Section 3

Pascal's Principle

Reading Preview

Key Concepts

- What does Pascal's principle say about change in fluid pressure?
- How does a hydraulic system work?

Key Terms

- Pascal's principle
- hydraulic system

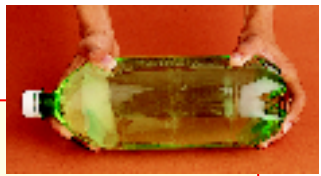
Target Reading Skill

Asking Questions Before you read, preview the red headings. In a graphic organizer like the one below, ask a *what* or *how* question for each heading. As you read, write the answers to your questions.

Pascal's Principle

Question	Answer
How is pressure transmitted in a fluid?	Pressure is transmitted . . .

Lab zone **Discover Activity**



How Does Pressure Change?

1. Fill an empty 2-liter plastic bottle with water. Then screw on the cap. There should be no bubbles in the bottle (or only very small bubbles).
2. Lay the bottle on its side. At one spot, push in the bottle with your left thumb.
3. With your right thumb, push in fairly hard on a spot at the other end, as shown. What does your left thumb feel?
4. Pick another spot on the bottle for your left thumb and repeat Step 3.

Think It Over

Observing When you push in with your right thumb, does the water pressure in the bottle increase, decrease, or remain the same? How do you know?

At first, you hesitate, but then you hold out your hand. The aquarium attendant places the sea star in your palm. You can feel motion on your skin. The many tiny "feet" on the animal's underside look something like suction cups, and they tickle just a bit! The attendant explains that the sea star has a system of tubes containing water in its body. As the water moves around in the tubes, it creates fluid pressure that allows the sea star to move. The sea star also uses this system to obtain its food.

A sea star uses fluid pressure to move. ▶

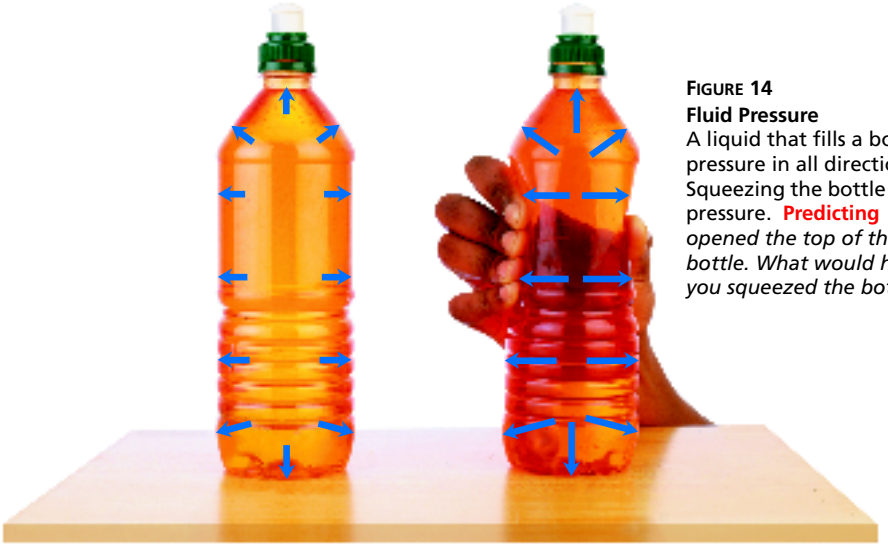


FIGURE 14
Fluid Pressure
A liquid that fills a bottle exerts pressure in all directions. Squeezing the bottle increases the pressure. **Predicting** *Suppose you opened the top of the water bottle. What would happen when you squeezed the bottle? Why?*

Transmitting Pressure in a Fluid

If you did the Discover Activity, you may be surprised to learn that a sea star's water-filled tube system is like the closed bottle you pushed your thumb against. Recall that the fluid pressure in the closed container increased when you pushed against its side. By changing the fluid pressure at any spot in the closed container, you transmitted pressure throughout the container. In the 1600s, a French mathematician named Blaise Pascal developed a principle to explain how pressure is transmitted in a fluid. Pascal's name is used for the unit of pressure.

What Is Pascal's Principle? As you learned in Section 1, fluid exerts pressure on any surface it touches. For example, the water in each bottle shown in Figure 14 exerts pressure on the entire surface of the bottle—up, down, and sideways.

What happens if you squeeze the bottle when its top is closed? The water has nowhere to go, so it presses harder on the inside surface of the bottle. The water pressure increases everywhere in the bottle. This is shown by the increased length of the arrows on the right in Figure 14.

