UNIT C Fluids

An industrial pipeline system transports fluids.

Unit Overview

Fundamental Concepts

In Science and Technology for grades 7 and 8, six fundamental concepts occur throughout. This unit addresses the following two:

- Matter
- Systems and Interactions

Big Ideas

As you work through this unit, you will develop a deeper understanding of the following big ideas:

- Fluids are an important component of many systems.
- Fluids have different properties that determine how they can be used.
- Fluids are essential to life.

Overall Expectations

By the end of this unit, you will be expected to:

1. analyze how the properties of fluids are used in various technologies and assess the impact of these technologies on society and the environment
2. investigate the properties of fluids
3. demonstrate an understanding of the properties and uses of fluids

Exploring

A child in Malaysia uses a Canadian invention.

When you want a drink of water, you simply need to turn on a tap and use the water pumped to your home from a well, lake, or reservoir. But for many people in the world, access to clean, safe water is a daily challenge. That challenge has been made easier in some developing countries, thanks to an invention by researchers at the University of Waterloo, in Ontario. Their invention is a low-cost, shallow-well hand pump that has the following advantages:

- The pump is durable enough to work continuously for 18 hours a day.
- The pump is inexpensive enough for people in developing countries to afford.
- The pump is simple enough that villagers can maintain and repair it themselves.
- The pump can be manufactured within developing countries, creating jobs and ensuring that spare parts are available.

New Technology from Old

When the inventors were researching pump designs, they noticed a pump at a Mennonite community in southern Ontario that had been used for many years. With this pump as a model, they designed a hand pump with tubing made out of a plastic called polyvinyl chloride (PVC). In the past, pumps were made of iron and steel, materials that are scarce and costly in many developing countries. PVC is inexpensive, available everywhere around the world, and does not rust. The PVC hand pump is light, sturdy, cheap to build, and easy to install and maintain.

The new PVC hand pump is based on a metal pump like this one.

Adapting the Technology

Over 11 000 PVC hand pumps are now in use in 13 developing nations. The pumps are modified for local conditions. For example, in Sri Lanka, a leather washer is used instead of a plastic one. The advantage of the leather washer is that it can be made locally. In Malawi, the spigot on the pump is now made out of black metal instead of the original white plastic. The white spigots looked somewhat like bones, and the local hyenas kept chewing them off the pump.

The PVC hand pump is a good example of the importance of understanding a concept and then applying that understanding to different situations. In this case, the inventors knew about the properties of fluids and how a water pump operates. They applied this knowledge to develop a better pump that could be made locally, work reliably for long hours, and be easy to fix.

In this unit, you will learn about the properties of fluids and discover how fluids can be used to solve a variety of practical problems. You will learn that fluids include both liquids and gases, and that you put fluids to work for you every day.

...MORE TO EXPLORE

C1 *Quick Lab*

Pump Up the Volume

Many people of the world obtain the water they use from a well. The device used to transfer this water must be reliable, efficient, and sanitary.

Purpose

To test and evaluate several methods of transferring water from a low elevation to a high elevation

Materials & Equipment

- large plastic container
- 5 disposable cups
- felt pen
- water
- stopwatch
- plastic straw
- spoon straw
- small sponge
- spoon
- cardboard tube

Procedure

1. Place a large container of water (the well) on the floor at the base of your table.
2. Label the five disposable cups A, B, C, D, and E. Place them in a row on your table.
3. Predict which "pump" will transfer the most water in 30 s. Your "pumps" are the straws, sponge, spoon, and cardboard tube.
4. Have a partner time 30 s while you use plastic straw A to transfer as much water from the well into cup A. Do not put any of the devices in your mouth. Be careful not to spill any water. Clean up any spills immediately.
5. Repeat step 4 for the remaining pumps, using pump B for cup B, and so on.
6. Determine which cup contains the most water.

Questions

7. Which pump transferred the most water in 30 s? How did this result compare to your original prediction?
8. The best pump is the one that transfers lots of water, lasts a long time, and is the most sanitary. Use these criteria to explain which of the five pumps is the best.

C2 *Thinking about Science, Technology, Society, and the Environment*

STSE

Fluids on the Move

Suppose you were in charge of designing a pipeline to bring fresh water from a lake to a village at the top of a hill 20 km away.

1. How would you decide what materials to use to build the pipeline?
2. How would you decide which route the pipeline should follow?
3. How would you raise the water from the low level of the lake to the high level of the hill?
4. Who should pay for the pipeline? The villagers desperately need the water, but are unable to pay the full cost.

UNIT C

Contents

Unit Task

Pipelines transport fluids across Canada. Our understanding of the properties of fluids helps us design pipelines to function without spills or problems. In your Unit Task, you will investigate the effect of changing a variable on the movement of fluid in a pipeline that you design.

Essential Question

How do the properties of fluids explain the factors that influence the movement of fluids through a pipeline?

