Density and Buoyancy

**The BIG Idea**
A fluid exerts an upward force on an object that is placed in the fluid.

**LESSON 1**
Density

(Main Idea) The density of a material is a measure of how much matter is packed into a unit volume of the material.

**LESSON 2**
Pressure and the Buoyant Force

(Main Idea) Objects in a fluid experience a buoyant force resulting from the pressure exerted by the fluid.

**LESSON 3**
Sinking and Floating

(Main Idea) An object will float in a fluid if the density of the object is less than the density of the fluid.

Floating on Air
These hot-air balloons weigh hundreds of pounds, but still are able to rise through the air. A hot-air balloon has three main parts—the balloon envelope, the burner, and the basket. When the burner heats the air inside the envelope, the envelope expands and the balloon rises. What forces push the balloon upward?

Compare and contrast three objects that float with three objects that sink.
Can you push the beach ball under water?

A beach ball is made of lightweight material and is filled with air. It is easy to lift and throw into the air. Is it difficult to hold the ball under water?

Procedure
1. Complete a lab safety form.
2. Put the beach ball into a large bucket filled with tap water.
3. Slowly push the ball downward.
4. Draw a diagram of the forces acting on the ball.

Think About This
• Name other objects you have observed floating. How are they similar to the ball? How are they different?
• Propose a reason why the ball does not stay underwater when you push it down into the water.

Floating and Sinking
Make the following Foldable to increase your understanding of what causes floating and sinking.

STEP 1 Fold a sheet of paper into thirds lengthwise and fold the top down about 3 cm from the top.

STEP 2 Unfold and draw lines along the folds. Label as shown.

Using What You Know
In the first column, list everything you already know about floating and sinking. In the second column, write the things that you would like to know more about. As you read this chapter, check your Foldable to make sure that your understanding of floating and sinking is correct. Record explanations and new information in the last column.

Visit ca8.msscience.com to:
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- explore Virtual Labs
- access content-related Web links
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Learn It! What should you do if you find a word you don’t know or understand? Here are some suggested strategies:

1. Use context clues (from the sentence or the paragraph) to help you define it.
2. Look for prefixes, suffixes, or root words that you already know.
3. Write it down and ask for help with the meaning.
4. Guess at its meaning.
5. Look it up in the glossary or a dictionary.

Practice It! Look at the word *vertical* in the following passage. See how context clues can help you understand its meaning.

Think about the forces acting on the boat in Figure 13. Gravity is pulling the boat down, yet the boat doesn’t accelerate downward. Because the boat is not accelerating up or down, the vertical forces on the boat are balanced. There must be an upward force balancing the downward force of gravity that keeps the sailboat from sinking.

— from page 146

Apply It! Make a vocabulary bookmark with a strip of paper. As you read, keep track of words you do not know or want to learn more about.
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.

<table>
<thead>
<tr>
<th>Before You Read A or D</th>
<th>Statement</th>
<th>After You Read A or D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Density is calculated by dividing volume by mass.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Air pressure increases as you climb a mountain.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Things can float only in liquids such as water.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 All fluids are liquids.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 You calculate the volume of all solids by multiplying length times width times height.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 Heavy things sink when placed in water.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Compared to liquids, particles in gases are very close together.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 Only solid objects can exert forces.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 Hot-air balloons can fly because they are less dense than air.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Air pressure only pushes down on you.</td>
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</table>

Print a worksheet of this page at ca8.msscience.com.
Density

Main Idea: The density of a material is a measure of how much matter is packed into a unit volume of the material.

Real-World Reading Connection: Can you imagine trying to lift a rock that is as big as a basketball? The rock and the basketball are the same size, but the rock is much heavier because it has more matter packed into the same volume of space.

What is density?

Which would have more mass, the balloon filled with air or the bottle of water shown in Figure 1? The mass of an object depends not only on the size of the object, but also on the material the object contains. All materials, such as the air in the balloon and the water in the bottle, have a property called density. Density (DEN suh tee) is the amount of mass per unit volume of a material.

Matter is made of particles, such as atoms or molecules, that have mass. The density of a material depends on the masses and the number of particles packed into a given volume. Figure 1 shows that the volume of air has fewer particles and less mass than the same volume of water. As a result, the density of air is less than the density of water.

Figure 1: The balloon has less mass because it contains fewer particles of matter than the water in the bottle does.

Compare the density of air to the density of water.
Calculating Density

The density of an object is the mass of an object divided by its volume. Density can be calculated using the following equation:

\[
\text{Density Equation} \\
\text{density} \ (\text{in } \text{g/cm}^3) = \frac{\text{mass} \ (\text{in } \text{g})}{\text{volume} \ (\text{in } \text{cm}^3)} \\
D = \frac{m}{V}
\]

In this equation, \(D\) is density, \(m\) is the mass of the material, and \(V\) is the volume of the material. Because density equals mass divided by volume, the units for density always are a mass unit divided by a volume unit. If mass is measured in grams (g) and volume is measured in cubic centimeters (cm\(^3\)), density has units of g/cm\(^3\). Density is the mass in grams of 1 cubic centimeter of the material. For example, silver has a density of 10.5 g/cm\(^3\). This means that 1 cm\(^3\) of silver has a mass of 10.5 g.

What are the units of density?

**Density Equation**

**Solve for Density** A piece of metal has a mass of 90.51 g and its volume is 11.5 cm\(^3\). What is the density of the metal?

1. **This is what you know:**
   - mass: \(m = 90.51\) g
   - volume: \(V = 11.5\) cm\(^3\)

2. **This is what you need to find:** density: \(D\)

3. **Use this formula:**
   \[D = \frac{m}{V}\]

4. **Substitute:**
   Substituting the values for \(m\) and \(V\)
   \[D = \frac{90.51}{11.5} = 7.87\]

5. **Determine the units:**
   units of \(D\) = units of \(\frac{m}{V}\) = \(\frac{\text{g}}{\text{cm}^3}\) = g/cm\(^3\)

**Answer:** The density is 7.87 g/cm\(^3\).

**Practice Problems**

1. Find the density of a gold bar that has a mass of 1,930 g and a volume of 100 cm\(^3\).
2. What is the density of a bar of soap that has a volume of 80 cm\(^3\) and a mass of 90 g?
Calculating Mass and Volume

The density equation on the preceding page is the relationship among the mass, volume, and density of an object. You can use the density equation to calculate either the mass or the volume of an object. For example, if you know the volume and the density of the object, you can use the density equation to find the object’s mass. If you know the mass and the density, the density equation can be solved for the volume. The math feature at the end of this lesson shows how to use the density equation to solve for the mass and the volume.

