Emile Gagnan in 1943. This invention allowed divers to move freely underwater for long periods of time.

Scuba diving has become a popular form of recreation, with about one million people becoming certified divers every year. To rent scuba equipment, divers must be certified by an organization such as the Professional Association of Diving Instructors (PADI) or the National Association of Underwater Instructors (NAUI). Some organizations certify divers as young as 10 years old, while other groups have an age requirement of 12 years. In order to receive a certification, divers must take an open water diving course, which can last from three days to six weeks.

Alisha Bracken

Scuba Instructor
Alisha Bracken first started scuba diving in her freshman year of college. Her first dives were in a saltwater hot spring near Salt Lake City, Utah. “It was awesome,” Bracken says. “There were nurse sharks, angelfish, puffer fish and brine shrimp!” Bracken enjoyed her experience so much that she wanted to share it with other people. The best way to do that was to become an instructor and teach other people to dive.

Bracken says one of the biggest challenges of being a scuba instructor is teaching people to adapt and function in a foreign environment. She believes that learning to dive properly is important not only for the safety of the diver but also for the protection of the underwater environment. She relies on science principles to help teach people how to control their movements and protect the natural environment. “Buoyancy is the foundation of teaching people to dive comfortably,” she explains. “Without it, we cannot float on the surface or stay off the bottom. Underwater life can be damaged if students do not learn and apply the concepts of buoyancy.”

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