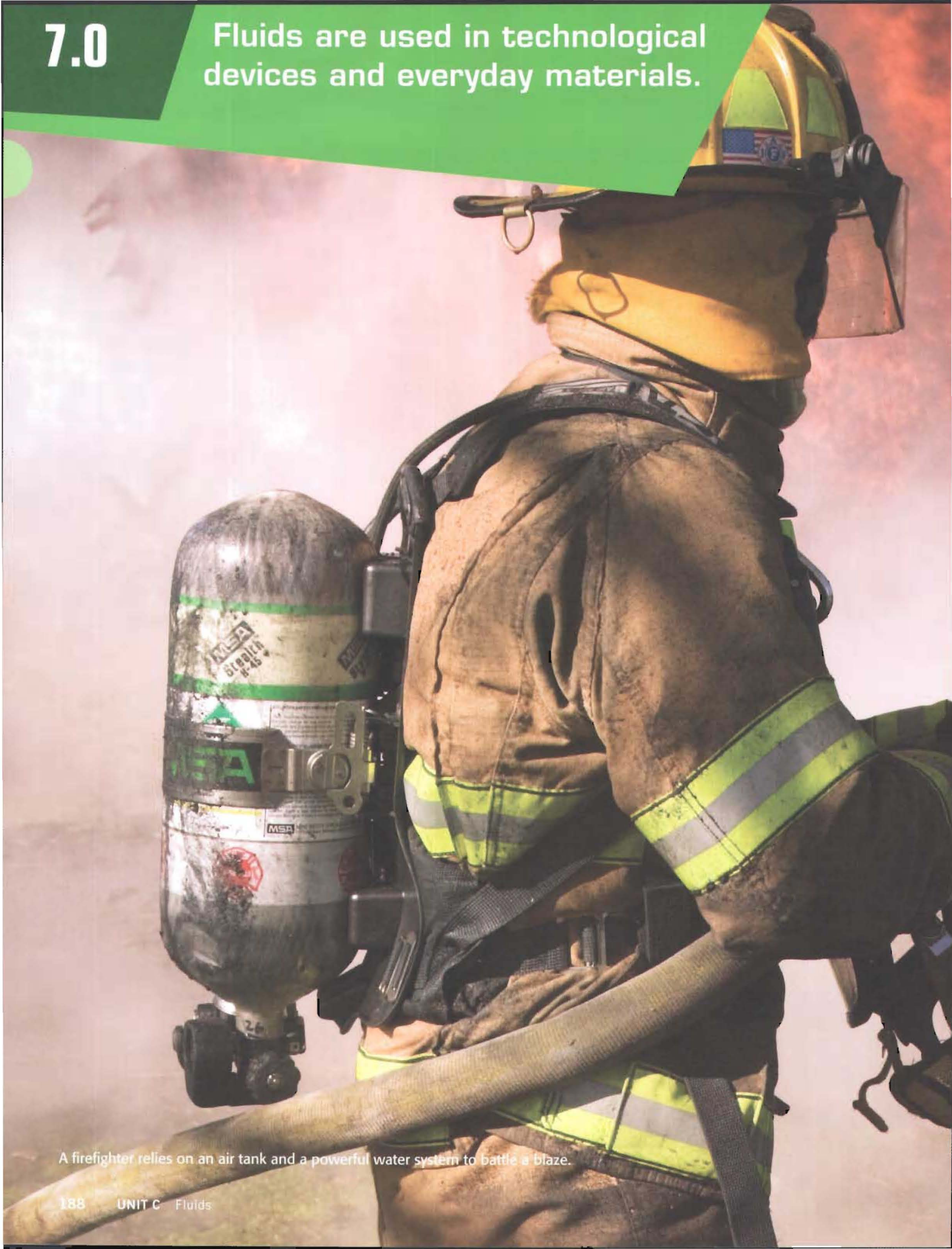
Getting Ready to Read

Thinking Literacy

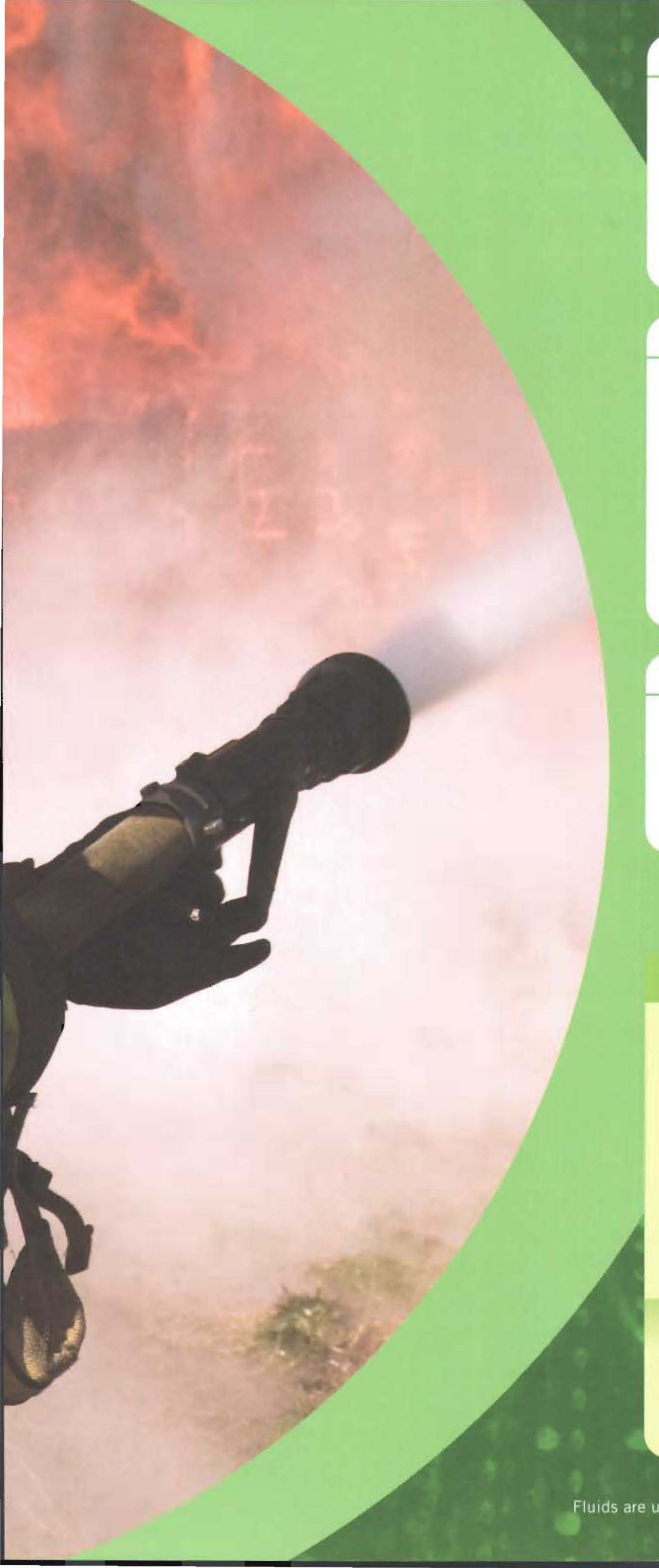
Probable Passage

You will encounter the following terms in this unit: "fluids," "solid," "liquid," "gas," "volume," "particle theory of matter," and "thermal expansion." Which of these terms can you already define? Which are you unsure of? Write your prediction of what you will learn in this unit.

7.0 Fluids are used in technological devices and everyday materials.



A firefighter relies on an air tank and a powerful water system to battle a blaze.



What You Will Learn

In this chapter, you will:

- explain the difference between solids, liquids, and gases using the particle theory of matter
- recognize a variety of uses for fluid technologies

Skills You Will Use

In this chapter, you will:

- follow safety practices for using apparatus, tools, and materials
- use appropriate science and technology vocabulary
- use a variety of forms to communicate with different audiences and for a variety of purposes

Why This Is Important

When you understand how fluids can change and move, you can more easily put fluids to work for you. Fluids are an important part of many devices and systems.

Before Reading

Thinking Literacy

Making Predictions

This chapter builds on your learning in science in previous years and your everyday life. As you consider the title for this chapter, "Fluids are used in technological devices and everyday materials" and scan the photographs, use your prior knowledge to make a prediction about what you will learn.

