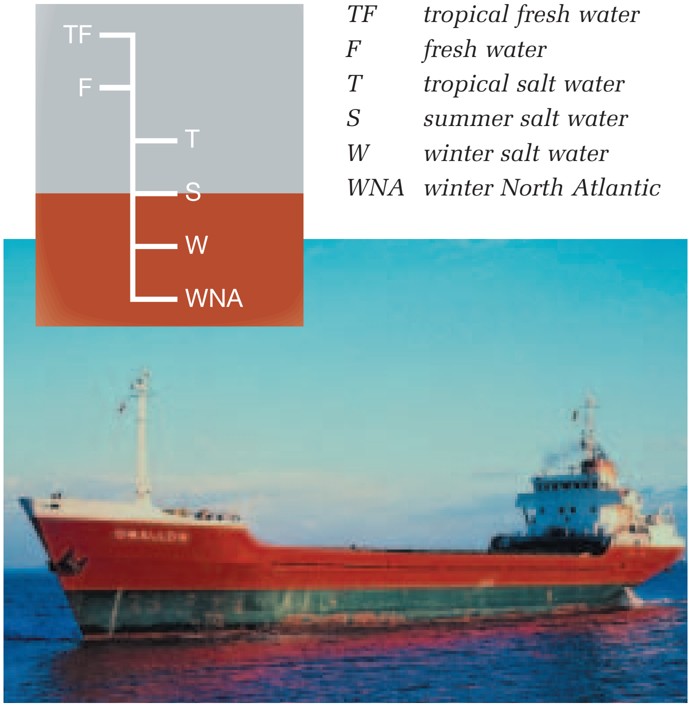
Plimsoll Line

A fully loaded cargo ship sails across the Atlantic Ocean. As it enters the fresh water of the St. Lawrence River, it sinks dangerously low. Why? It sinks because fresh water is less dense than salt water. The ship floats lower in the less dense water. The same thing happens when a ship sails from cold northern water into warm tropical water. Warm water is less dense than cold water.

Because of density variations in the world's oceans and rivers, all cargo ships have what is known as a *Plimsoll line* painted on their hulls. The Plimsoll line shows how heavily a ship can be safely loaded in different water conditions. Look at Figure 3.11. The marks on the left indicate where the waterline should be in fresh water. The marks on the right indicate where it should be in salt water.



Legend

TF	*tropical fresh water*
F	*fresh water*
T	*tropical salt water*
S	*summer salt water*
W	*winter salt water*
WNA	*winter North Atlantic*

Figure 3.11 The Plimsoll line indicates how heavily loaded a ship can be in different densities of water.

Hot Air Balloons

Another transportation technology where buoyancy is important is in hot air ballooning. As the air in the balloon is heated, it becomes less dense than the surrounding air. The buoyant force pushes the balloon up into the air. The balloon stops rising when the buoyant force equals the force of gravity. That's the point when the balloonist stops adding heat to the air in the balloon.

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Airships

Early airships looked something like the Goodyear blimp that flies over sports events, but they were much larger. These airships were called *zeppelins*, after their inventor, Count Ferdinand von Zeppelin. The Graf Zeppelin airship was 236 m long and could travel at 129 km/h.

Find out more about early airships. Why did these balloon-like aircraft have to be so large? Why did the Hindenburg, shown here, go up in flames?

The Hindenburg

Check and Reflect

1. What units are usually used for measuring the density of solids? of liquids?
2. Use the particle model of matter to describe what happens to the density of a substance when it cools.
3. Look at Figure 3.12. Can you spot the mistake in the directions for this water-play air mattress? Explain your answer.

Figure 3.12 Question 3. Air mattress warning tag

TRY This at Home

ACTIVITY

Sink or Swim

You can make your own model of a diver at home using a plastic pop bottle with a cap, water, and an eyedropper.

- Fill a plastic pop bottle about three-quarters full of water.
- Float an eyedropper on the surface of the water.
- Use the cap to seal the bottle tightly.
- Squeeze the bottle with your hands so the sides go in.
- Can you explain what happens?
- What would happen if you used a fluid other than water? Try it and see.

3.4 Compression of Fluids

Another useful property of some fluids is **compressibility**. When a force pushes on an object, the object is said to be under compression. Objects under compression tend to deform in shape. For example, when you kick a soccer ball, the force of your foot compresses the ball and temporarily deforms it, as shown in Figure 3.13. In this example, your foot is actually compressing the fluid (air) that fills the ball.

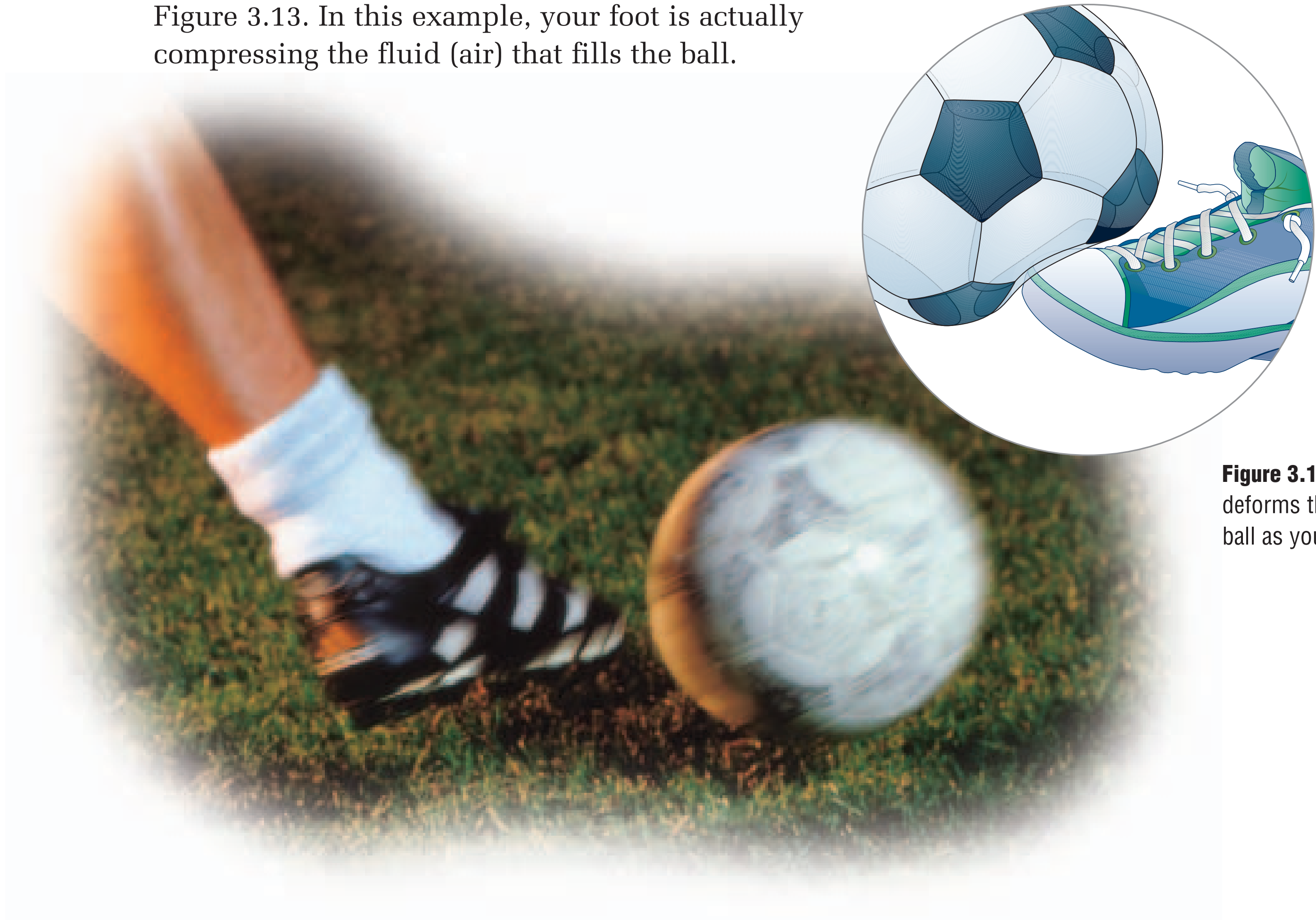

Figure 3.13 Your foot deforms the soccer ball as you kick it.

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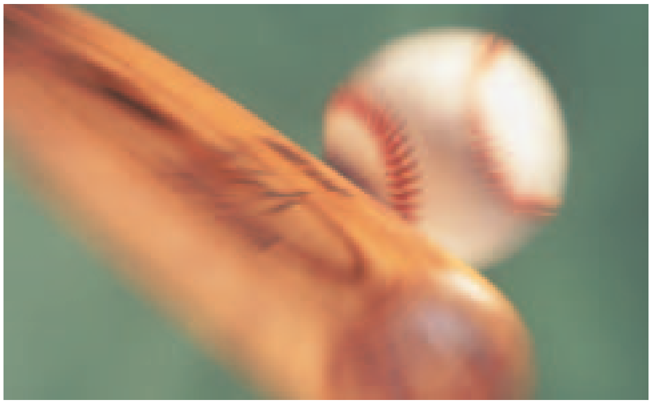
Compressing Solid Objects

A solid object can be compressed if a great enough force is applied to it. The photo shows that the force exerted by the baseball bat on the baseball compresses and deforms the ball.