Pascal discovered that pressure increases by the same amount throughout an enclosed or confined fluid. **When force is applied to a confined fluid, the change in pressure is transmitted equally to all parts of the fluid.** This relationship is known as **Pascal's principle.**

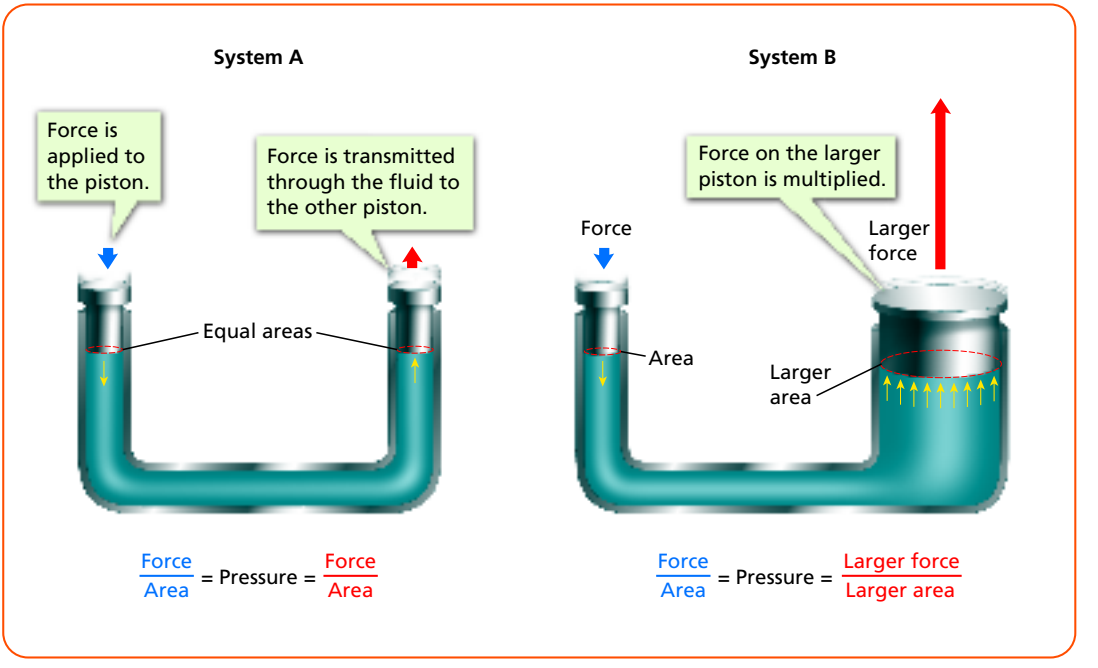


FIGURE 15
Hydraulic Devices
In a hydraulic device, a force applied to one piston increases the fluid pressure equally throughout the fluid. By changing the size of the pistons, the force can be multiplied.
Problem Solving *To multiply the force applied to the left piston four times, how large must the right piston be?*

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Using Pascal's Principle You can see Pascal's principle at work in Figure 15, which shows a model of a hydraulic device. A hydraulic device is operated by the movement and force of a fluid. The device consists of two pistons, one at each end of a U-shaped tube. A piston is like a stopper that slides up and down in a tube.

Suppose you fill System A with water and then push down on the left piston. The increase in fluid pressure will be transmitted to the right piston. According to Pascal's principle, both pistons experience the same fluid pressure. So, because both pistons have the same surface area, they will experience the same force.

Now look at System B. The right piston has a greater surface area than the left piston. Suppose the area of the small piston is 1 square centimeter and the area of the large piston is 9 square centimeters. Then the right piston has an area nine times greater than the area of the left piston. If you push down on the left piston, pressure is transmitted equally to the right piston. But, because the area of the right piston is nine times greater, the force you exert on the left piston is multiplied nine times on the right piston. By changing the size of the pistons, you can multiply force by almost any amount you wish.

Reading Checkpoint **How is force multiplied in System B?**

Hydraulic Systems

Hydraulic systems make use of hydraulic devices to perform a variety of functions. A **hydraulic system** uses liquids to transmit pressure in a confined fluid. **A hydraulic system multiplies force by applying the force to a small surface area. The increase in pressure is then transmitted to another part of the confined fluid, which pushes on a larger surface area.** You have probably seen a number of hydraulic systems at work, including lift systems and the brakes of a car. Because they use fluids to transmit pressure, hydraulic systems have few moving parts that can jam, break, or wear down.

Hydraulic Lifts Hydraulic lift systems are used to raise cars off the ground so mechanics can repair them with ease. You may be surprised to learn that hydraulic systems are also used to lift the heavy ladder on a fire truck to reach the upper windows of a burning building. In addition, hydraulic lifts are used to operate many pieces of heavy construction equipment such as dump trucks, backhoes, snowplows, and cranes. Next time you see a construction vehicle at work, see if you can spot the hydraulic pistons in action.

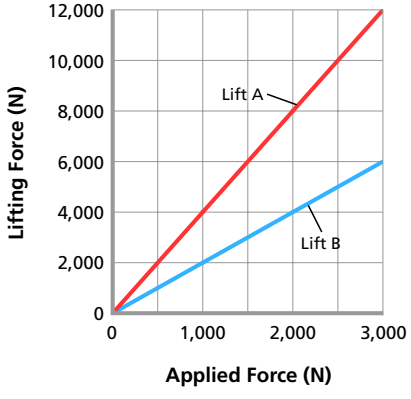
Reading Checkpoint **What are some uses of hydraulic systems?**

Math Analyzing Data

Comparing Hydraulic Lifts

In the hydraulic device in Figure 15, a force applied to the piston on the left produces a lifting force in the piston on the right. The graph shows the relationship between the applied force and the lifting force for two hydraulic lifts.