Key Terms

- mass
- volume
- matter
- thermal expansion
- particle theory of matter
- fluid

7.0 Getting Started

Figure 7.1 HMCS *Victoria* is one of Canada's four diesel-electric patrol submarines. Each submarine of its class is over 70 m long and can dive to a depth of more than 200 m.

How is a submarine able to dive, travel along at a constant depth, and then rise to the surface of the water? Why does a submarine not simply float, like a boat, or sink, like a huge piece of metal? The answer is related to the weight of the water a submarine takes the place of, or displaces. For example, when HMCS *Victoria* is at the surface, it displaces over 2100 tonnes of water (Figure 7.1). When HMCS *Victoria* is below the surface, it displaces over 2400 tonnes.

In order for a submarine to sink from the surface to the depths, its weight must be more than the weight of the water it displaces. When the submarine rises back to the surface, its weight must be less than the weight of the water it displaces. The weight of a submarine changes depending on whether seawater or compressed air fills its ballast tanks.

When the ballast tanks are filled with seawater, the weight of the submarine is greater than the weight of the water it displaces, and so the submarine sinks (Figure 7.2). When seawater is pumped out of the ballast tanks and is replaced by compressed air, the submarine becomes lighter than the water it displaces and rises to the surface. A balance of seawater and compressed air in the ballast tanks allows the submarine to stay at a constant depth.