The effect of a baseball bat on a baseball

Inquiry Activity

Compressing Fluids

Materials & Equipment

Part 1

- 50-mL syringe
- 5 cm of latex tubing
- bulldog clamp
- water
- sink or bowl

Part 2

- 2 burette clamps
- modified 50-mL syringe with platform
- 5 cm of latex tubing
- bulldog clamp
- support stand
- 4 1-kg masses
- water
- empty container

Figure 3.14 Step 1. The plunger should be three-quarters of the way up the tube.

The Question

What happens to air as it is compressed? Does water react in the same way?

Procedure

Part 1 Compressing Air

1. Attach the latex tubing to the end of the syringe. Place the plunger of the syringe three-quarters of the way up the tube. Seal the tubing at the end of the syringe with the bulldog clamp.
2. Before you press the plunger down, predict how far the plunger will go. Record your prediction. Test your prediction.
3. Press down the plunger and record the change in volume in the syringe.
4. Unclamp the tubing, and place the syringe in a sink or bowl of water. Pull up the plunger to draw in water until the syringe is filled to the same level as in step 1. If you get air in your syringe, turn the syringe upside down so the plunger points downward. Allow the air to rise to the top of the syringe. Then gently push the plunger up until all the air has escaped. Add more water if necessary. Clamp the end of the tubing shut.
5. Before you press the plunger down, predict how far you think the plunger will go. Record your prediction. Test your prediction.
6. Press down the plunger and record the change in volume in the syringe.

Part 2 Compressing Water

7. Use the burette clamps to attach a modified syringe (with platform) to a support stand, as shown in Figure 3.15.
8. Attach the latex tubing to the end of the syringe. Pull the plunger to the 50-mL mark. Seal the tubing with the bulldog clamp.
9. Place a 1-kg mass on the centre of the platform that is attached to the syringe. (This applies a 10-N force.) Measure and record the volume of air in the syringe.
10. Repeat step 9 by adding another 1-kg mass so that you have a 2-kg mass (a 20-N force).
11. Repeat step 10 for the following masses (forces): 3 kg (30 N) and 4 kg (40 N). Place the masses in the centre of the platform.

Figure 3.15 Step 7. Be sure to follow safe work procedures. Clamp the syringe tightly at right angles to the stand.

12 Remove all the masses.

13 Remove the syringe from the burette clamps and place it in a sink or bowl of water. Fill the syringe to the 50-mL mark by pulling on the plunger, not the platform. Remove any air bubbles as before. Reattach the syringe with the burette clamps. Place an empty container under the syringe. Repeat steps 9, 10, and 11.

14 Clean and return your equipment to the appropriate location.

Collecting Data

Part 1

15 Record your predictions in your notebook.

16 Record the volume in the syringe before and after you push down the plunger.

Part 2

17 Record your data in a table like the one shown below.

Force Acting on Fluid in Syringe (N)	Volume of Air (mL)	Volume of Water (mL)
0		
10		

Analyzing and Interpreting

18 How did your predictions compare with your results?

19 Which fluid compressed more? Why do you think this happened?

20 How did the force affect the compression of the air and the water?

21 Draw a line graph of the compression of the air and water from Part 2 using a different colour for each. Put the volume on the vertical axis, and the force on the horizontal axis.

Forming Conclusions

22 Use the particle model to explain what happened when you compressed the air and the water. Focus your explanation on the differences in the amount of space between particles in air and water. Use your observations, and remember to refer to your graph to support your explanation.

Applying and Connecting

The property of compressibility in fluids is useful to other living things, besides humans. For example, starfish move by filling their tube feet with water.

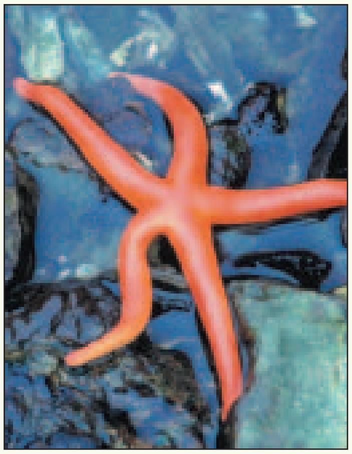


Figure 3.16 Starfish

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Engine Compression
Find out why compression is important in a car's engine.

Differences in Compressibility between Gases and Liquids

One of the properties of fluids is that gases can be compressed much more than liquids can. Think about squeezing a sealed plastic bottle when it's full of juice and then when it's empty. How much more can you compress it when it's empty than when it's full? The particle model can explain this situation. Figure 3.17 shows that there is much more space between particles in the gas than between those in the liquid.

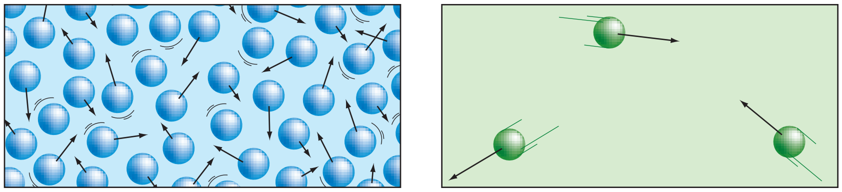

Figure 3.17 There is much more space between particles in a gas than there is between particles in a liquid.

As a result, when a force is applied to the particles, much more compression takes place in the gas than in the liquid. The gas particles have more space to move. In fact, very little compression occurs in liquids. Materials in a liquid state are said to be **incompressible**; that is, they cannot be compressed easily. This property of liquids is very useful. Can you think of any situations where it would be used?

Check and Reflect

1. Use the particle model to explain the differences in compressibility between liquids and gases.
2. Use your explanation in question 1 to identify which material in each pair below would compress more than the other. Provide a brief reason for each answer.
   a) a helium balloon or a water balloon
   b) a solid rubber bicycle tire and an inflated mountain bike tire
   c) plastic bubble-wrap or a liquid-filled baby's teething ring
   d) a golf ball or a soccer ball

3.5 Pressure in Fluids—Pascal's Law

Fluids can be very useful in helping us perform tasks because of the way they transmit pressure. For example, you may already know something about hydraulics and pneumatics, where fluids are used in devices. In this subsection, you'll learn why this property makes fluids so useful.

An important part of understanding how to use fluids in devices is knowing the relationship between force, area, and pressure. **Pressure** is the amount of force applied to a given area. It is measured in pascals (Pa). A pascal equals the force of 1 N (newton) over an area of 1 m^2 ($1 \text{ Pa} = \frac{1 \text{ N}}{1 \text{ m}^2}$). The more force you can apply to a given area, the greater the pressure. You can write this relationship as an equation: $p = F/A$, where p is pressure, F is force, and A is area.

Here is an example of how to calculate pressure. You have a force of 10 N on an area of 2 m^2. What would the pressure be?

$$\text{Pressure } (p) = \frac{\text{Force } (F)}{\text{Area } (A)} = \frac{10 \text{ N}}{2 \text{ m}^2} = \frac{5 \text{ N}}{\text{m}^2} = 5 \text{ Pa}$$

Look at the examples of pressure measurements in the *info*BIT on this page. They are all in kilopascals (1 kPa = 1000 Pa). Scientists use kilopascals because 1 Pa is a very small amount of pressure. It's about the amount of pressure exerted on your desk by a small sheet of paper lying on it. Note that pressure can also be measured in newtons per square centimetre (N/cm^2).

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Examples of Pressure

- The average air pressure at sea level is 101.3 kPa (kilopascals).
- The jaws of an ant exert a pressure of 0.005 kPa.
- A ballet dancer standing on the toes of one foot exerts a pressure of 2500 kPa on the floor.

Blaise Pascal Investigates

In the mid-1600s, the French mathematician Blaise Pascal was curious about how pressure is exerted in a fluid. In one of his first experiments, he investigated the relationship between water pressure and depth. Look at Figure 3.18, showing water flowing out of two holes at the same level in a can. Working with a partner, develop an explanation for what you observe. Use the following words in your explanation: *pressure*, *sides of the can*, *force*, *equal*, and *depth*. Be prepared to share your explanation with your class.