Hydraulic Lifts



1. **Reading Graphs** Suppose a force of 1,000 N is applied to both lifts. Use the graph to determine the lifting force of each lift.
2. **Reading Graphs** For Lift A, how much force must be applied to lift a 12,000-N object?
3. **Interpreting Data** By how much is the applied force multiplied for each lift?
4. **Interpreting Data** What can you learn from the slope of the line for each lift?
5. **Drawing Conclusions** Which lift would you choose if you wanted to produce the greater lifting force?

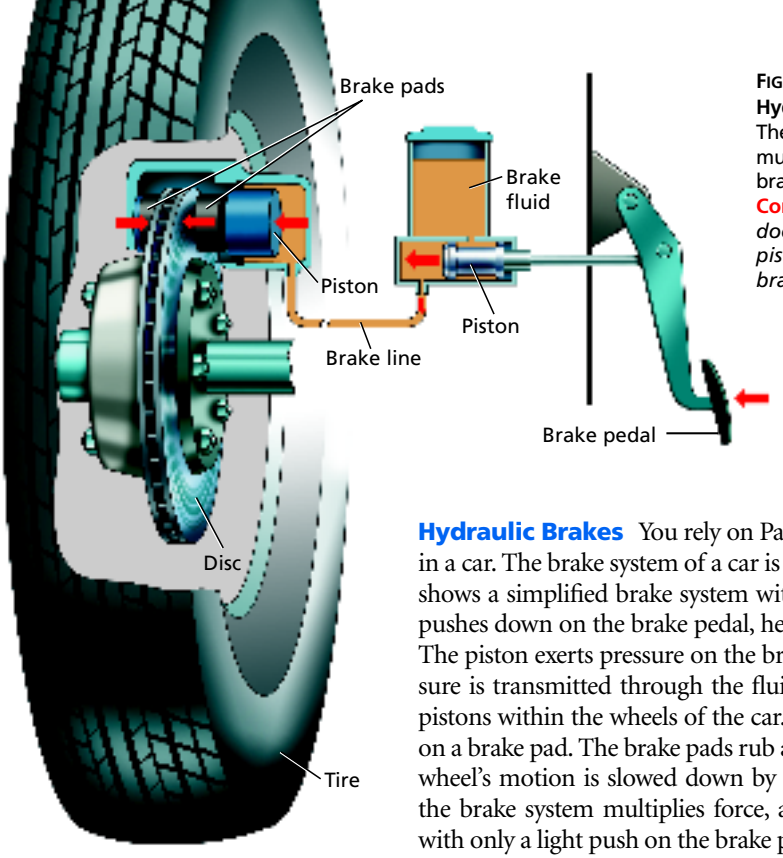
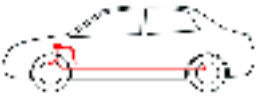


FIGURE 16
Hydraulic Brakes
The hydraulic brake system of a car multiplies the force exerted on the brake pedal.
Comparing and Contrasting *How does the size of the brake pedal piston compare with the size of a brake pad piston?*



Hydraulic Brakes You rely on Pascal's principle when you ride in a car. The brake system of a car is a hydraulic system. Figure 16 shows a simplified brake system with disc brakes. When a driver pushes down on the brake pedal, he or she pushes a small piston. The piston exerts pressure on the brake fluid. The increased pressure is transmitted through the fluid in the brake lines to larger pistons within the wheels of the car. Each of these pistons pushes on a brake pad. The brake pads rub against the brake disc, and the wheel's motion is slowed down by the force of friction. Because the brake system multiplies force, a person can stop a large car with only a light push on the brake pedal.

Section 3 Assessment

Target Reading Skill **Asking Questions** Use the answers to the questions you wrote about the headings to help you answer the questions below.

Reviewing Key Concepts

1. **a.** **Reviewing** According to Pascal's principle, how is pressure transmitted in a fluid?
   b. **Relating Cause and Effect** How does a hydraulic device multiply force?
   c. **Calculating** Suppose you apply a 10-N force to a 10-cm^2 piston in a hydraulic device. If the force is transmitted to another piston with an area of 100 cm^2, by how much will the force be multiplied?
2. **a.** **Defining** What is a hydraulic system?
   b. **Explaining** How does a hydraulic system work?
   c. **Sequencing** Describe what happens in the brake system of a car from the time a driver steps on the brake pedal to the time the car stops.

Writing in Science

Cause-and-Effect Letter You are a mechanic who fixes hydraulic brakes. A customer asks you why his brakes do not work. When you examine the car, you notice a leak in the brake line and repair it. Write a letter to the customer explaining why a leak in the brake line caused his brakes to fail.