Density and Materials

Imagine you have a chocolate bar, such as the one shown in Figure 2, that has a density of 1.2 g/cm³. Suppose you break the bar into two pieces. The two pieces of chocolate now are smaller than the whole chocolate bar. Does the density of the chocolate change when the pieces become smaller?

However, as Figure 2 shows, the density of each of the two pieces is the same as the whole bar. The density of an object, such as a piece of chocolate, depends only on the material the object is made from. It does not depend on the object’s size. If you break the chocolate bar into smaller pieces, each piece will have the same density. The density of each piece will be 1.2 g/cm³, the same as the density of the whole bar. The density of each piece is the same because each piece is made from the same material—chocolate.

**Figure 2** The density of a piece of chocolate does not depend on the size of the piece. Identify the variables of the density equation that do change as the chocolate bar is broken into smaller pieces.

- Mass of chocolate bar = 226 g, volume = 190 cm³
- Density = mass/volume
  - = (226 g)/(190 cm³)
  - = 1.2 g/cm³

- Mass of each piece = 113 g
- Volume of each piece = 95 cm³
- Density of each piece = mass/volume
  - = (113 g)/(95 cm³)
  - = 1.2 g/cm³
What does density depend on?

The densities of some solids, liquids, and gases are listed in Table 1. The table shows that the density of gold, for example, is more than 19 times greater than the density of water. Also, the density of some solids and liquids, such as mercury, can be more than 10,000 times greater than the density of some gases, such as helium. Why do different materials have different densities?

**Mass of Particles** The density of a material depends on the mass of the particles, such as atoms or molecules, that make up the material. The more mass these particles have, the greater the density of the material. For example, the mass of a gold atom is more than seven times the mass of an aluminum atom. As a result, the density of gold is much greater than the density of aluminum.

**Distance Between Particles** The density of a material also depends on the distance between the particles in the material. The greater the distance between the atoms or molecules, the smaller the density. Table 1 shows that in gases, particles are much farther apart than in solids or liquids. As a result, the density of a gas is usually much less than the density of a solid or a liquid.

**Table 1** Which solids listed are less dense than water?
Measuring Density

To measure the density of a material or an object, you first need to measure both its mass and its volume. The volume of a liquid is usually measured using a graduated cylinder. The method for measuring the volume of a solid depends on whether it has a rectangular or an irregular shape.

Measuring Mass

A balance can be used to determine the mass of an object or a material. You can place most solids directly on the pan of the balance and read the result. If the solid is a powder, or if you want to find the mass of a liquid, you use a container and follow the steps shown in Figure 3. First, measure the mass of the empty container. Then, find the total mass of the container and sample. Finally, subtract the mass of the container from the total mass.

Measuring the Volume of a Liquid

The method for measuring volume is different for liquids and solids. For a liquid, you can use a graduated cylinder to measure volume, as shown in Figure 4. Then, the volume will be measured in units of milliliters. The density of a liquid can be determined by using a balance to measure the mass of the liquid and a graduated cylinder to measure its volume. Then, these values for mass and volume are substituted into the density equation to calculate the liquid’s density. Suppose that you measure a volume of 73 mL for a liquid. If the mass of the liquid is 80.3 g, then its density is 80.3 g divided by 73 mL, or 1.1 g/mL. Because 1 mL is equal to 1 cm$^3$, this density value can also be written as 1.1 g/cm$^3$. 

Figure 3 Two measurements are needed to measure the mass of a liquid.

| Mass of beaker | 144 g |
| Mass of beaker and liquid | 331 g |
| Mass of liquid | (Mass of beaker and liquid) – (Mass of beaker) |
| Mass of liquid | 331 g – 144 g |
| = 187 g |

Figure 4 A graduated cylinder can be used to find the volume of a liquid.
Measuring the Volume of a Rectangular Solid

You can use a graduated cylinder to measure a liquid’s volume. How can you measure the volume of a solid? The method for measuring a solid’s volume depends on the solid’s shape. A rectangular (rehk TAN gyoo lar) solid is a six-sided block in which all sides are rectangles, as shown in Figure 5. To determine the volume of a rectangular solid, first measure its length, width, and height, and then use the following equation to find the volume:

Volume of a Rectangular Solid

\[ \text{volume (cm}^3\) = \text{length (cm)} \times \text{width (cm)} \times \text{height (cm)} \]

\[ V = l \times w \times h \]

Can the formula shown above be used to find the volume of any solid object? Explain.

---

Solve for Volume

A rectangular block of stone has a length of 12.3 cm, a width of 7.6 cm, and a height of 4.7 cm. What is the volume of the stone block?

1. **This is what you know:**
   - length: \( l = 12.3 \text{ cm} \)
   - width: \( w = 7.6 \text{ cm} \)
   - height: \( h = 4.7 \text{ cm} \)

2. **This is what you need to find:** volume: \( V \)

3. **Use this formula:**
   \[ V = l \times w \times h \]

4. **Substitute:** the values for \( l, w, \) and \( h \) into the formula and multiply.
   \[ V = (12.3) \times (7.6) \times (4.7) = 439.4 \]

5. **Determine the units:**
   - units of \( V = (\text{units of } l) \times (\text{units of } w) \times (\text{units of } h) \)
   - \( = \text{cm} \times \text{cm} \times \text{cm} = \text{cm}^3 \)

**Answer:** The volume is 439.4 cm³.

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**Practice Problems**

1. What is the volume of a brick that is 20.3 cm long, 8.9 cm wide, and 5.7 cm high?

2. Find the volume of a box with a height of 15 cm, a width of 18 cm, and a length of 30 cm.

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Measuring the Volume of an Irregular Solid

There isn’t a simple formula to find the volume of a solid if the object has an irregular shape. For example, how would you measure the volume of a football or a fork? Figure 6 shows how to find the volume of a solid with an irregular shape using the displacement method. Displacement occurs when an object is placed in a liquid. The object pushes aside, or displaces, some of the liquid.

Using the Displacement Method

When you place an object in the graduated cylinder shown in Figure 6, the level of the liquid moves upward. However, the volume of the liquid hasn’t changed. Instead, the liquid level moves upward because the solid has displaced some of the liquid. The volume at the new level of liquid is the combined volume of the liquid and the object. You can find the volume of the object by subtracting the liquid volume from the combined volume of the liquid and the object, as shown in Figure 6. After you find the volume, you can calculate the density of the object by dividing its mass by its volume.

Density as a Physical Property

A physical property is a property of a material that you can measure without changing the composition of the material. The composition of a material changes when the material changes into a different substance. When you measure the density of a material, you measure the material’s mass and volume. However, measuring the mass or the volume doesn’t cause the material to change into a different substance. This means that density is a physical property of a material. You will read more about density and physical properties of materials in Chapter 7.