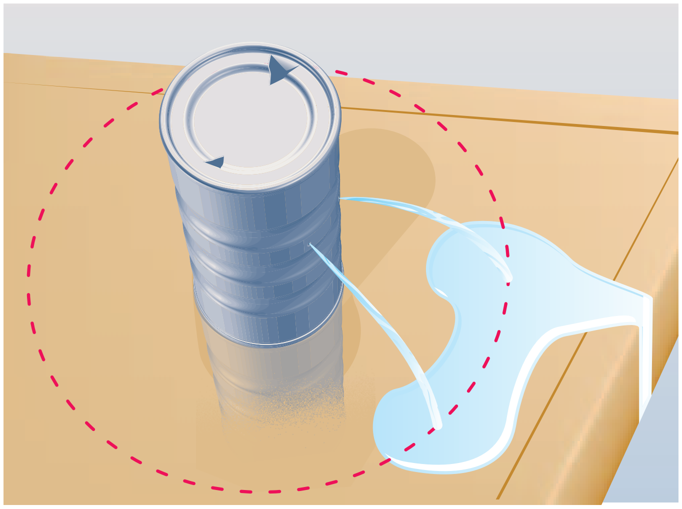


Figure 3.18 Why does the water flow out of the can in this way?

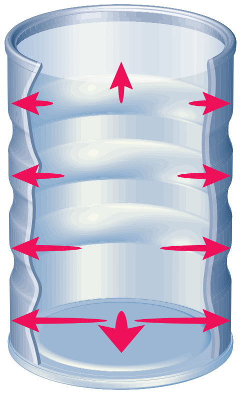


Figure 3.19 The water exerts pressure in all directions in the container.

Pressure and Depth

From Figure 3.18, you and your class may have determined that the pressure of the water on the sides of the can was equal at the same depth. You could infer this because the water that came out of the holes travelled the same distance outward before hitting the ground. This observation leads to another question: How does pressure change as the depth of the water changes? What do you think would happen if you put holes in the can at different depths?

The Greater the Depth, the Greater the Pressure

In the introduction to this subsection, you saw that pressure forced water out of holes in a container. The water was exerting pressure on the walls of the container. The weight of water in the upper part of the container also pressed down on the water in the lower part of the container. The more water above a hole, the greater the pressure, and the farther water will flow out of the container. So, the greater the depth of water, the greater the pressure at that point.

Pascal's Law

Pascal continued his investigations into pressure by studying enclosed fluids. He wondered what would happen if a force was applied to a fluid in a closed system. Through experimentation, he found that the force created pressure that was transmitted equally in all directions throughout the fluid. He developed a law to describe his observations. **Pascal's law** states that an enclosed fluid transmits pressure equally in all directions. The examples of applications of Pascal's law below will help to explain it further.

Hydraulic Devices

Pascal's discovery of this law led to the invention of many different types of hydraulic and pneumatic devices. **Hydraulic systems** use a liquid as the enclosed fluid. **Pneumatic systems** use air. Figure 3.20 shows a hydraulic device that is used for lifting cars. You may have noticed these in car repair garages. Such a device uses two pistons of different sizes to create pressure and to lift the car. A piston is a disk that moves inside a cylinder. The small piston is the input piston, which pushes down on the liquid to create pressure. This pressure is then transmitted through the liquid where it pushes up on the large piston, which is the output piston.

Recall that pressure equals force divided by area ($p=F/A$), and look at Figure 3.20. You can see that the output piston has a much larger area than the input piston does, but the pressure is the same everywhere in the system. So, because $p=F/A$, the force of the larger piston is greater than the force of the smaller piston.

The area of the output piston in this example is 16 times larger than the area of the input piston. The result is an output force 16 times greater than the input force—a force strong enough to lift a car! One of the benefits of a hydraulic system is that it can multiply force. However, to move the large piston, the small piston must move much farther that the large piston does. You will learn more about hydraulic systems in Unit D: Mechanical Systems.

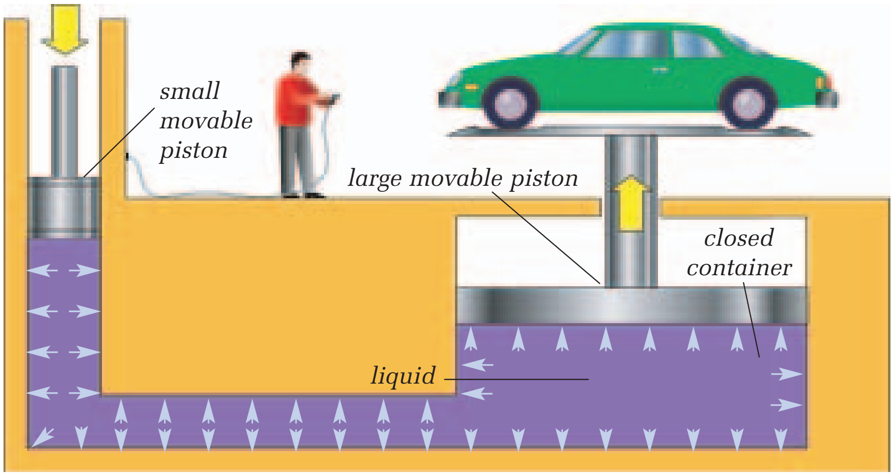
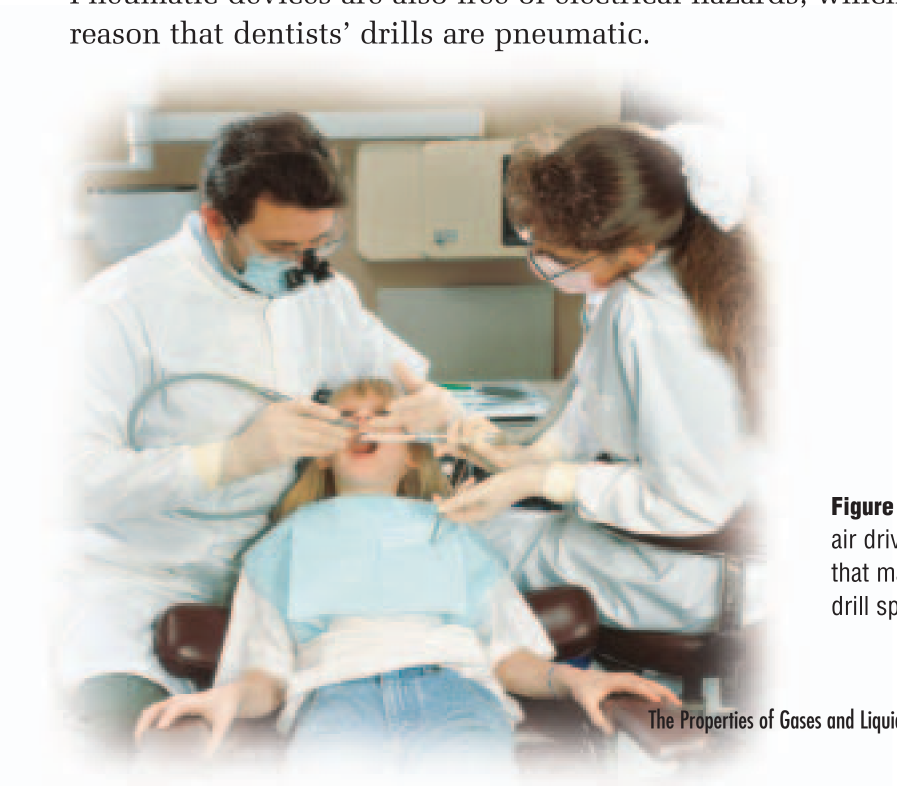


Figure 3.20 A car lift or hoist. The arrows in the liquid indicate the pressure transmitted throughout the system. Hoists are used in repair garages so that mechanics can work under cars more easily.

Pneumatic Devices

Pneumatic devices use compressed air to do tasks. Dentists' drills, jack hammers, paint sprayers, and air brakes on trucks are all examples of pneumatic devices.

Reasonable cost and safety are two advantages of pneumatic systems. Compressed air is cheap and safe, as the devices do not create sparks within the system. This can be important if you are working in a mine where a spark could cause an explosion. Pneumatic devices are also free of electrical hazards, which is one reason that dentists' drills are pneumatic.



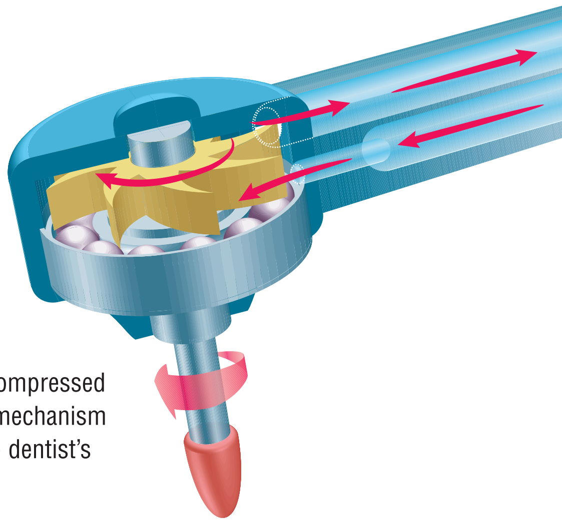


Figure 3.21 Compressed air drives the mechanism that makes the dentist's drill spin.

