9.4 Effects of External Pressure on Fluids

pressure (scientific definition): the force per unit area

You have seen how increasing the pressure on a gas can force it into a smaller volume. In science and technology, **pressure** refers to the force applied to a unit of surface area.

Some devices, such as thumbtacks, are designed to increase pressure. The force you apply to the head of the tack is transferred to the tiny area of the point. As the force is concentrated on a smaller area, pressure increases. Other devices are designed to decrease pressure. When a person wears snowshoes or uses a snowboard, he or she can stay on top of the snow. The force of the person's weight is spread over a larger area than if he or she were wearing boots. Spreading the force over a larger area reduces the pressure and prevents the person from sinking into the snow.

Mathematically, we write pressure (p) = force/unit area, or

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

Pressure is measured in pascals (Pa) and 1 Pa = 1 N/m^2.

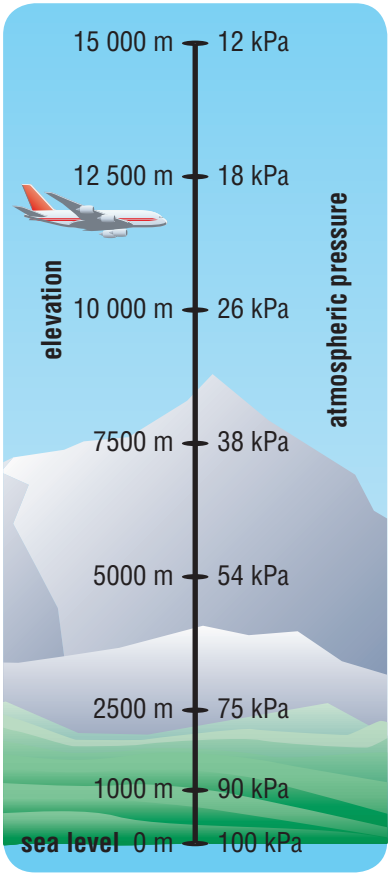

Figure 1 Atmospheric pressure on Earth

atmospheric pressure: the force the atmosphere exerts on a unit of surface area

Air and Water Pressure

Fluids also exert pressure. Earth's atmosphere is approximately 160 km thick, and gravity pulls on every particle of it. Think of a newspaper spread out on your table. It has an area of about 1 m^2 and a weight of about 1 N. So the pressure on the table from only the newspaper is about 1 N/m^2 or 1 Pa. Now consider the weight of all the air directly above that newspaper pressing down on it. **Atmospheric pressure**, or air pressure, is the force exerted by the atmosphere (Figure 1) on the newspaper. It is 100 000 times greater than the pressure caused by the newspaper alone! Atmospheric pressure decreases the higher you ascend, because there is less air above you pressing down.

TRY THIS: Observing Atmospheric Pressure

SKILLS MENU: performing, observing, analyzing

Does atmospheric pressure only press downward? This activity will help you find an answer to this question.

Equipment and Materials: plastic cup; plastic catch basin; file card (large enough to cover the top of the cup); water

1. Fill a plastic cup about three-quarters full of water. Place a file card over the top of the cup.
2. With your hand pressing the card to the cup, turn the cup upside down and hold it over the catch basin.
3. Slowly and carefully remove your hand without disturbing the card. Record your observations.

A. Use the idea of atmospheric pressure to explain what happened.

The Try This activity demonstrates that air pressure acts in all directions. It can apply enough force on the card to keep the water in the glass. Even though water is much heavier than the same volume of air, the force of gravity on the water in the glass was not enough to overcome the force of air pressure pushing up on the card. This is why the water did not fall out.

Like air, water also exerts pressure. When you swim underwater, the water presses on all parts of your body and in all directions. Since water is much heavier than air, it exerts more pressure than does air. In fact, the pressure of deep water is so great that deep-sea divers require much greater protection than scuba divers swimming near the surface (Figure 2). Submarines must have special hulls to keep the pressure of the water from crushing them.

Figure 2 Deep-sea divers must be able to withstand much greater pressure than that experienced by divers closer to the surface.

Pressure and Pascal's Law

Blaise Pascal (1623–1662) was a French mathematician and physicist. Pascal is famous for many theories in mathematics and he developed one of the first mechanical calculators. Pascal also studied the behaviour of fluids and later invented the syringe. Pascal found that when fluids in a container are put under pressure, they push in all directions. That is why balloons bulge when filled or squeezed. **Pascal's Law** states that when pressure is applied from an outside source to a contained fluid, the force is transferred throughout the fluid in all directions (Figure 3). This ability of fluids to transfer force is used in nature and in many human-made devices.