Figure 6 What are the three steps used to measure volume with the displacement method?

What is a physical property?
What have you learned?

In this lesson you read that the density of a material depends on the kinds of particles that make up the material as well as the spacing of the particles in the material. You also read that density does not change as the size of the sample changes. Finally, you read about how to measure an object’s mass and volume to be able to calculate the density of the object. You will use your knowledge of density in the next lessons as you study sinking and floating.
Using the Density Equation to Find Mass and Volume

The density equation is a relationship between the mass of an object, its volume, and the density of the object. If you know any two of the variables in the density equation, you can calculate the unknown variable.

Using the Density Equation to Find Mass

If the density, \( D \), and volume, \( V \), of an object are known, you can find the mass, \( m \), of the object.

First multiply both sides of the density equation by \( V \):

\[
V \times D = V \times \frac{m}{V}
\]

The variable \( V \) cancels on the right side of the above equation:

\[
V \times D = \frac{V \times m}{V} = m
\]

So the equation for the mass of an object if its density and volume are known is:

\[
m = V \times D
\]

You can find the mass by multiplying the volume and the density.

Using the Density Equation to Find Volume

If the density, \( D \), and mass, \( m \), of an object are known, you can find the volume, \( V \), of the object.

Use the equation above, and divide both sides by \( D \):

\[
\frac{m}{D} = \frac{V \times D}{D}
\]

The variable \( D \) cancels on the right side of the above equation:

\[
\frac{m}{D} = \frac{V \times D}{D} = V
\]

So the equation for the volume of an object if its density and mass are known is:

\[
V = \frac{m}{D}
\]

You can find the volume by dividing the mass by the density.

Practice Problems

1. Lead has a density of 11.3 g/cm³. If a piece of lead has a volume of 4 cm³, what is its mass?

2. A stainless steel rod has a mass of 59.2 g and a density of 7.9 g/cm³. What is the volume of the rod?
Can you calculate the density?

Regardless of a sample’s form, it has mass, volume, and density. If you can measure the mass and volume, you can calculate the sample’s density.

**Data Collection**

1. Read and complete a lab safety form.
2. Make a data table as shown below.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Description</th>
<th>Mass (g)</th>
<th>Volume (cm³)</th>
<th>Density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Write a brief description of the sample in the table.
4. Use a balance to measure the mass of the material. For a liquid, follow the steps shown in Figure 3.
5. Find the volume of the sample. Use a graduated cylinder to find the volume of a liquid or an irregular solid. For an irregular solid, follow the steps in Figure 6.
6. Repeat steps 3, 4, and 5 for the remaining sample.

**Data Analysis**

1. Calculate the density for each sample.
2. Explain how the density you calculated would change if the size of the sample doubled.
3. Compare your results to those of other groups.

**Science Content Standards**

- **8.b** Students know how to calculate the density of substances (regular and irregular solids and liquids) from measurements of mass and volume.
- **9.f** Apply simple mathematic relationships to determine a missing quantity in a mathematic expression, given the two remaining terms (including speed = distance/time, density = mass/volume, force = pressure \times area, volume = area \times height).
**Pressure and the Buoyant Force**

*(Main Idea)* Objects in a fluid experience a buoyant force resulting from the pressure exerted by the fluid.

**Real-World Reading Connection** A beach ball filled with air floats on the surface of a swimming pool. Pushing the beach ball under water can be hard to do. If you hold the ball under water, why does the ball pop out of the water when you let go?

**Pressure in a Fluid**

You probably can think of many examples in which the force exerted by an object pushes or pulls on another object. A bat exerts a force on a baseball. Your hand pulls on a handle to open a door. It might seem that only solid objects can exert forces on each other. However, liquids and gases also can exert forces. Think about the waves crashing against you at the seashore or the air pushing against you on a windy day. Liquids and gases are fluids, which are materials that can flow and have no definite shape. Like solid objects, fluids can exert forces.

For example, when the swimmer in *Figure 7* tries to push the beach ball under the water, the water exerts an upward force on the ball. This force becomes greater as more of the ball is pushed into the water. When the swimmer lets go, the upward force exerted by the water can cause the ball to pop up.

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**Science Content Standards**

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

**Reading Guide**

**What You’ll Learn**

- **Describe** how a fluid exerts pressure on objects submerged in the fluid.
- **Compare** the pressure on an object at different depths in a fluid.
- **Explain** Archimedes’ principle.

**Why It’s Important**

The buoyant force explains how huge ships made of metal are able to float.

**Vocabulary**

- fluid
- pressure
- atmospheric pressure
- buoyant force
- Archimedes’ principle

**Review Vocabulary**

*force:* a push or a pull (p. 88)
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 ride a bicycle with narrow tires over the sand or the snow, the tires would sink even deeper than your feet.

How deep you sink depends on two things. One is the force you apply to the surface of the sand or the snow. This force is equal to your weight. How deep you sink also depends on the area over which the force is applied. Like the person in Figure 8, when you stand on two feet, the force you exert is spread out over the area covered by your two feet. However, suppose you stand on a large board, as in Figure 8. Then the force you exert on the sand is spread out over the area covered by the board. Because this area is larger than the area covered by your feet, the force you apply is more spread out when you stand on the board.

What happens when the area over which a force is applied increases?

Why don’t you sink as deep when you stand on the board? In both cases, you exerted a downward force on the sand. What changed was the area over which the force was exerted on the sand. By changing this area, you changed the pressure you exerted on the sand. Pressure is the force per unit of area applied on the surface of an object. Pressure decreases when a force is spread out over a larger area. When you stood on the board, the pressure you exerted on the sand decreased. As a result, you didn’t sink as deep.
Calculating Pressure

Pressure depends on the force applied and the area of contact over which the force is applied. Pressure can be calculated from the following equation:

\[
\text{Pressure Equation} \quad P = \frac{F}{A}
\]

The unit of pressure is the pascal, abbreviated Pa. Recall from Chapter 2 that the unit for force is the newton (N). A pressure of 1 Pa 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 pressure, larger pressures are often expressed in units of a kilopascal (kPa), which is 1,000 Pa.

**Pressure Equation**

<table>
<thead>
<tr>
<th>Pressure (in pascals)</th>
<th>Force (in newtons)</th>
<th>Area (in meters squared)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P ) = ( \frac{F}{A} )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**SCIENCE USE v. COMMON USE**

**pressure**

- **Science Use**: amount of force exerted per unit of area. The can was crushed by the large pressure acting on it.
- **Common Use**: physical or mental stress. David felt great pressure when called on in class to answer a question.

**WORD ORIGIN**

**pressure**

from Latin *premere*; means to press

**SOLVE FOR PRESSURE**

A box exerts a force of 420 N on a floor. The bottom of the box has an area of 0.7 m\(^2\). What is the pressure exerted by the box on the floor?