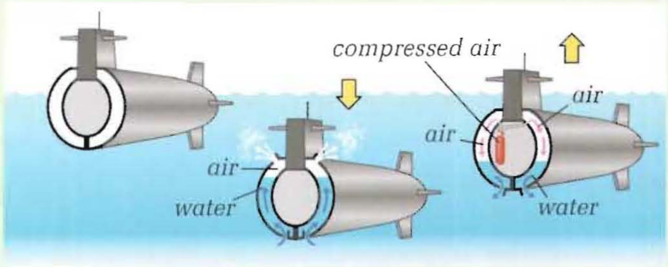


Figure 7.2 The ballast tanks are located between the inner and outer hulls of the submarine.

The technology that allows a submarine to rise, sink, or stay at a constant level is similar to a technology used by fish. A fish has an internal organ under its backbone called a gas bladder. By making changes to the volume of gases in the bladder, a fish can control whether it stays at a constant depth, rises, or sinks.

C3 Quick Lab

Cartesian Diver

This type of diver is named after Rene Descartes, a French scientist, mathematician, and philosopher who lived about 400 years ago.

Purpose

To model the movement of a submarine by making a Cartesian diver

Materials & Equipment

- 2-L plastic bottle with cap
- medicine dropper
- water

Procedure

1. Completely fill the 2-L plastic bottle with water.
2. Fill the medicine dropper about two-thirds full of water and place it in the bottle. The medicine dropper should float at the top of the 2-L bottle.
3. Continue to increase the amount of water in the medicine dropper until it floats at the top but is almost completely submerged.
4. Put the cap on the bottle and tighten securely.
5. Squeeze the sides of the bottle. Observe what happens.
6. Release the sides of the bottle. Observe what happens.

Questions

7. State what happened to the diver when you:

   (a) squeezed the sides of the bottle

   (b) released the sides of the bottle
8. Did the weight of the diver increase or decrease when you squeezed the bottle? Explain.
9. Suggest a possible explanation for why the weight of the diver changed.

7.1 The Many Uses of Fluids

Here is a summary of what you will learn in this section:

- A fluid is any substance that flows.
- Fluids have many uses, including holding and transporting other materials.
- Substances in their fluid form can be shaped and then cooled to become solids.

Every time you brush your teeth with toothpaste, take a drink of juice, or draw in a breath of air, you are using a fluid. A **fluid** is any substance that flows. The blood flowing through your blood vessels is a fluid. Lava flowing from a volcano and honey flowing from a spoon onto your toast are also fluids. Other fluids include gases, such as oxygen and carbon dioxide, and liquids, such as shampoo, salad dressing, window cleaner, and engine oil. We use the properties of fluids in many different devices and systems to improve our lives.

C4 Starting Point

Skills P C

Finding Flowing Fluids

Whether it is a race car or a family car, an automobile needs fluids and fluid technologies to run smoothly, safely, and efficiently (Figure 7.3).

1. With a partner, make a list of all of the different fluids you can think of that are used in an automobile. You can include uses by people who drive and ride in automobiles as well.
2. Group your examples into four different categories. Label each category with a title.

Figure 7.3 There are many uses for fluids in transportation.

Putting Fluids to Work

One of the reasons why fluids are so important is that they make it easier to transport, process, and use different kinds of materials, even if these materials are solids (Figure 7.4).

Figure 7.4 You can use air to move solids, such as leaves and paper.

Fluids Can Transport Solids

A mixture of water and solids is called a **slurry**. Slurry technology — the transport of solids in water — is important in many applications. The paper you write on was once a slurry of wood pulp and water. Hydroseeding is the process of spraying a slurry of seeds, fertilizer, and sawdust to plant difficult-to-reach areas (Figure 7.5). Mines, such as the Campbell Gold Mine in northwestern Ontario, use slurry technology to process the minerals. Some mineral ores are converted to liquids in a method called *froth flotation* so that they can be transported more easily.

Figure 7.5 A slurry of seeds and nutrients can be used to replant an area.

Fluids Can Hold Other Materials

The ability of fluids to hold or carry other materials makes them useful in many applications (Figure 7.6). For example, the watery cytoplasm in your cells holds the organelles that allow a cell to expand, grow, and replicate. Fluids can hold abrasive particles to clean other surfaces, such as marble, metal, and your teeth (Figure 7.7).

Figure 7.6 An airplane drops a load of fluid containing fire retardant on a forest fire.

Figure 7.7 Toothpaste is a fluid that holds materials to clean, polish, and protect your teeth

Figure 7.8 Cement is a mixture of materials, such as limestone, clay, and gypsum.

Fluids Become Solids

Fluids are easy to move, and they take the shape of their containers. Because of these properties, many of the solid objects we see and use were originally prepared as fluids.

A slurry of water and cement is easy to transport. As it hardens, the cement can be shaped to become a smooth and level concrete sidewalk (Figure 7.8).