Pascal's Law: states that a force applied to a fluid is distributed equally through all parts of the fluid

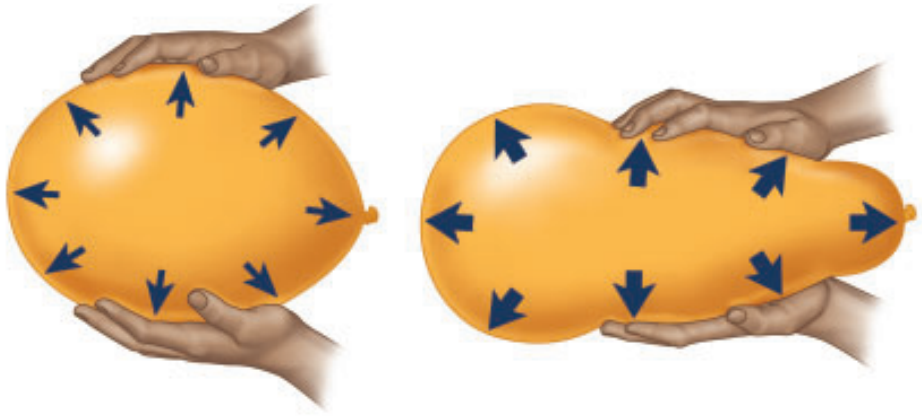

Figure 3 The inward force of the hands is transferred equally in all directions.

Applying Pascal's Law

When you connect two syringes of different sizes together and push on their plungers, you quickly notice two things:

- The plunger in the smaller syringe moves farther than the plunger in the larger syringe.
- The plunger in the smaller syringe is easier to move than the plunger in the larger syringe.

LINKING TO LITERACY

Taking Notes: Main Ideas

Keep your notes short and to the point. To do this, look for the main idea in each paragraph—it is usually the first (or second) sentence. Write the main ideas in point form in your own words.

Figure 4 shows that when the fluid in a small chamber is pushed into a larger chamber, it is spread throughout a bigger volume. This is why the small plunger (or piston) moves much more than the large plunger. However, the force applied to the small piston is transferred to every part of the fluid equally. Since the large piston covers a greater area, the force that the large piston can apply is much greater than the force applied to the small piston.

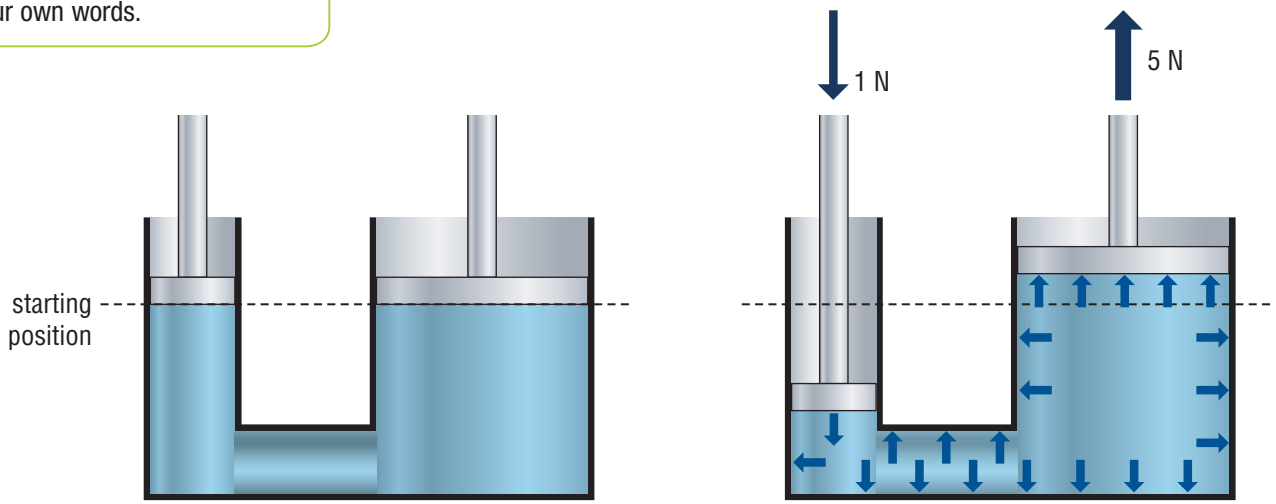

Figure 4 The distance moved by the large piston is always less than the distance moved by the small one. However, since the large piston has an area five times larger than the small piston, the force from the small piston is multiplied five times.

We use Pascal's Law today in devices like hydraulic brakes and heavy equipment. Using the ability of fluids to transfer force, we can control the amount of force applied in a system's mechanisms, as well as the distances moved by the parts of the mechanisms.

Liquids cannot be compressed very much. When you apply force to one part of a hydraulic system, the force transfers immediately to all other parts. Since gases are much more compressible than liquids, pneumatic systems are often used when a "cushioning" effect is desired. For example, many bus and streetcar doors use pneumatic systems. Should something or someone get caught in the door, the door does not squeeze as hard or as quickly as a hydraulic system might (Figure 5).

Figure 5 Many buses and streetcars use pneumatic systems to open and close the doors.

Unit Task Consider whether your toy will work better using a hydraulic system or a pneumatic system.

CHECK YOUR LEARNING

1. What is meant by "pressure" in a scientific sense? What units are used to measure pressure?
2. In your own words, describe atmospheric pressure and water pressure.
3. Describe Pascal's Law in your own words. You may use a diagram to help.
4. Why do deep-sea divers require greater protection than scuba divers?