1. **This is what you know:**
   - force: \( F = 420 \text{ N} \)
   - area: \( A = 0.7 \text{ m}^2 \)

2. **This is what you need to find:**
   - pressure: \( P \)

3. **Use this formula:**
   \[ P = \frac{F}{A} \]

4. **Substitute:**
   - the values for \( F \) and \( A \) into the formula and divide.
   \[ P = \frac{420}{0.7} = 600 \text{ Pa} \]

5. **Determine the units:**
   - units of \( P \) = units of \( \frac{F}{A} \) = \( \frac{N}{\text{m}^2} = \text{N/m}^2 = \text{Pa} \)

**Answer:** The pressure is 600 Pa.

**Practice Problems**

1. A person lying on a floor exerts a force of 750 N over a floor area of 1.1 m\(^2\). Find the pressure exerted by the person on the floor.

2. A car makes contact with the ground over an area of 0.85 m\(^2\). What is the pressure exerted by the car on the ground if the car exerts a force of 9,350 N on the ground?

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Pressure and Fluid Height

Suppose you pour the same amount of water into wide and narrow graduated cylinders, as shown in the left photo of Figure 9. Notice that the height of the water in the narrow cylinder is greater than in the wide cylinder. Is the pressure caused by the weight of the water 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 narrow cylinder is smaller. Therefore, the pressure is greater at the bottom of the small cylinder.

Why is the pressure greater at the bottom of the narrow cylinder than at the bottom of the wide cylinder?

How could you increase the pressure at the bottom of the wide cylinder? If you added water to the cylinder, the weight of the water would increase. This would increase the force on the bottom of the cylinder, thereby increasing the pressure. In the right photo, the pressure at the bottom of both cylinders is the same. What do you notice about the height of the column of water in each cylinder? It is the same, too! This is not just a coincidence resulting from the shapes of the containers. It is true for any fluid: the pressure depends only on the height of the column of fluid above the surface where you measure the pressure. The greater the height of the column of fluid above a surface, the greater the pressure exerted by the fluid on the surface.

Pressure and Depth

Figure 10 shows how pressure changes with depth. At the top of the glass, the water pressure is zero because there is no column of water above that level. Pressure in the middle of the glass depends on the column of water from the top of the glass to the middle of the glass. Pressure at the bottom depends on the entire height of the water. Pressure increases with depth because the column of water pushing down becomes taller and heavier. You can feel how pressure changes with depth if you dive under water. As you swim deeper, the water pressure on you increases.
Pressure in All Directions

If the pressure exerted by a fluid is a result of the weight of the fluid, is the pressure in a fluid exerted only downward? The illustration in Figure 11 shows a small, solid cube in a fluid. The fluid exerts pressure on each face of this cube, not just on the top. The pressure is perpendicular to the surface, and the amount of pressure depends only on the depth in the fluid. As shown in the photograph in Figure 11, this is true for any object in a fluid, no matter how complicated the shape. The pressure on the object is always perpendicular to the surface of the object.

In which direction does pressure exerted by a fluid push?

Atmospheric Pressure

When you read about the pressure in fluids, you might think only about liquids such as water. However, remember that gases are fluids, too. Like liquids, a gas exerts pressure on an object depending on the height of the gas above the object. Atmospheric (AT muh sfihr ik) pressure is the force exerted per unit area by air particles. If you start at the top of a mountain and walk down, the height of the column of air above you increases. This means that atmospheric pressure increases as your elevation decreases. Figure 12 shows how pressure varies as you go from the tallest mountains to deep under water in the ocean.

You can sense the change in atmospheric pressure when you fly in an airplane or take an elevator to the top of a tall building. The sudden change in pressure can make your ears pop. You sometimes can feel changes in pressure, but you probably don’t notice the air pressing on you right now. The column of air above you is more than 10 km thick. The total force of the air pushing on the surface area of your skin is about the same as the weight of ten cars! You don’t feel this pressure because there is an equal, internal pressure pushing out from the inside of your body. This internal pressure balances the external pressure exerted on you by the atmosphere.
Air pressure is the pressure exerted by the weight of the atmosphere above you. At sea level, the atmosphere exerts a force of about 100,000 N on every square meter of area. This pressure is also called one atmosphere (atm) and is equal to 100 kPa.

Deep in the Ocean

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 the atmospheric pressure at sea level.

High Elevation

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

Reef Level

When you descend below the sea surface, pressure increases by about 1 atm every 10 m. At 20 m 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.

Contributed by National Geographic
**What causes the buoyant force?**

Think about the forces acting on the boat in Figure 13. Gravity is pulling the boat down, yet the boat doesn’t accelerate downward. Because the boat is not accelerating up or down, the vertical forces on the boat are balanced. There must be an upward force balancing the downward force of gravity that keeps the sailboat from sinking.

**Buoyant Force and Pressure**

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 of the object. The other is that the pressure exerted by a fluid increases as you go deeper into the fluid. Figure 14 shows these two properties of pressure exerted by a fluid.

The forces acting in the horizontal direction cancel because there are equal forces pushing to the left and to the right. For objects of any shape submerged in a liquid, there is no net horizontal force caused by water pressure.

However, water pressure at the top surface of the fish is less than water pressure at the bottom surface. The force pushing up on the fish is therefore greater than the force pushing down on the fish. The vertical forces do not balance each other. There is an upward force on the fish resulting from differences in water pressure. The **buoyant** (BOY unt) **force** is the upward force on an object in a fluid exerted by the surrounding fluid. The buoyant force is a result of increasing pressure at increasing depth.

**WORD ORIGIN**

**buoyant**  
from Spanish *boyante*; means *to float*
Buoyant Force and Depth
The pressure exerted by a fluid increases with depth. However, the buoyant force on the fish in Figure 14 doesn’t change as the fish swims deeper. The reason is that the buoyant force is the difference in the forces exerted on the upper and lower surfaces of the fish. As the fish swims deeper, the pressure on these surfaces increases by the same amount. The difference in the forces doesn’t change and the buoyant force on the fish stays the same.

How does the buoyant force change as the depth of the object changes?

Archimedes’ Principle
A beach ball floating in water displaces some of the water. The volume of the water displaced by the ball is equal to the volume of the ball that is in the water. Archimedes, a Greek mathematician who lived more than 2,200 years ago, found that the buoyant force on an object depends on the displaced fluid. According to Archimedes’ principle, the buoyant force on an object is equal to the weight of the fluid the object displaces. The weight of the fluid displaced depends only on the density and the volume of the fluid displaced. As Figure 15 shows, the buoyant force on an object does not depend on the object’s density or its weight.