Steel is an example of the use of fluids in processing materials. Steel consists of a mixture of iron, carbon, and small quantities of other substances. This mixture is heated to 1650 °C to melt everything together so that more materials can be added. The fluid steel is then shaped into the desired forms and allowed to cool (Figure 7.9).

Figure 7.9 Molten steel on a rolling mill

C5 *During Reading*

POE (Predict, Observe, Explain)

Readers often make an "educated guess" about what will happen as they approach new or unfamiliar text or topics. This same strategy can help us in science. This chapter contains several Quick Labs and an Inquiry Activity. Set up a three-column chart in your notes with the headings: Predict, Observe, and Explain.

Read through C6 Quick Lab, Functions of Fluids, on page 195. Notice the title, purpose, and procedure. How can you connect them to other learning or experiences you have had? Use this background knowledge to predict what you think will happen when you do the lab. Record and explain your prediction in the first column of your chart. You have now formed a hypothesis about what you think will happen!

As you do the lab, record what did happen in the Observe column. The Explain column is a place for you to connect to your learning in this chapter and explain the results of the Quick Lab.

Other Uses for Fluids

Fluids have many other uses. For example, oil is added to the engine of a car to decrease friction, and to reduce noise, heat, and wear. Paint is applied to iron to create a barrier that prevents rust from forming. A fluid circulating in the back of a refrigerator keeps the temperature cool, and a fluid circulating in a radiator can warm a room. Some fluids, such as gases, can be forced into a smaller volume, such as the air that pumps up a bicycle tire or the air in a breathing apparatus for scuba divers (Figure 7.10).

Take It Further

Plasma is considered to be a fourth state of matter. How is plasma different from a gas? Begin your search at ScienceSource.

Figure 7.10 Scuba tanks are sometimes filled with a mixture of gases that includes slightly more oxygen than what is found in ordinary samples of air.

C6 Quick Lab

Functions of Fluids

You are at a birthday party and all around you are colourful balloons. Helium balloons are floating near the ceiling and air-filled balloons cover the walls. A balloon is an example of an everyday object that requires a fluid to function properly.

Purpose

To identify, describe, and explain a variety of everyday common devices that require a fluid to function

Materials & Equipment

- chart paper
- felt pens
- fluid-operated device supplied by your teacher

Procedure

1. Brainstorm with your partner objects or devices that require the use of a fluid to operate. List your ideas on the chart paper.
2. From your list, identify 10 objects or devices that use a variety of different fluids.
3. Create a chart that explains how each object or device functions. You may want to use a chart like Table 7.1.

Table 7.1 Functions of Fluids

Object or Device	Type of fluid used to operate object or device	How the fluid helps the object or device to function

4. Your teacher will provide you with a device that requires a fluid to operate. Add the name of this device to your chart and complete the chart.
5. Present your chart to the class.

Questions

6. (a) List the different fluids that you and your classmates identified.
   (b) Explain how the fluids were used in various objects and devices.
7. What was the most common state of matter for the fluids you identified?
8. Choose one object or device. How could it operate if another fluid were used in place of the one usually used?

7.1 CHECK and REFLECT

Key Concept Review

1. Name two fluid technologies that make use of air.
2. Name two fluid technologies that make use of water.
3. Describe an example where materials are prepared as fluids so that they can be moved more easily.
4. Explain why it is important for steel to go through a fluid phase as it is being produced.

Connect Your Understanding

5. Review the list of fluids and their uses that you made for Figure 7.3 on page 192. What changes would you make based on what you have learned?
6. Add at least three other examples of fluids to your list in question 5. Make one new category for your list.

Practise Your Skills

7. Describe how different fluids are used to operate the can of spray paint shown below.

For more questions, go to ScienceSource.

C7 Thinking about Science and Technology

Useful Properties of Fluids

Each of these photographs shows fluids in use.

1. How are our lives improved by each of the uses shown?
2. How have advances in technology contributed to each use?
3. What are environmental issues raised by each use?

(a)

(b)

(c)

7.2 Fluids and the Particle Theory of Matter

Here is a summary of what you will learn in this section:

- Matter is anything that has mass and volume.
- The particle theory of matter is a way of explaining the behaviour of matter.
- Solids hold a definite shape because their particles are packed closely together and vibrate in one place.
- Liquids can flow and take the shape of their container because their particles have partly overcome their attraction for each other.
- Gases can flow and spread out because their particles are far apart and have overcome their attraction for each other.

In how many different states is water shown in Figure 7.11? There is liquid water around the kayak, water in its solid state in the iceberg, and water in its gaseous state in the air. The water, the iceberg, and the clouds are all examples of matter. The kayak, the person, and the paddle are also matter. **Matter** is anything that has mass and volume. **Mass** is a measure of how much matter there is in a substance. **Volume** is a measure of how much space a substance takes up.

Figure 7.11 Three states of matter are shown in this photograph.