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Ultrahigh-Pressure Water Systems

An ultrahigh-pressure water system forces water out of a hose at 275 000 kPa of pressure. This water jet can be used for cleaning, blasting, cutting, and processing materials. Using the library or the Internet, research applications of ultrahigh-pressure water systems.

Maintaining the Pressure

For a pneumatic or hydraulic system to function properly, the entire system must be completely sealed. Even the smallest hole or leak can cause the system to fail. For example, cars have hydraulic brakes. If there is a leak in the hydraulic line, the brakes can fail. Pneumatic bus doors also depend on a sealed system, so that the door can open and close. A leak in the system allows air to escape. This loss of pressure means that the system can't generate enough force to close the door if it's already open, or to open the door if it's already closed!

Figure 3.22 Pneumatic systems are used for bus doors and for brakes in large vehicles like buses and trucks.

Check and Reflect

1. Describe how pressure is transferred in a fluid.
2. If 10 N of force is applied to an area of 1 m^2, what is the pressure?
3. What is the difference between a hydraulic and a pneumatic system?
4. A hydraulic lift has 1000 N applied to an input piston that has an area of 30 cm^2.
   a) What is the pressure exerted on the liquid by the input piston?
   b) If the force were doubled, what would be the pressure?
   c) If the area were reduced to 15 cm^2, what would be the pressure?

Assess Your Learning

1. What is viscosity? Why is it an important property?
2. Use the particle model to describe why ketchup is more viscous than liquid dish soap.
3. How does temperature affect the viscosity of a fluid?
4. What does density measure?
5. Describe how you find the density of an object.
6. a) What is the density of a shampoo if 13.2 g of the shampoo fills a 5-mL container?
   b) What is the density of vegetable oil if 50 g of the oil has a volume of 8 mL?
   c) What is the density of gasoline if 90 mL of it has a mass of 62 g?
   d) If you had 50 mL of each of these substances, which one would have the least mass?
7. How does the particle model of matter help you explain why cold water is denser than hot water?
8. Why does a liquid compress much less than a gas does?
9. Describe Pascal's law and give one example of its application.
10. A full juice can has a hole at the top and another hole near the bottom. How will the juice flow out of the two holes? Why is there a difference?
11. How does a car lift work? What problems does a car lift solve?

Focus On SCIENCE AND TECHNOLOGY

Any scientific investigation or technological development leads to new questions and problems. Think back to the information you learned and the activities you did in this section.

1. After learning about viscosity, what two new questions do you have about this property of fluids?
2. Identify one problem you encountered in this section and describe how you solved it.
3. At the end of the unit, you will do a project to design a soft drink with a grape floating in it. What did you learn about density that would help you float the grape?

4.0 Many technologies are based on the properties of fluids.

Key Concepts

In this section, you will learn about the following key concepts:

- properties of fluids
- fluid technology applications

Learning Outcomes

When you have completed this section, you will be able to:

- describe examples of technologies based on solubility
- describe examples of technologies based on flow rates and moving fluids
- explain how to design and construct a working model of a fluid-using device

In this unit, you have had an opportunity to learn about the properties of fluids. Now it is time to look at some applications of this knowledge. Applied scientific knowledge results in new technologies. Technology includes devices, systems, and processes that meet people's needs or wants. In this section, you will explore technologies that meet needs to keep things clean, cure "the bends," move fluids, and explore uncharted waters where humans have never gone before.

For Web links relating to 4.0, visit **www.pearsoned.ca/scienceinaction**

4.1 Technologies Based on Solubility

While you are eating a hamburger, a glob of mustard falls on your favourite jeans. This could be a disaster but you're sure that the laundry detergent will get the stain out. What is it about detergents that give them their special cleaning power?

A *detergent* is a substance that can remove dirt from fabric. Most detergents are liquids or powders that can dissolve in water. Detergents contain a cleaning agent called a *surfactant*. Surfactants are particles that attach themselves to dirt and oil particles, separating them from fabric or other material. Figure 4.1 illustrates this process.

How Detergent Works

Dirt and grease on fabric

The mixture of water, detergent, and clothes is agitated in the washing machine. Dirt breaks off from the clothes.

Surfactants in the detergent surround the dirt particles so they can't re-attach to clothes.

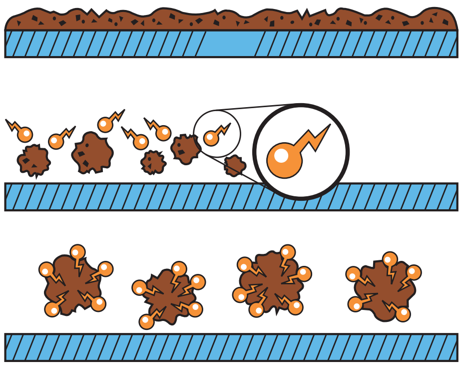

Figure 4.1 Detergents use surfactants to carry away dirt.

In the past, manufacturers added chemicals called *phosphates* to detergents. Phosphates made detergents work better in hard water. However, the phosphates damaged the environment by polluting the water. Today, most detergents do not include phosphates.

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Ingredients in a Typical Laundry Detergent

Ingredient	What It Does	Ingredient	What It Does
surfactant	*cleans clothes*	*builder*	*softens water to help surfactant clean*
filler	*stops detergent from clumping*	*corrosion inhibitor*	*prevents washer from rusting*
suspension agent	*stops dirt from re-attaching to material*	*enzyme*	*removes protein stains*
bleach	*removes stains*	*optical whitener*	*adds brightness*
fragrance	*adds scent*	*colouring agent*	*gives detergent colour*

Inquiry Activity

Cleaning Solvents

Materials & Equipment
- 3 250-mL beakers
- water (at room temperature)
- rubbing alcohol (at room temperature)
- vinegar (at room temperature)
- graduated cylinder
- 3 identical pieces of fabric
- mud
- lipstick
- chocolate
- laundry detergent
- pair of forceps or tweezers

Figure 4.2 Step 4. Swirl the fabric around in each solution using the forceps.

The Question
Which solvent is best for removing stains from clothing?

The Hypothesis
Write a hypothesis that predicts which solvent in this inquiry activity works best at removing stains.

Procedure
1. Pour 50 mL of water into one beaker, 50 mL of rubbing alcohol into another beaker, and 50 mL of vinegar into a third beaker. Label the beakers.
2. Predict which solvent will be best for removing stains.
3. Mark each piece of fabric with mud, lipstick, and chocolate.
4. Place one piece of soiled fabric into each beaker. Swirl the fabric around in each solution using the forceps. Leave for at least 10 min. Look at the stains.
5. Add some laundry detergent to the beaker containing water. Use the forceps to swirl the fabric around in the solution. Leave for at least 10 min. Look at the stains.

Collecting Data
6 Make a chart of your observations.

Analyzing and Interpreting
7 Did the mud dissolve in each solvent? Explain.

8 Did the lipstick dissolve in each solvent? Explain.

9 Did the chocolate dissolve in each solvent? Explain.

10 Did the detergent help the water dissolve the stains?

Forming Conclusions
11 Describe the results from your investigation. Conclude which solvent did the best cleaning job for each type of stain and which did the worst job. Support your conclusions with your data. Also, include one new thing you learned in this activity that you didn't know before.

Applying and Connecting
Canadian researchers have been at the forefront of developing environmentally friendly inventions. Ragui Ghali of Ontario invented Spil-Kleen. Made from old phone books, Spil-Kleen soaks up water, and cleans up oil spills.

Extending
Make a cleaner by mixing 50 mL of baking soda in 4 L of water and adding 125 mL of vinegar. Create a fair test to compare the cleaning ability of your home-made cleaner with that of store-bought brands.

Diving and Decompression

People are able to dive deep below the surface of oceans and lakes because of an invention that uses fluids. SCUBA stands for Self-Contained Underwater Breathing Apparatus. It consists of air tanks and regulators to maintain the flow of air. Another fluid-based technology helps us deal with the stress on our bodies of deep dives.

At greater water pressures, nitrogen gas dissolves in our blood and tissues at a much higher concentration than normal. If a diver ascends slowly to the surface, the extra gas leaves the body gradually as the water pressure decreases.

A problem arises when the diver ascends too quickly, so that the pressure decreases rapidly. Decompression sickness, called "the bends," can result. The sudden change in pressure causes nitrogen gas to bubble out of the blood and tissues. These bubbles can collect in other body parts and cause considerable pain. Death can occur if the condition is left untreated.

One treatment for "the bends" is to place the affected diver in a special chamber. This chamber increases the pressure surrounding the diver's body. The greater pressure forces the gas bubbles to re-dissolve back into the blood and tissues. By very slowly decreasing the pressure back to normal, the gas slowly leaves the body.