Archimedes’ principle explains why the upward buoyant force on a beach ball increases as the ball is pushed underwater. The volume of the water displaced by the ball is much greater when it is underwater than when it is floating. So the weight of the water displaced, and the buoyant force, also is much greater when the ball is underwater than when it is floating.

Figure 15 The buoyant force on each cube is the same, because each cube has the same volume and displaces the same amount of water. Determine which cube has the greatest weight.
What have you learned?

A fluid exerts an upward buoyant force on an object in the fluid. The buoyant force acting on an object submerged in a fluid is caused by the difference in pressure on the top and bottom of the object. This difference in pressure does not change as the object moves deeper into the fluid. This means that the buoyant force does not change as the depth of the object changes. According to Archimedes’ principle, this buoyant force also equals the weight of the fluid displaced by the object. This means that the buoyant force on an object does not depend on the weight of the object. Instead, it depends on the volume and the density of the displaced fluid.
Can you feel the buoyant force?

A fluid exerts an upward buoyant force on all objects placed in the fluid. Can you detect the buoyant force that acts on a heavy rock?

**Procedure**

1. Read and complete a lab safety form.
2. **Station A:** Fill a clear plastic bowl or pitcher with clean tap water. Put a sandwich bag under water and fill it so no air gets into the bag. Seal the bag while it is underwater. Remove the bag from the water. Place the bag into the bowl of water and observe how far it sinks. Write your observations in your Science Journal.
3. **Station B:** Observe the heavy rock with the rope tied around it at the bottom of the large plastic storage container filled with clear tap water. Lift the rock halfway up in the container, but keep it under the water. Think about how difficult or easy it was to lift. Lift the rock all the way out of the water and hold it above the water. Think about how difficult or easy it was to lift and to hold in this position. Write your observations in your Science Journal.

**Analysis**

1. Compare the behavior of the bag of water and the rock to the beach ball you studied in the Launch Lab. How do the densities of the bag of water, the rock, and the ball compare to the density of water?
2. Diagram the forces acting on the rock when it is sitting at the bottom of the container, when you held it above the bottom but still underwater, and when you held it out of the water.

**Science Content Standards**

8.c Students know the buoyant force on an object in a fluid is an upward force equal to the weight of the fluid the object has displaced.
Sinking and Floating

**Main Idea** An object will float in a fluid if the density of the object is less than the density of the fluid.

**Real-World Reading Connection** If you’ve visited a lake or an ocean, you’ve probably seen boats of all sizes and shapes. A small fishing boat might be just big enough for two or three people. A larger group of people can fit on a large sailing boat. A cruise ship can carry thousands of people! Think about the weight of all the people and equipment on a cruise ship. What keeps this heavy ship from sinking?

**Why do objects sink or float?**

A fluid exerts pressure on any object that is in the fluid. This pressure exerts an upward buoyant force on the object. However, the buoyant force isn’t the only force acting on the object. The force due to Earth’s gravity pulls down on an object. This downward force is the object’s weight. Whether an object sinks or floats depends on the sizes of the upward buoyant force on the object and object’s weight. Why do some objects sink and some objects float?

**Sinking and Buoyant Force**

If the upward buoyant force on an object is less than the object’s weight, then the net force on the object is downward. The object accelerates downward because the unbalanced force is downward. The stone in Figure 16 moves downward, or sinks, because its weight is greater than the buoyant force acting on it.
Floating and Buoyant Force

The woman floating on the water in Figure 17 isn’t accelerating in the vertical direction. When an object isn’t accelerating, the forces acting on the object are balanced. The downward weight of the woman is balanced by the buoyant force pushing upward on the woman. If an object is floating, the buoyant force equals the object’s weight.

If an object is floating, what are the relative sizes of the weight and the buoyant force?

The Buoyant Force and Density

According to Archimedes’ principle, the buoyant force equals the weight of the displaced fluid. Therefore, if an object is floating, the weight of the displaced fluid equals the weight of the object. For example, the weight of the water displaced by the woman in Figure 17 equals the weight of the woman.

How can metal boats float?

Almost all metals have a density greater than the density of water. According to Archimedes’ principle, you might predict that a piece of metal will sink in water. Why, then, do metal boats such as the ship in Figure 18 float? Remember that the mass of an object doesn’t determine whether or not it floats. For an object to float, the overall density of the object must be less than the density of the fluid it is in. The overall density of a metal boat is made smaller by making the volume of the boat larger. The ship in Figure 18 has a large volume that is filled with air. By making the air-filled volume large enough, the overall density of the boat can be made smaller than the density of water. As a result, the boat floats, even though it is made from metal.

Figure 18 How does changing the shape of the metal affect the density of the boat?
Measuring Density with a Hydrometer

There is another way to measure the density of liquid besides first measuring its mass and volume. A hydrometer (hi DRA mih ter) is an instrument that measures the density of a liquid.

When the hydrometer is placed in a liquid, it sinks to a certain depth. The depth to which it sinks depends on the density of the liquid, as shown in Figure 19. The lower the density of the liquid, the deeper the hydrometer sinks. The length of the hydrometer tube below the liquid, or submerged, is related to the density of the liquid. The lower the density of the liquid, the longer the length of the hydrometer tube submerged below the liquid.

To measure the density of a liquid, the hydrometer is first placed in water. Then the length of the hydrometer below the surface of the water is measured. Next, the hydrometer is placed in the liquid and the length of the hydrometer below the surface of the liquid is measured. The ratio of the submerged lengths of the hydrometer in the water and in the liquid is related to the ratio of the densities of the water and the liquid. For example, suppose the ratio of the length submerged in water divided by the length submerged in the liquid is 2.0. Then the density of the unknown liquid is 2.0 times the density of water. Water has a density of 1.0 g/cm³, so the density of the liquid is 2.0 g/cm³.

Figure 19 A hydrometer measures the density of a liquid.
Compare the weight of liquid displaced by the hydrometer in each illustration.
Floating and Sinking in the Atmosphere

Objects float in all fluids, including gases. Air is a fluid made of gases. Objects can float or rise in air because of the buoyant force produced by air pressure.

Helium Balloons

The balloons in Figure 20 can float in air because they contain helium gas. Air is made of mostly nitrogen gas and oxygen gas, which are much denser than helium. When a balloon is filled with helium, its density is less than the density of the surrounding air. The balloon rises if the buoyant force on the balloon is greater than the weight of the balloon.

Why does a helium balloon float in air?

If you’ve ever had a helium balloon, you know that it eventually stops floating. The helium atoms are so small that they can seep out through tiny holes in the rubber balloon. This causes the balloon to shrink. As a result, the density of the balloon increases. When the density of the balloon becomes greater than the density of the surrounding air, the balloon sinks.