C8 *Starting Point*

Skills A C

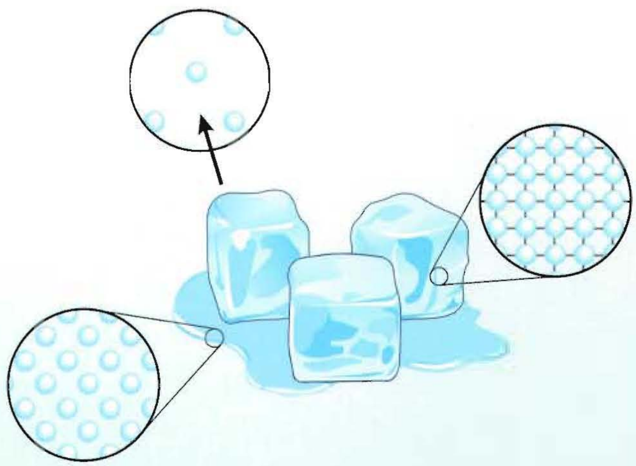
Colourful Crystal

A crystal of potassium permanganate was carefully added to the still water in Figure 7.12(a). The photograph in Figure 7.12(b) shows the potassium permanganate after 5 min. What do you think happened? How do you think this happened?

Figure 7.12 Potassium permanganate in water (a) (b)

The Particle Theory of Matter

In earlier grades, you may have learned about the particle theory of matter. The **particle theory of matter** is a simple way of describing matter and its behaviour. You can use the particle theory of matter to help you understand how matter behaves in each state. The particle theory has six main points that describe the structure of matter.



1 All matter is made up of tiny particles.

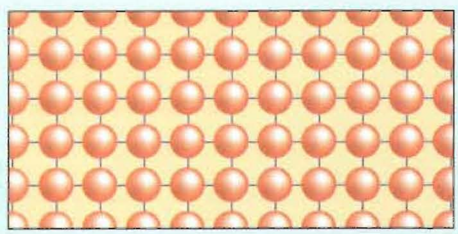
2 All particles are in constant motion.

3 All particles of one substance are identical.

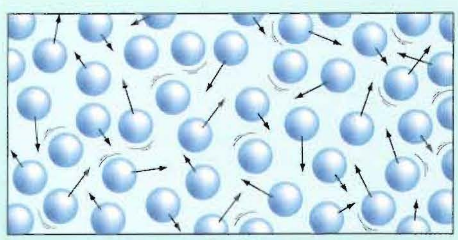
4 Temperature affects the speed at which particles move.

5 In liquids and solids, the particles are close together and have strong forces of attraction between them.

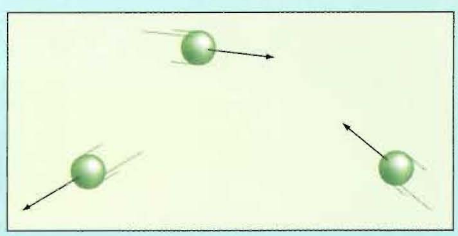
6 In a gas, there are spaces between the particles.



solid



liquid



gas

C9 Learning Checkpoint

Understand the Text

Answer the following questions. You can check your answers by looking back through the previous two pages.

1. Which has more particles in the same volume, liquid water or water vapour?

liquid water

2. In which state of matter do particles stay in more or less the same position? solid
3. In which state of matter is there the greatest space between particles? gas

How the Particle Theory Explains Properties of Fluids

The particle theory states that particles are attracted to each other. However, particles in some substances may be more attracted to particles in other substances than they are to each other. For example, when potassium permanganate is placed in water, its particles are more attracted to the water particles than to other potassium permanganate particles. Since the water particles are continually moving, the potassium permanganate particles are moved farther apart. This is the process we call dissolving.

Liquids Can Flow

Particles in a liquid can overcome some of their attraction to each other and slide past each other. This is why liquids flow and take the shape of their container. For example, water takes a different shape in a vase compared to in a bowl.

Gases Can Flow

Gas particles move so quickly and are so far apart that they overcome almost all of their attraction to each other. This is why gases flow and spread out to all parts of their container. For example, if you spray some air freshener in one part of a room, you can soon smell it in other parts of the room.

Suggested Activities

C10 Quick Lab on page 200
C11 Inquiry Activity on page 201

Figure 7.13 When the temperature drops, the particles in the tube move closer together and the level of liquid falls.

Thermal Expansion and Contraction

When the temperature of a solid, liquid, or gas increases, its particles move faster and farther apart. As a result, the substance expands. **Thermal expansion** is an increase in the volume of a substance in response to an increase in its temperature.

When the temperature of a solid, liquid, or gas decreases, its particles move more slowly and closer together. As a result, the substance shrinks, or contracts. Substances expand or contract with changing temperature at their own particular rate.

A thermometer shows the temperature by the expansion or contraction of a liquid in a narrow tube (Figure 7.13). When the temperature rises, the particles in the tube move farther apart as their motion increases. Even a slight expansion results in a large change on the temperature scale.