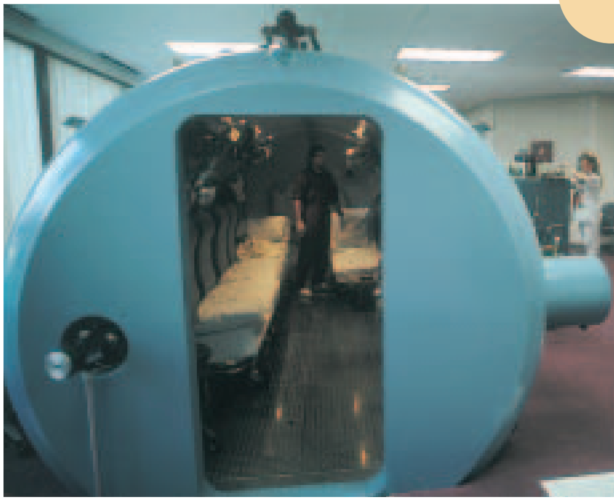

Figure 4.3 This person is in a hyperbaric chamber to cure a case of "the bends." *Hyperbaric* means high pressure.

Check and Reflect

1. Describe one new thing you learned about cleaners.
2. How does a detergent remove a stain?
3. The following statements were taken from an advertisement for laundry detergents. What ingredients are being emphasized?
   a) "Now brighter and whiter than ever."
   b) "Cleans your washing machine as it cleans your clothes."
   c) "Removes the toughest stains."
   d) "Now in new ocean mist scent."
4. What do divers need to know about solubility?

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Dry Cleaning

What is dry cleaning? Find out how clothes are dry-cleaned and what happens to the chemicals after they are used.

4.2 Technologies Based on Flow Rates and Moving Fluids

Imagine having to move a fluid from one place to another. Maybe you are putting air in a basketball. Or maybe you want to filter the water in your aquarium. What would you use?

For both examples, you probably thought that a pump would be the solution. What exactly is a pump and how does it work? A **pump** is a device that moves a fluid through or into something. To fill up your basketball, you use a pump to force air into the ball. Your aquarium pump moves water through a filter to clean it and add air. Pumps also exist in nature. The most important one to you is your heart—it pumps blood through your body.

Two Types of Pumps—Diaphragm and Archimedes Screw

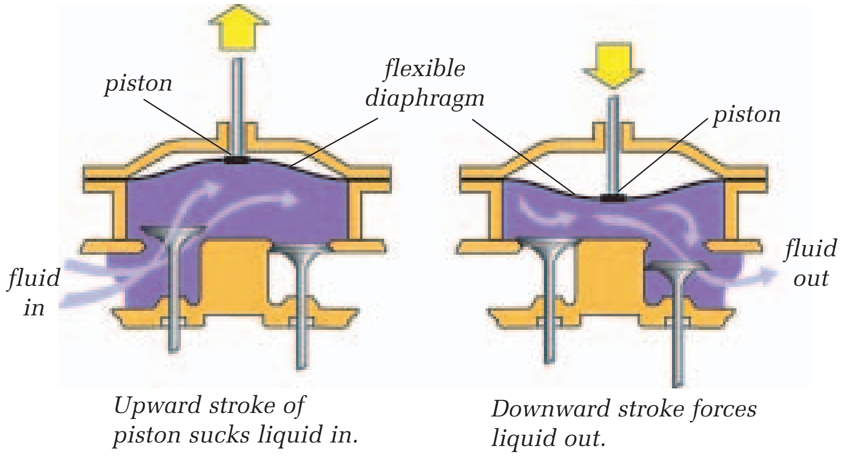

Figure 4.4 Diaphragm pumps are used for both liquids and gases, such as the air pumped into this aquarium.

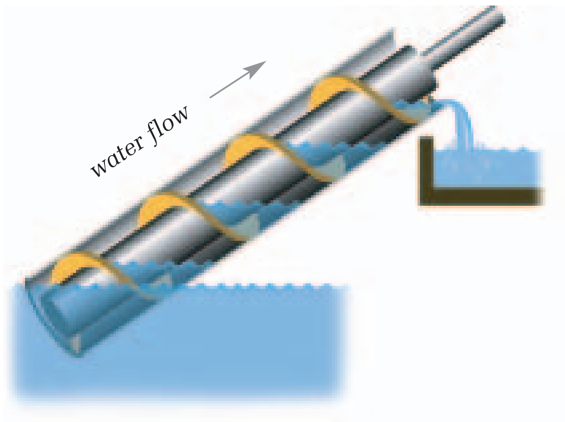

Figure 4.5 The Archimedes screw is a pump supposedly invented by Archimedes to remove water from the hold of a ship. Here it is used as a sand washer on a construction site.

The Bicycle Pump

There are many different kinds of pumps, but one of the most common is the bicycle pump. This kind of pump has a piston that moves up and down in a cylinder. When you pull up the piston, air fills the cylinder. By pushing down on the piston, you apply a force to the air in the cylinder. This compresses the air. The pressure of the air in the pump therefore increases. If the opening at the bottom of the cylinder is connected to an area of lower pressure, the air will move to that area. For example, the area of lower pressure could be a flat bicycle tire or an uninflated soccer ball.

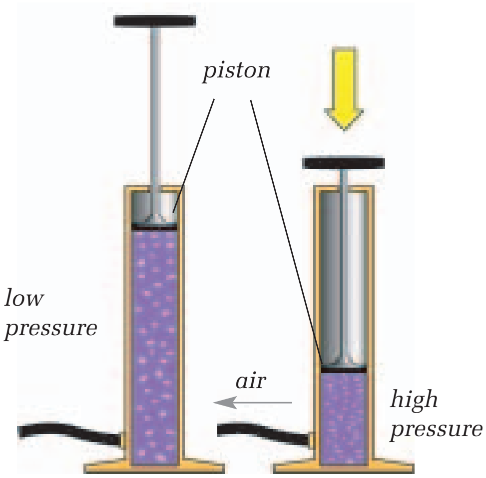

Figure 4.6 When force is applied to the air in the cylinder, the pressure increases.

Pipeline Pigs

The oil and natural gas that we depend on for heat and transportation move across the country in bulk through pipelines. Pumps push these fluids along at a steady rate. In large natural gas pipelines, the pressure of this flow is used to help keep the pipeline clean to ensure a clean fuel supply. A computerized unit called a "pig" is placed in the pipeline and pushed through it by the moving gas. The "pig" cleans the pipe with brushes as it moves through. At the same time, the "pig's" sensors check the pipe and record its condition so any necessary repairs can be made.

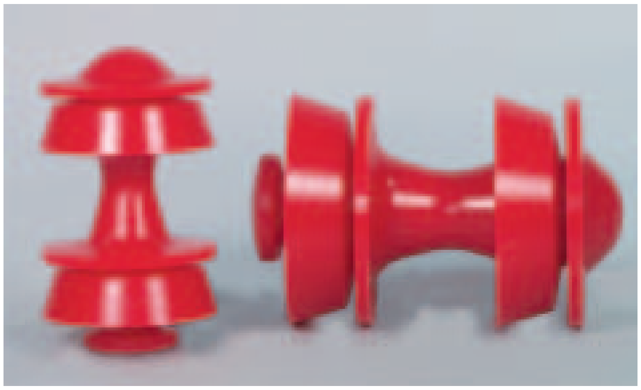

Figure 4.7 A pipeline "pig" relies on the flow of the fluid to move it through the pipeline.

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Oil Sands Production

The oil in the oil sands is a thick, viscous substance called *bitumen*. One method of extracting bitumen uses two wells. Steam is pumped down one well to heat the bitumen in place. The heated bitumen now has a lower viscosity, so it flows into the other well. It is pumped out of there and sent for processing.

*re*SEARCH

Artificial Hearts

Doctors and engineers have been working for many years to develop artificial hearts that will help save lives. Find out how valves and pumps are being used in this technology.

VALVES

Valves are an important part of any system for moving fluids. They are devices to control or regulate the amount of flow, like the valves in your bathroom taps. Turning your tap one way allows water to flow out. Turning it the other way closes off the flow of water. Valves can also be used to control the level of fluid in a container, like the valve in the toilet tank. The float in the toilet tank is connected to a valve that closes off the flow of water when the water reaches the right level. That's why your toilet tank doesn't overflow when you flush the toilet. Two other kinds of valves are shown in Figures 4.8 and 4.9.

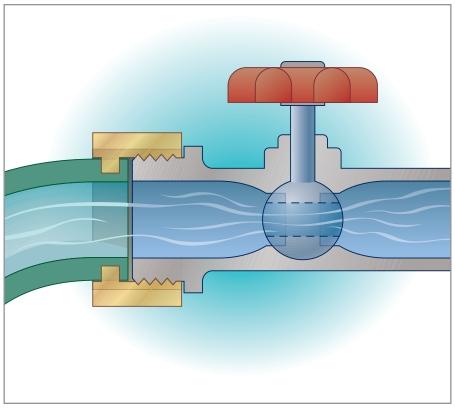


Figure 4.8 A ball valve works by turning. In one direction, it allows water to flow through. If you turn it in another direction, it stops the flow. This ball valve is in a hose.