Hot-Air Balloons

A hot-air balloon, such as the one shown in Figure 21, floats because its density is less than the density of the surrounding air. The overall density of the hot-air balloon is controlled by changing the temperature of the air inside the balloon. A pilot controls the air temperature using burners below the opening of the balloon.

When the flame of the burner heats the air in the balloon, the air particles move farther apart. The density of the balloon decreases and becomes less dense than the air outside the balloon. This causes the balloon to rise. When the burner is turned off, the air in the balloon cools and its density increases. If the air in the balloon cools enough, the balloon will sink. The rising and sinking of the balloon is determined by the densities of the air inside and outside the balloon.

Figure 20 This helium balloon rises in air because its weight is less than the buoyant force exerted by the air.

Figure 21 A hot-air balloon rises when the air in the balloon is heated. This makes the balloon’s overall density less than the density of the surrounding air.

Explain how heating the air in the balloon affects the density of the balloon.
What have you learned?

In this lesson you read about sinking and floating. You used the things you learned about forces in the previous chapter to explain why things sink or float. When placed in a fluid, an object sinks if the buoyant force and the object’s weight are unbalanced. If the object floats, the forces are balanced.

You also combined your understanding of forces with facts you learned about density to explain how even heavy metal boats can float. You read that boats that weigh thousands of tons can float because the overall density of the boat is less than the density of water.
Do cold things float?

On a hot day, you might put a few ice cubes into a glass of water to cool off. The ice cubes float near the top of the liquid. Do ice cubes float because they are cold? What does temperature have to do with sinking and floating?

**Procedure**

1. Read and complete a lab safety form.
2. Get a container of **room-temperature water** from your teacher.
3. Fill a **sandwich bag** with some **hot water** and seal the bag. Be sure to remove any air bubbles from the bag.
4. Write a prediction in your Science Journal. Will the bag filled with hot water sink or float in the room-temperature water? Observe the bag in the water and record the observation.
5. Get another container of room-temperature water from your teacher and another sandwich bag. Fill the bag with **cold tap water** and place **several ice cubes** into the bag before sealing it. Let the bag sit for a few minutes while the ice cools the water.
6. Write a prediction. Do you think the cold water will sink or float? Place the bag in the room-temperature water and observe. Record the observation.

**Analysis**

1. **Describe** what happened when you put the hot water into the room-temperature water. What happened when you put the cold water into the room temperature water?
2. **Compare** the behavior of the hot and cold bags of water to the bag of water you observed in the MiniLab at the end of Lesson 2.
3. **Explain** what effect temperature has on the density of the water. How did this affect the floating of the bags?

**Science Content Standards**

8.d Students know how to predict whether an object will float or sink.
Investigation Lab: A Homemade Hydrometer

Problem
A hydrometer is a device used to compare the densities of liquids. You can make a hydrometer by using a pencil with a thumbtack in the eraser. With your pencil hydrometer, you can compare the densities of several liquids to the density of water. You can even make a scale on your pencil to have a quantitative comparison for the liquids that you test.

Form a Hypothesis
Review the results from this chapter’s laboratory investigations.
Make a prediction about the densities of the unknown liquids. Are they more or less dense than water? Why do you think so?

Collect Data and Make Observations
1. Read and complete a lab safety form.
2. Make a data table like the one on the next page.
3. Add clean tap water to the graduated cylinder until it is three-fourths full.
4. Measuring from the tip of the eraser, mark on the pencil in half-centimeter steps.
5. Push the thumbtack into the eraser of the pencil. Drop the pencil into the graduated cylinder so that the pencil floats upright with the eraser end down.
6. Measure the length of the part of the pencil that was submerged in the water. This length represents a density of 1.0 g/cm³. Record this value in your data table.
7. Wipe the pencil dry and then place it in one of the unknown liquids. Measure the length of the pencil that was submerged in the liquid. Record this value in your data table.
8. Repeat step 7 for the other unknown liquid.
Analyze and Conclude

1. **Explain** why it was important to clean the hydrometer before each test of a new liquid.

2. **Calculate** the ratio, W/U, of the submerged length of the pencil in water (W) to the submerged length of the pencil in the first unknown liquid (U). Record this ratio in your data table.

3. **Infer** from your calculation whether the density of the first liquid is greater or less than the density of water. Explain.

4. **Calculate** the ratio, W/U, of the submerged length of the pencil in water (W) to the submerged length of the pencil in the second unknown liquid (U). Record this ratio in your data table.

5. **Infer** from your calculation whether the density of the second liquid is greater or less than the density of water. Explain.

6. **Calculate** the density of each unknown liquid by multiplying the ratio W/U for each liquid by the density of water, 1.0 g/cm³. Record the calculated values in your data table.

7. **Compare** the weight of the displaced fluid when the pencil is placed in each of the three liquids.

### Comparison of Density of Water to Unknown Liquids

<table>
<thead>
<tr>
<th>W Submerged Length of Hydrometer in Water (cm)</th>
<th>U Submerged Length of Hydrometer in Unknown Liquid (cm)</th>
<th>Ratio W/U</th>
<th>Density of Unknown Liquid (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Communicate

Research how hydrometers are used in different industries, such as the food industry, and how they are used by auto mechanics. Write a one-page report on one application for hydrometers. Explain why the measurement of density is important.
Can ice cubes sink in water?

You are probably familiar with the ice that is in your freezer or ice that forms outside on cold days. However, there are over a dozen different kinds of ice that can form depending on temperature and pressure. Some even sink in water instead of floating. Physicists and chemists research properties such as density of water and ice. To prepare for this type of research, take chemistry, physics, and math classes in high school and college.

Visit Careers at ca8.msscience.com to find out more about scientific research. List five questions you have about ice. Suggest two things you could do to answer these questions.

Biodiesel

Density is very important in separations of liquids and gases. Biodiesel, a vegetable-based fuel, is made by mixing methanol and cooking oil. The reaction forms glycerin, an ingredient used to make soap, and biodiesel. Because biodiesel is less dense than glycerin, it rises to the top of the reaction chamber. The glycerin is drained and the biodeisel that remains is used as a fuel.

Create a layered sugar solution. Make the water green, the low-sugar solution colorless, and the high-sugar solution red. Carefully layer the less dense fluid on the denser fluid using a plastic syringe.
CANNERY ROW

Cold water from the bottom of the Pacific Ocean rises upward off the California coast. This nutrient-rich water nourishes an enormous number of fish. At one time, large numbers of these fish were caught by the California sardine industry. But a failure to impose sustainable limits on the catch and natural cycles led to the end of the trade.

Visit History at ca8.msscience.com to read more about the California sardine industry. Imagine you are a fisherman in 1933. Write a journal entry discussing your business and your outlook for each year until 1943.