Take It **Further**

You have probably heard about atoms. How are atoms related to particles? Find out about atomic structure at ScienceSource.

C10 Quick Lab

Balloon Tricks

Purpose

To observe evidence of the particle theory of matter

Materials & Equipment

- 2 round balloons
- measuring tape
- heat lamp
- felt pen
- bowl of ice water

Procedure

1. Make a table to record your data.
2. Blow up the two balloons about three-quarters full, and tie them off.
3. Use the felt pen to label one balloon "cool" and the other balloon "warm."
4. Measure and record the circumference of the largest part of each balloon.
5. Place the balloon labelled "cool" in a bowl of ice water until you observe a change in its size.
6. Place the balloon, labelled "warm" near a heat lamp until you observe a change in its size.
7. Measure and record the circumference of the largest part of each balloon.

Questions

8. (a) How did the balloon change when it was cooled?

   (b) How did the balloon change when it was warmed?
9. How would you explain your observations using the particle theory of matter?

C11 Inquiry Activity

Toolkit 2

SKILLS YOU WILL USE
- Measuring
- Drawing conclusions

Mixtures of Matter

Question

How does the particle theory of matter explain what happens when substances are combined?

Materials & Equipment

- 50 mL of small marbles in a 250-mL beaker or graduated cylinder
- 50 mL of sand
- 50 mL of water

Procedure

Part 1 – Predict and Measure

1. Copy the following table into your notebook. Give your table a title.

Table 7.2 Data Table

	Predicted Volume (mL)	Actual Volume (mL)
50 mL of marbles + 50 mL of sand		
50 mL of marbles and 50 mL of sand + 50 mL of water		

2. Predict and record the volume that will result when you add 50 mL of sand to 50 mL of marbles.
3. Slowly pour the 50 mL of sand into the container of marbles. Measure and record the total volume.
4. Predict and record the volume that will result when you add 50 mL of water to the mixture.
5. Slowly pour the 50 mL of water into the container of marbles and sand. Measure and record the total volume. Be sure to wipe up any spills immediately.

Part 2 – Combining Two Liquids

6. A lab technician measured 20 mL of rubbing alcohol into one graduated cylinder and 20 mL of water into a second graduated cylinder as shown in Figure 7.14(a). She then combined the two liquids. The combined liquid filled the graduated cylinder to a level of 39 mL in Figure 7.14(b).

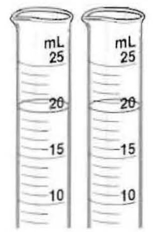


Figure 7.14(a) 20 mL of rubbing alcohol and 20 mL of water in separate 25-mL graduated cylinders

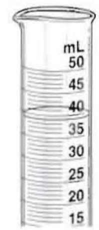


Figure 7.14(b) The two liquids combined in one graduated cylinder

Analyzing and Interpreting

7. (a) Would the end total volume in Part 1 be the same if you added the marbles to the sand instead of vice versa?

   (b) Why or why not?

8. (a) Would it make a difference to the total volume if you added the water to the marbles before the sand in Part 1?

   (b) Why or why not?

Skill Builder

9. What are possible sources of error when the technician combined the liquids in Part 2?

Forming Conclusions

10. If no error occurred in Part 2, why was the sum of the volumes of the liquids less than 40 mL?

CHECK and REFLECT

Key Concept Review

1. (a) What does "mass" mean?
   (b) What does "volume" mean?
2. According to the particle theory of matter:
   (a) How is the motion of particles in a liquid different from the motion of particles in a solid?
   (b) How is the motion of particles in a gas different from the motion of particles in a liquid?
3. (a) What determines a liquid's shape?
   (b) What determines a gas's volume?
4. Which two states of matter can flow?

Connect Your Understanding

5. Why did the potassium permanganate crystals in Figure 7.12 on page 197 start to dissolve in water without being stirred or shaken?

Practise Your Skills

6. Explain why highways and bridges must be built with gaps, as shown in the photograph below.

For more questions, go to ScienceSource.

C12 *Thinking about Science and Technology*

When Water Freezes

The volume of most fluids decreases when they cool from a liquid to a solid. Water is an exception. When water freezes, the resulting ice takes up more volume than the liquid water did. The repeated freezing and thawing of water in cracks damages roads by causing potholes, bumps, and cracking.

What to Do

With a partner or in a group, discuss and record your ideas about the following questions.

1. What are the safety issues of water that freezes and thaws?
2. Suggest a method that could be used to prevent damage to roads caused by water freezing and thawing.
3. What are the costs associated with water freezing and thawing? Who pays? Who should pay if there is an accident?