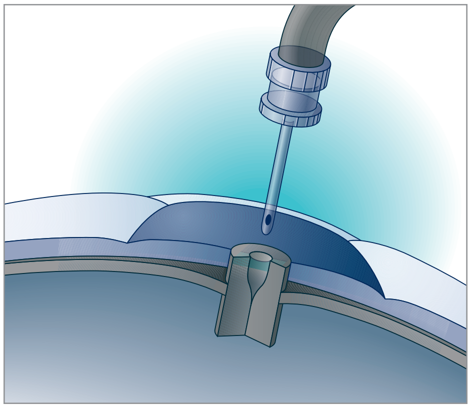


Figure 4.9 This type of valve allows you to inflate a ball, but also keeps air from leaking out. To open the valve, you insert a hollow pin. You inflate the ball by pumping air through the pin. You deflate the ball by allowing air to escape through the pin.

CHECK AND REFLECT

1. List and describe the different types of pumps you have read about.
2. Look at the drawing of the hand pump in Figure 4.10. How does the particle model help to explain how a hand pump operates?
3. Identify the different functions of valves. Give one example of a valve application that has not already been mentioned.

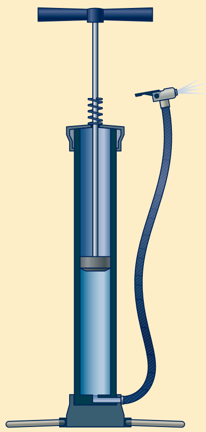


Figure 4.10 Question 2. A hand pump

4.3 Designing a Working Model of a Fluid-Using Device

How could an understanding of the properties of fluids help you go to the deepest spot on the planet? This spot is about 11 000 m below sea level in the Marianas Trench in the Pacific Ocean, about 330 km south of Guam. Humans cannot dive this deep by themselves because the pressure is too great. To go this deep, you need an underwater ship called a *bathyscaph*. The name comes from the Greek words *bathos* for "deep" and *scaphos* for "ship." The Swiss scientist Auguste Piccard invented the bathyscaph and called his vessel the *Trieste*.

Since the *Trieste*, many different types of submersible exploration ships have been designed and built. One example is the Canadian submersible called the Remotely Operated Platform for Ocean Science (ROPOS) shown in Figure 4.12.

infoBIT

Changing Buoyancy Naturally

Most fish use a swim bladder to change their buoyancy. This is a gas-filled sac found just under the backbone. Dissolved gases in the fish's blood move into the sac to give it greater buoyancy. The swim bladder empties when the fish wants to dive deeper.

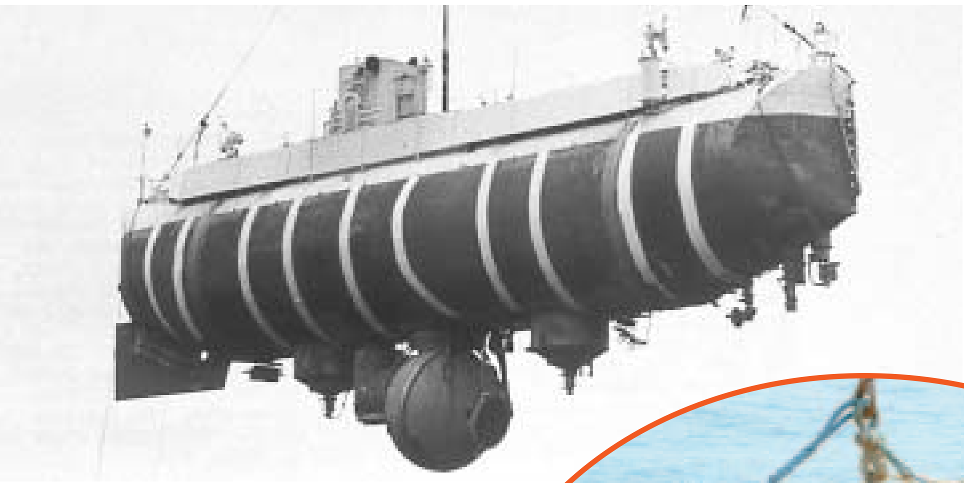


Figure 4.11 The bathyscaph *Trieste* made it to the bottom of the Marianas Trench in 1960. A bathyscaph consists of a large float with a metal sphere underneath. The sphere is where the people sit.

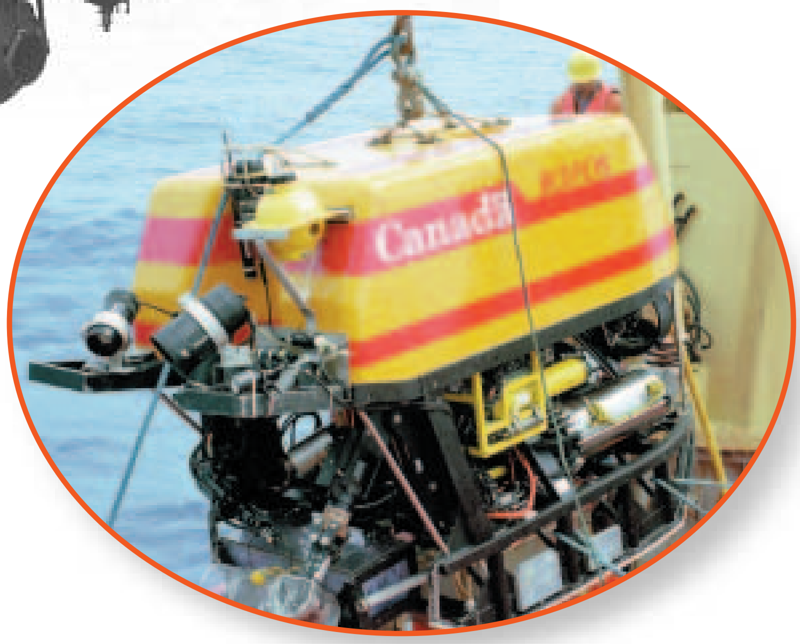


Figure 4.12 This submersible robot ROPOS is equipped with two robotic arms and can dive to 5000 m.

Problem Solving Activity

DIVING DEEPLY

Recognize a Need

At the cottage, your cousin drops a precious gold necklace into the lake. It disappears into about 5 m of murky water.

The Problem

Create a model of a bathyscaph that could carry a battery-operated video camera to the bottom of the lake to search for the necklace.

Criteria for Success

For your model to be successful, it must meet the following criteria:

- solve the problem described above
- be designed first on paper
- be built and tested as a prototype
- be made of common materials
- be controlled from the surface so it can travel to the bottom and back to the surface by a transfer of fluid from or to it
- be watertight
- be usable more than once

Brainstorm Ideas

1 You will be working in teams. As a team, brainstorm possible solutions to the problem. Once you have several solutions, choose the one you think will work the best to meet the above criteria.

Build a Prototype

2 Create a plan for how you will build your bathyscaph. Include a diagram of the bathyscaph and a list of materials you require. Show your plan to your teacher for approval.

3 Assemble your materials and build your prototype. Remember that you may need to modify or change your design as you build your prototype. Make sure to note any changes you make to your original design.

Figure 4.13 Step 3. Assemble your materials and build your prototype.

Test and Evaluate

4 Once you have built your prototype, test it to see if it meets the criteria. After your test, you may need to make some modifications or changes to the bathyscaph and retest it.

Communicate

5 What do you have to do to make the bathyscaph go up and down in the water?

6 Would this model work in the lake or would you have to make further modifications? What would they be?

How a Submarine Works

How does a submarine move up and down in the water? A submarine moves through three stages in the water: floating on the surface, diving, and re-surfacing. Figure 4.14 shows how a submarine operates. Notice that the submarine has air tanks called *ballast tanks* between the inner and outer hulls of the submarine. The submarine also carries compressed air in tanks to help it re-surface.