ELA8: W 1.1

LOS ANGELES Smog

The San Fernando Valley traps the pollution created in Los Angeles. A warm layer of air is trapped between dense, cooler layers above and below, and between the sea and the mountains. It holds chemicals that sunlight turns to smog, which can irritate the lungs and eyes.

Visit Society at ca8.msscience.com to find out more about the history and future of air pollution control. List five things you can do now to reduce air pollution, and list five things you will be able to do when you are 25 years old.
A fluid exerts an upward force on an object that is placed in the fluid.

**Lesson 1 Density**

**Main Idea** The density of a material is a measure of how much matter is packed into a unit volume of the material.

- Density is the mass of a material divided by its volume.
- Mass can be measured with a balance.
- The volume of a liquid is measured with a graduated cylinder.
- The volume of a solid can be found by using the displacement method.

- density (p. 130)
- rectangular solid (p. 135)

**Lesson 2 Pressure and the Buoyant Force**

**Main Idea** Objects in a fluid experience a buoyant force resulting from the pressure exerted by the fluid.

- Pressure is force divided by unit area.
- The pressure in a fluid increases with depth.
- Fluid pressure causes a buoyant force on an object in the fluid.
- Pressure is exerted on all surfaces of an object in a fluid.
- Forces due to fluid pressure act perpendicular to any surface in a fluid.
- The buoyant force on an object is equal to the weight of the fluid the object displaces.

- Archimedes’ principle (p. 147)
- atmospheric pressure (p. 144)
- buoyant force (p. 146)
- fluid (p. 140)
- pressure (p. 141)

**Lesson 3 Sinking and Floating**

**Main Idea** An object will float in a fluid if the density of the object is less than the density of the fluid.

- An object sinks if the buoyant force is less than the weight of the object.
- An object floats if the buoyant force equals the weight of the object.
- An object will float if the density of the object is less than the density of the fluid.
- A hydrometer measures the density of a fluid.

- hydrometer (p. 152)

Download quizzes, key terms, and flash cards from ca8.msscience.com.
Linking Vocabulary and Main Ideas

Use vocabulary terms from page 160 to complete this concept map.

Using Vocabulary

Match a vocabulary term to each definition below.

8. the force per unit area exerted by air particles  
9. any material that can flow, including liquids and gases  
10. force per unit area  
11. upward force on an object submerged in a fluid  
12. the mass per unit volume of a material  
13. an instrument that measures the density of a fluid  
14. the buoyant force exerted by a fluid on an object equals the weight of the fluid displaced by the object
Understanding Main Ideas
Choose the word or phrase that best answers the question.

1. Gold has a density of 19.3 g/cm³. Silver has a density of 10.5 g/cm³. Which is a true statement?
   A. A 2-cm³ block of gold has less mass than a 2-cm³ block of silver.
   B. 50 g of gold has a lower volume than 50 g of silver.
   C. The weight of a 10.5-g block of gold equals the weight of a 19.3-g block of silver.
   D. The volume of a 15-g block of gold is greater than the volume of a 35-g block of silver.

2. A student measured the densities of four different materials. The table below shows the results of the measurements.

<table>
<thead>
<tr>
<th>Material</th>
<th>Density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.93</td>
</tr>
<tr>
<td>2</td>
<td>1.05</td>
</tr>
<tr>
<td>3</td>
<td>1.13</td>
</tr>
<tr>
<td>4</td>
<td>0.87</td>
</tr>
</tbody>
</table>

Which of the materials would you expect to float if they were placed in water?
   A. materials 2 and 3
   B. materials 1 and 4
   C. materials 2 and 4
   D. materials 1 and 3

3. If you toss a rock into a lake, what happens to the rock as it sinks?
   A. Pressure increases; buoyant force changes very little.
   B. Buoyant force increases; pressure changes very little.
   C. Pressure decreases; buoyant force changes very little.
   D. Buoyant force decreases; pressure changes very little.

4. Which is true about an inflatable beach ball as it is pushed under water?
   A. When the ball is under water, the pressure on the ball is the same at all places on the surface of the ball.
   B. The buoyant force on the ball increases the farther below the surface of the water you push the ball.
   C. The buoyant force on the ball increases until the entire ball is underwater.
   D. The ball experiences pressure from the water only in the vertical direction.

5. What does the buoyant force on an object submerged in a fluid equal?
   A. weight of the object that the buoyant force acts on
   B. weight of the fluid displaced by the object
   C. weight of the column of fluid above the object
   D. weight of the object minus the weight of the displaced fluid

6. Which of the four objects listed below would you expect to float?

<table>
<thead>
<tr>
<th>Object</th>
<th>Weight (N)</th>
<th>Buoyant Force (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>17</td>
<td>12</td>
</tr>
<tr>
<td>B</td>
<td>116</td>
<td>86</td>
</tr>
<tr>
<td>C</td>
<td>325</td>
<td>325</td>
</tr>
<tr>
<td>D</td>
<td>53</td>
<td>35</td>
</tr>
</tbody>
</table>
Applying Science

7. Suggest a way that you could determine whether a silver spoon is made of pure silver or a mixture of metals.  
8. Give an example of how you know an object in a liquid experiences a buoyant force.  
9. Compare the buoyant force on a fish as it swims from the water’s surface into deep water.  
10. Suggest two ways to determine the volume of a baseball.  
11. Imagine you attach a lead block to a spring scale and observe its weight. You then lower the lead block, still attached to the spring scale, into water. Explain how the weight measured by the scale will change as you lower the block into the water.  
12. Predict what you would observe if you mixed the liquids shown in the table below.  

<table>
<thead>
<tr>
<th>Liquid</th>
<th>Density (g/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Olive oil</td>
<td>0.918</td>
</tr>
<tr>
<td>Corn oil</td>
<td>0.922</td>
</tr>
<tr>
<td>Water</td>
<td>1.00</td>
</tr>
</tbody>
</table>

13. Suggest why it is important to use a strong material when making an air tank used by scuba divers for swimming deep below the ocean surface.  
14. Infer the relative densities of ice and water if you see ice floating in water.  
15. Compare the buoyant force on two objects submerged in water that have the same volume but different densities.  

WRITING in Science

16. Write a news article about the sinking of a fictional ship. The article should be at least two paragraphs long. It should explain to the reader why the ship was unable to float.

Cumulative Review

17. Imagine a rock at rest on the bottom of a lake. What three vertical forces are acting on the rock? Are the forces acting on the rock balanced? Explain how you know.  
18. Suppose a rock that weighs 57 N experiences a buoyant force of 35 N when it is submerged in water. What is the sum of these two forces acting on the rock as it sinks through the water?  

Applying Math

19. What is the density of a metal bolt that has a volume of 5.2 cm³ and a mass of 41.0 g?  
20. Platinum has a density of 21.45 g/cm³. If a piece of platinum has a volume of 1.2 cm³, what is its mass?  
21. The density of sodium is 0.97 g/cm³. Find the volume of a sample that has a mass of 6.7 g.  
22. The palm of Sheila’s hand has an area of 0.0017 m². If the atmospheric pressure on the palm is 100,000 Pa, what force is being exerted on Sheila’s palm by the atmosphere?  
23. The table shows the pressure in a pond at different depths.

<table>
<thead>
<tr>
<th>Pressure in a Pond</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth (m)</td>
</tr>
<tr>
<td>0.1</td>
</tr>
<tr>
<td>0.5</td>
</tr>
<tr>
<td>1.0</td>
</tr>
</tbody>
</table>

What would be the pressure in the pond at a depth of 1.5 m?
Use the figure below to answer questions 1 and 2.

1. The figure on the left shows the dancer’s footprints while standing with her feet flat on the floor. The figure on the right shows her footprints when standing on her toes. How does the pressure exerted on the floor in the left figure compare with the pressure exerted in the right figure?
   A. The pressure is greater in the left figure.
   B. The pressure is greater in the right figure.
   C. The pressure is the same in both figures.
   D. The pressure is smaller in the right figure.

2. The area of the floor in contact with the dancer’s feet is 300 cm² in the left photo and 30 cm² in the right photo. How does the force exerted on the floor change from the left photo to the right photo?
   A. The force decreases by 270 N.
   B. The force becomes 10 times larger.
   C. The force becomes 10 times smaller.
   D. The force acting on the floor does not change.

A force of 25 N is exerted on a surface with an area of 0.1 m². What is the pressure exerted on the surface?
   A. 0.04 Pa
   B. 2.5 Pa
   C. 25 Pa
   D. 250 Pa

A 15-g block of aluminum has a volume of 5.5 cm³. What is the block’s density?
   A. 0.37 g/cm³
   B. 2.7 g/cm³
   C. 20.5 g/cm³
   D. 82.5 g/cm³
Use the figure below to answer questions 8, 9, and 10.

**8. The boat and the cube have the same mass. Which statement is correct?**

A. The boat displaces less water than the cube.
B. The densities of the boat and the 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.

**9. A student measures the density of an unknown liquid. She finds the density is 1.42 g/cm³. She then pours half of the liquid into another container and measures the density again. What should be the result of her second measurement?**

A. 0.71 g/cm³
B. 1.42 g/cm³
C. 2.00 g/cm³
D. 2.84 g/cm³

**10. The density of gold is 19.3 g/cm³. What is the volume of a 100-g gold necklace?**

A. 0.193 cm³
B. 5.18 cm³
C. 119.3 cm³
D. 1930 cm³

**11. As you drive down a high mountain, what happens to the atmospheric pressure?**

A. It decreases.
B. It increases.
C. It increases, then decreases.
D. It stays the same.

**12. The photograph below shows a large boat floating in the ocean. How does the buoyant force acting on the boat change if the boat is loaded so that more of the boat is below the water?**

A. The buoyant force increases.
B. The buoyant force decreases.
C. The buoyant force stays the same.
D. The buoyant force decreases, then returns to the original value.
Are you interested in learning more about motion, forces, buoyancy, and density? If so, check out these great books.

**Science Fiction**

*Project Pendulum*, by Robert Silverberg, is the story of Earth’s first time travelers in 2016. One brother is carried back 95 million years in time and the other forward 95 million years in time. The book records each brother’s observations in alternating chapters. *The content of this book is related to Science Standard 8.1.*

**Nonfiction**

*The Cartoon Guide to Physics*, by Larry Gonick, provides concise explanations of physical principles with the help of amusing cartoons. Topics include motion, Newton’s laws, momentum, energy, electricity, and magnetism. *The content of this book is related to Science Standard 8.1.*

**Nonfiction**

*Objects in Motion: Principles of Classical Mechanics*, by Paul Fleisher, uses real-life examples to make natural laws easy to understand. The topics covered in this book include planetary motion, pendulums and falling objects, Newton’s three laws of motion, the law of universal gravitation, and conservation of momentum. *The content of this book is related to Science Standard 8.2.*

**Narrative Nonfiction**

*Dive! My Adventures in the Deep Frontier*, by Sylvia Earle, is the author’s story of her investigation and exploration of the marine ecosystem. Her experiences include tracking whales, living in an underwater laboratory, and helping design a deep-water submarine. *The content of this book is related to Science Standard 8.8.*
Choose the word or phrase that best answers the question.

1. Which of these is not a vector?
   A. force
   B. distance
   C. position
   D. velocity
   
   **Answer:** D. velocity

2. Which type of force causes a sliding box to slow down and stop?
   A. buoyant
   B. compression
   C. friction
   D. gravity
   
   **Answer:** C. friction

3. The forces applied to an object are 8 N to the left and 5 N to the right. What is the net force on the object?
   A. 3 N to the right
   B. 3 N to the left
   C. 13 N to the right
   D. 13 N to the left
   
   **Answer:** A. 3 N to the right

4. In which situation are the forces acting on a bicycle balanced?
   A. The bicycle speeds up as you pedal.
   B. The speed of the bicycle is constant as it turns.
   C. The bicycle slows down as it coasts.
   D. The bicycle moves in a straight line with constant speed as you pedal.
   
   **Answer:** B. The speed of the bicycle is constant as it turns.

5. What is the density of a ring that has a mass of 11.5 g and a volume of 0.8 cm³?
   A. 0.07 g/cm³
   B. 9.2 g/cm³
   C. 12.3 g/cm³
   D. 14.4 g/cm³
   
   **Answer:** A. 0.07 g/cm³

6. The graph below shows how Paul’s position changed as he walked to school.

   ![Distance Travelled over Time graph](distance_graph.png)

   **Calculate** Paul’s average speed over his entire trip.

   **Predict** A baseball is traveling 40 km/h east toward a batter. After the batter hits the ball, the ball is moving west at 40 km/h. Did the ball accelerate? Support your reasoning.

   **Describe** A rocket coasting toward Earth fires one of its rocket engines. The force exerted on the ship is in the direction opposite to the rocket’s velocity. How does the motion of the rocket change?

   **Predict** An object weighing 30 N is floating in water. What is the weight of the water displaced by the object? Support your reasoning.

   **Analyze** why it is easier to lift an object that is under water than it is to lift the object when it is out of the water.

   **Evaluate** how the gravitational force between Earth and the space shuttle changes as the shuttle moves farther from Earth.

   **Explain** how a balloon filled with helium floats in the air.