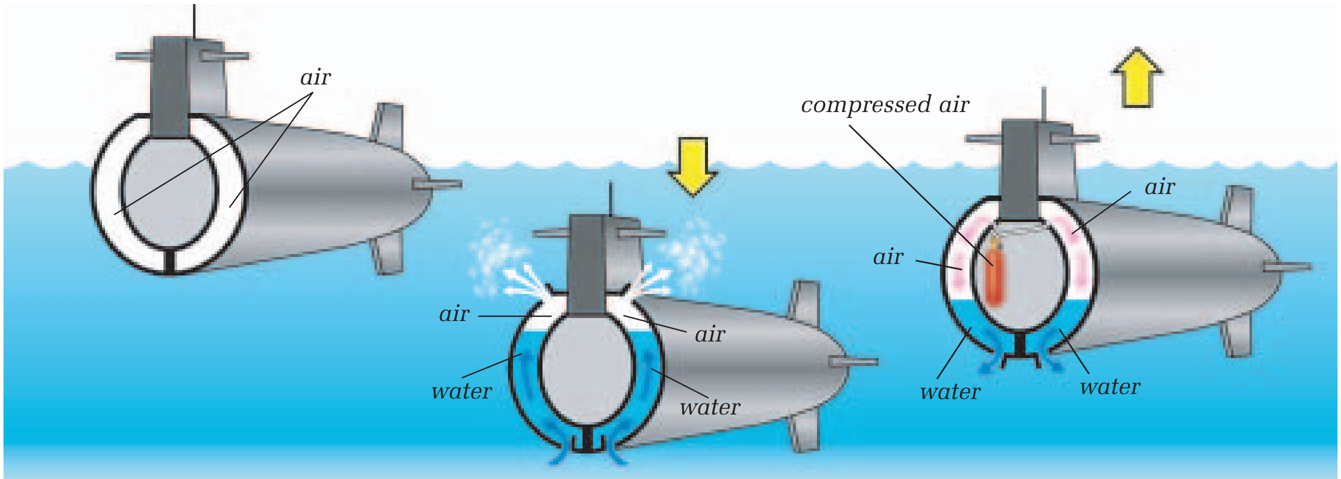


Figure 4.14a) On the Surface. When the submarine is on the surface, its ballast tanks are full of air. The average density of the submarine is less dense than the density of the water, and it floats.

Figure 4.14b) Diving. To dive, the submarine releases air from the ballast tanks through valves on the top of the tanks. Other valves at the bottom of the tanks open and allow seawater to enter. The density of the submarine with seawater in the tanks becomes greater than the density of water outside, so the submarine begins to sink.

Figure 4.14c) Re-surfacing. To surface, compressed air is forced into the ballast tanks through the valves at the top. This forces the seawater out of the bottom valves. The density of the submarine with air in the tanks becomes less than the density of the water, so the submarine rises to the surface.

Check and Reflect

1. What is a bathyscaph?
2. What is the difference between a bathyscaph and a submarine? Hint: Read the caption for Figure 4.11.
3. Describe how a submarine can stay underwater and then move up to the surface.

Experiment ON YOUR OWN

Design and Build a Hydraulic or Pneumatic Elevator

Before You Start ...

One of the most common ways to move people or things up and down is an elevator. Primitive elevators existed as early as the 3rd century B.C., but elevators were put into buildings only in the 1800s. These early devices were powered by steam engines or operated with a hydraulic system. Their use was limited because of safety concerns. The main concern was that the rope or cable lifting the elevator could snap. This changed when an inventor named Elisha Graves Otis developed a "safety elevator" in 1852.

By the late 1800s, motors began to replace hydraulic systems in elevators. Today, the limitations of an elevator are more human than technological. Some people feel sick if an elevator moves too fast.

Other types of elevators or lifts include hydraulic ladders, such as those on firetrucks, which you saw earlier in this unit, and hydraulic cherry pickers on repair vehicles.

Now you'll have an opportunity to design your own hydraulic or pneumatic elevator.

Figure 4.15 Elisha Graves Otis and his "safety elevator"

The Question

What would you have to do to design and build a hydraulic or pneumatic elevator that could lift a golf ball 30 cm?

Design and Conduct Your Experiment

1 Working by yourself or in a small group, generate possible ideas on how you could design your device.

2 Create a plan for how you will build your device. Include a detailed sketch of your device and a list of equipment you will need. Show your plan to your teacher for approval.

3 Build your device. Be prepared to demonstrate how your device works to your class.

4 Compare your device with others in the class. How successful were the other devices?

Figure 4.16 A cherry picker makes it easier for workers to do tasks in high places where they need to be able to use both hands.

Section Review

Assess Your Learning

1. How can a detergent clean grease off clothes?
2. If you had a beaker of water, a beaker of rubbing alcohol, and a beaker of vinegar, describe how you would construct a fair test to determine which liquid was the best cleaner.
3. What is a pipeline "pig," and how does it move?
4. Describe a technology that uses pressure to change the solubility of gas.
5. Describe three uses of pumps.
6. What are two major uses of valves?
7. How does a bathyscaph work?
8. Identify one industry that uses the properties of fluids.

Focus On Science and Technology

Technological problems often lend themselves to more than one solution. These solutions may involve different designs, materials, and processes. Think back to what you learned in this section.

1. What examples did you encounter of multiple solutions to a problem?
2. Was one solution better than the others?
3. How did you know when you had a solution that would work in your own activities?

The Alberta Oil Sands Deposits

The Issue

The oil sands have important benefits and potential costs to everyone living in Alberta. What do you think these benefits and costs are? Read the background information below and use the "Go Further" suggestions in the next column to find out more.

Petroleum was once called "black gold" because of both its dark colour and its high value. It made its finders rich because of its importance as a source of energy. Today, petroleum products flow into homes as heating oil, into cars and trucks as gasoline and diesel fuel, and onto roads as asphalt. Petroleum is also used to make plastics.

The first commercial oil wells were developed in the 1850s. Since then, people have been looking for and finding this valuable fluid all over the world. Alberta has been a petroleum producer since the 1940s. It is also home to the largest oil sands deposits in the world.

Oil sands deposits in Alberta. The largest deposits are in the Athabasca region.

The oil sands deposits are unique because they are a mechanical mixture. The sand particles are coated with a thick, tar-like substance called *bitumen* and small amounts of water. Unfortunately for the oil industry, bitumen isn't useful for anything except paving roads. In the early 1900s, some Edmonton streets were paved with oil sands.

The oil sands contain an estimated 1.7 trillion barrels of oil—more oil than all the world's known oil reserves combined. However, getting the oil out of the ground and refining it have not been easy.

Only about 18% of the oil sands within 50 m of the surface can be recovered with today's technology. Even so, almost 20% of Canada's oil supply now comes from these sands.

Go Further

Now it's your turn. Look into the following resources to help you form your opinion:

- Look on the Web: Check out oil sands or synthetic oil on the Internet.
- Ask the Experts: Try to find an expert, such as a petrochemical engineer or an environmental impact officer.
- Look It Up in Newspapers and Magazines: Look for articles about the Alberta oil sands, synthetic oil, or the environmental impact of the oil sands.

In Your Opinion

- What are the benefits of developing the oil sands?
- Based on the information you have, what do you think should be done with the oil sands?
- Which do you think is more important—the benefits or the costs?

Unit Summary: Mix and Flow of Matter

Key Concepts	Section Summaries
1.0 • WHMIS symbols • properties of fluids	**1.0 Fluids are used in technological devices and everyday materials.** • An understanding of the WHMIS symbols and safety procedures in your science class is very important. Unsafe behaviour is dangerous to both you and your classmates. • Fluids make it easier to transport, process, and use different kinds of materials. Slurry technology is an example of how fluids can be used to transport other materials. Glass and steel are examples of the use of fluids as a stage in the production process of materials. Toothpaste is an example of the use of fluids to make using other materials easier. • Fluids have properties such as viscosity, density, buoyancy, and compressibility that make them useful for meeting human needs.
2.0 • pure substances, mixtures, and solutions • solute and solvent • concentration • solubility and saturation points • particle model of matter	**2.0 The properties of mixtures and fluids can be explained by the particle model of matter.** • Matter can be divided into pure substances and mixtures. Mixtures can further be divided into mechanical mixtures and solutions. • Solutions are made with a solute and a solvent. The more solute in the solvent, the more concentrated the solution. Concentration can be calculated in grams per millilitre (g/mL). The solubility of a solute in a solvent depends on the temperature of the solution, the type of solute, and the type of solvent. • The particle model of matter provides a model for describing how particles behave in the three states of matter and in mixtures.
3.0 • properties of fluids • mass, volume, density • viscosity and flow rate • buoyancy	**3.0 The properties of gases and liquids can be explained by the particle model of matter.** • Viscosity is a fluid's internal resistance or friction that keeps it from flowing. As the temperature increases in a liquid, the viscosity decreases. • Density is the amount of mass in a given volume. It is calculated by dividing the mass of a substance by its volume. The density of a substance increases as its temperature decreases. Most substances have a greater density in their solid state than in their liquid and gas states. The particle model of matter describes particles in a solid and liquid being packed closer together than those in a gas. A gas has more space between particles. • Less dense objects float on more dense substances. An object floats because the buoyant force of the fluid acting on it is greater than the force of gravity acting on it. • Gases are compressible, but liquids are almost incompressible. Pressure is calculated by dividing the force exerted by the area over which the force is applied. Pascal's law states that when a force is applied to a fluid, the pressure is transmitted equally throughout the fluid.
4.0 • properties of fluids • fluid technology applications	**4.0 Many technologies are based on the properties of fluids.** • Many different technologies are based on the properties of fluids. Cleaners and cleaning solvents work because of the different solubilities of substances. Pumps move fluids from one place to another. Valves control the flow of fluids. Hydraulic and pneumatic systems use fluids to move objects and devices such as submarines.

PROJECT

CREATING DRINKIT

Getting Started

In this unit, you have developed a variety of skills and an understanding of the properties of mixtures and fluids. You learned how to make solutions, calculate density, and describe buoyancy. You will now use these skills and this knowledge to design a new drink. The e-mail to the right contains the information you need to get started on your project.

Your Goal

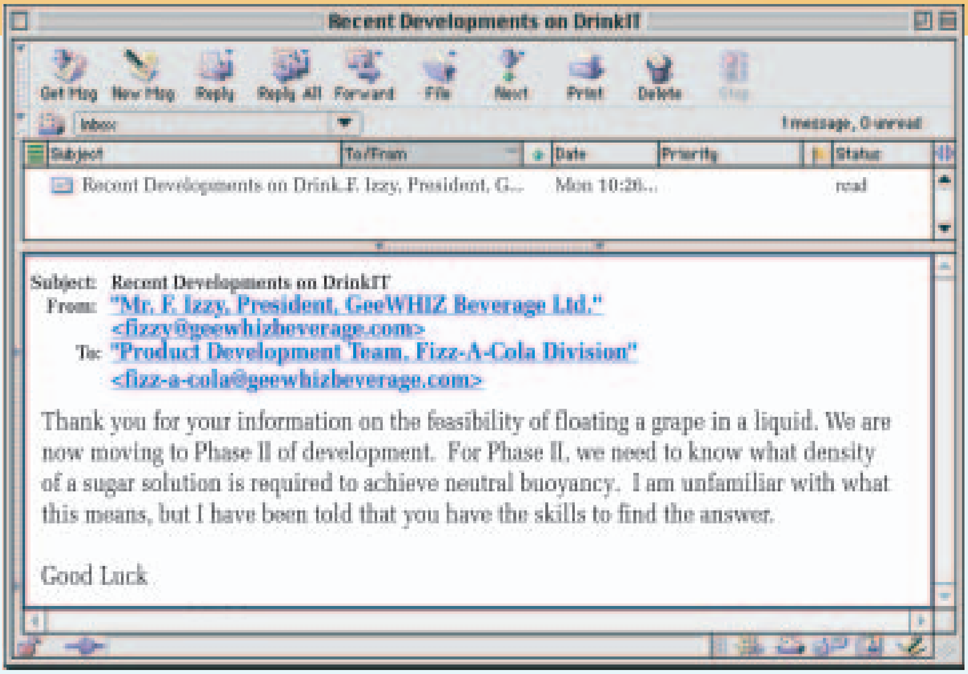
Your goal is to design and carry out a procedure that will allow you to determine the density of a sugar solution that can suspend a grape.

What You Need to Know

You will prepare a report to the president, F. Izzy, about your procedure and what you discovered. Your report should include the following:

- an outline of the procedure you developed and any modifications you made
- the data you collected during your investigation
- the results of your investigation
- recommendations for further work

Caution! Remember not to taste anything in the lab.



Subject: Recent Developments on DrinkIT
From: "Mr. F. Izzy, President, GeeWHIZ Beverage Ltd." <fizzy@geewhizbeverage.com>
To: "Product Development Team, Fizz-A-Cola Division" <fizz-a-cola@geewhizbeverage.com>

Thank you for your information on the feasibility of floating a grape in a liquid. We are now moving to Phase II of development. For Phase II, we need to know what density of a sugar solution is required to achieve neutral buoyancy. I am unfamiliar with what this means, but I have been told that you have the skills to find the answer.

Good Luck

Steps to Success

1. Work with your group to design a procedure for completing your assigned task. After you design your procedure, show it to your teacher for approval.
2. Collect the equipment you need and carry out your plan.
3. Make modifications to your plan as necessary. Write down any changes to your plan as you work through it.
4. Record the tests you made and your observations of the results.
5. Verify your results by making a fresh solution based on the results you recorded.

How Did It Go?

6. Describe the procedure you used when you were trying to determine the best sugar solution to use. Did you follow a specific procedure or did you just keep trying until you found the answer?
7. How did you determine the point where you had the appropriate solution concentration?
8. Could you have improved on your method of finding the appropriate solution concentration? Suggest changes you would make if you were to repeat this activity.
9. In any investigation, errors result. For example, after you determined the mass of sugar to add, some of the sugar may have spilled out before it was added to the beaker. What possible sources of error could have occurred in this activity? Why is it important to identify these sources of error when reporting your results?

Unit Review: Mix and Flow of Matter

Unit Vocabulary

1. Create a mind map that illustrates your understanding of the following terms. Use the word *fluid* as your starting word.

   pure substance
   mechanical mixture
   solution
   solute
   solvent
   concentration
   solubility
   viscosity
   density
   pressure
   hydraulic
   pneumatic

Check Your Knowledge

1.0

2. Identify the WHMIS symbols listed below and explain what each one means.

3. What should you do if a corrosive chemical spills on you?
4. Describe an example of a material being prepared as a fluid to make it easier to transport or use.
5. What are some important properties of fluids? Give an example of a technology that uses each property.

2.0

6. What is the difference between a pure substance, a mechanical mixture, and a solution? Give an example of each.
7. a) What is meant by the concentration of a solution?
   b) What units are usually used to measure concentration?
8. What is the difference between a solute and a solvent?
9. What factors affect the rate of dissolving?
10. How does the particle model of matter explain the following statement? *If you combine 25 mL of water with 25 mL of rubbing alcohol, the total volume is only 49 mL.*

3.0

11. How does the particle model explain viscosity?
12. What is the density of the following substances?

Substance	Mass (g)	Volume (mL)	Density
vegetable oil	92	100	
iron	39	5	
gold	326	20	

13. Why is hot water less dense than cold water?
14. Describe Pascal's law, and give one example of a device that uses this law to function.

15. What is the pressure exerted on the inside of a can if the surface area of the can is 0.2 m^2 and the force is 10 N?

4.0

16. Describe a technology that is based on the solubility of substances.

17. Describe one example of how a pump moves a fluid from one place to another.

18. How can a hydraulic system be used to transfer a force or control a motion?

Connect Your Understanding

19. When you open a can of cold soda pop, you hear a small noise. When you open a can of warm soda pop, the noise is much louder. What does this tell you about the relationship between the amount of carbon dioxide dissolved in the soda pop and the temperature of the soda pop?

20. Which solution is more concentrated: Solution A with 50 g of substance in 200 mL of water or Solution B with 12 g of the same substance in 40 mL of water? Explain your answer. Calculate the concentration of each solution in g/100 mL.

21. The solubility of a substance at 20°C is 40 g/100 mL of water. A solution has 30 g of this substance dissolved in 100 mL of water at 20°C. Is this solution saturated or unsaturated?

22. You have two samples of the same liquid. One is at 50°C and one is at 30°C.

a) What will happen if you pour the same amount of each liquid down a ramp? Which flow rate would be faster? Use the particle model to explain your answer.

b) If you poured the same amount of this liquid at 70°C down the ramp, what would happen?

23. Some medicines are more effective if they dissolve slowly. How would you design a pill that would take longer to dissolve?

24. On the coast of British Columbia, a fishing boat loaded with fish sank when it entered the Fraser River from the Strait of Georgia. The strait is part of the Pacific Ocean. Why do you think this happened?

25. How can a 2000-kg vehicle be lifted with a small force?

Practise Your Skills

26. Plan an experiment that would test the compressibility of three different fluids.

a) What materials would you need?

b) What procedure would you use?

c) What variables would you need to control?

27. A student dropped pennies one at a time into a known volume of water and measured the volume displaced. The table below shows the results.

Mass (g)	Volume (mL)
17	2
35	4
52	6
70	8
88	10

a) What is the density of a copper penny?

b) Graph this data with mass on the vertical axis and volume on the horizontal axis. Find the slope of the line. How does this slope compare with the density of pure copper at 8.96?

Self Assessment

Think back to the work you did during this unit.

28. Describe one situation where you observed the contributions of science and technology to the understanding of mixtures and fluids.

29. Give an example of one person's contribution to the science and technology of fluids and mixtures that you found interesting.

30. What is one idea or issue covered in this unit that you would like to explore in more detail?

31. Why do you think the environment should be considered when people use fluid technologies?

Focus On Science and Technology

In this unit, you have investigated science and technology related to fluids and mixtures. Consider the following questions.

32. Reread the three questions on page 7 about the role of the properties of fluids in science and technology. Use a creative way to demonstrate your understanding of one of these questions.

33. What examples demonstrated how fluid technology could provide solutions to a practical problem?

34. Describe a situation where a technological development involved trial and error and the use of knowledge from other scientific fields.

35. Describe the process involved in designing a device to perform a specific task. Was this a set step-by-step process or did it require changes as you developed the device?

36. Sometimes technology developers want to design a technology that works well in certain locations. Describe a situation where an understanding of local conditions made this possible.