Glowing Glass

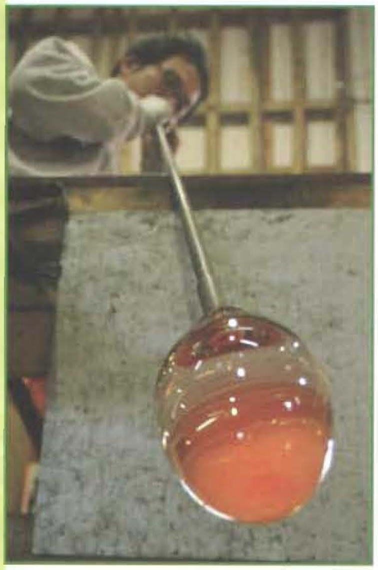


Figure 7.15 Blowing molten glass with a blowpipe

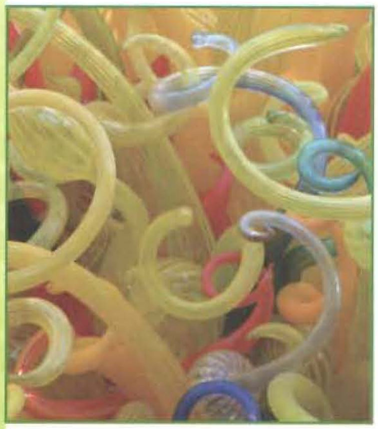


Figure 7.16 Glass can be sculpted into many colourful shapes and forms.

The art and technology of making beautiful glass sculptures began over 3500 years ago. In the early days of glass making, silica sand was heated to more than 1700°C. At this temperature, the sand melts and becomes a fluid, resembling syrup on a cold day. When the fluid slowly cools, the hardened material becomes glass, similar to that in windows.

Coloured glass was created by adding other compounds to the silica sand. For example, green-brown glass was created by adding iron oxide. Light blue and red glass needed copper compounds to be added.

Today, there are several different techniques for creating glass art that involve the glass being heated to different temperatures.

- *Slumping* involves heating the glass to temperatures around 600°C so it can be shaped in a mould. Slumping is sometimes used to make objects such as glass bowls.
- When glass is heated to between 700°C and 800°C, it starts to become "sticky." *Glass fusing* involves placing various pieces of glass on a surface so that they are in contact. When the assembled pieces are heated, they adhere and become one solid piece. Mosaic tiles and some stained glass windows are made this way.
- *Glass blowing* involves using air to shape the fluid glass, much like blowing a bubble with bubblegum. Glass blowing involves temperatures around 1000°C. At these temperatures, the liquid glass flows much more easily than at lower temperatures. A hollow blowpipe is dipped in the molten glass so that the end of the blowpipe is covered in glass, much like dipping a straw in liquid honey. The artisan then blows through the blowpipe to create the hollow bubble of glass. By using different tools and techniques, this bubble can be shaped and sculpted.

Questions

1. Explain what happens to how glass flows as it is heated.
2. Which of the three methods do you think would be used to create the glass in a light bulb? Explain.
3. In your opinion, is it more important for a glass sculpture to be beautiful or to be practical? Explain.

7.0 Chapter Review

Assess Your Learning

After Reading Thinking Literacy

Reflect and Evaluate

Revisit the prediction you made at the start of this chapter. Was your prediction correct? How did what you already know (your prior knowledge) help you make a prediction? Did making a prediction before a Quick Lab or Inquiry Activity help you? Share your ideas with a partner.

Key Concept Review

1. Describe the process for getting rid of broken glass in your class. k
2. What are the safety procedures for tasting and smelling substances in the science room? k
3. What are the six main points of the particle theory of matter? k
4. Make a particle sketch showing how the volume of a liquid changes when heat is added. k
5. Explain how a fluid is different from a solid in terms of its shape. k
6. Describe an example where materials are prepared as fluids to make it easier to use them. k

Connect Your Understanding

7. What symbols would you expect to find on containers of the following fluids? t
   - oven cleaner in a spray can
   - bleach
8. What is an example of thermal expansion that you have observed in your daily life? a
9. How does applying oil to a bicycle help the bicycle to work better? a

ACHIEVEMENT CHART CATEGORIES
k Knowledge and understanding t Thinking and investigation c Communication a Application

10. Arrange the following list into two columns titled "Fluids" and "Non-fluids."

- sunscreen
- baby powder
- hand lotion
- helium
- carbon dioxide
- syrup
- ketchup
- mustard
- flour
- sugar
- orange juice
- soy sauce

11. Use the particle model to explain the difference in appearance between steam and liquid water.

12. Why does a liquid take the shape of the container but not expand to completely fill the container?

13. Suppose you had to remove a tight-fitting lid from a jar. Would it be a good idea to heat the lid or cool it before trying to remove it? Explain your answer.

14. If you pour sand into a container, it appears to take the shape of the container. How could you prove that sand is not a fluid?

Practise Your Skills

15. Identify a fluid technology you have recently used to make your life easier or better. Draw a chain of events that shows the fluid, how you used it, and how it improved your life.

Unit Task Link

In your Unit Task, you will investigate the effect of a variable, such as temperature, on the movement of fluid in a pipeline. The fluid in this task will be a liquid. Use the particle model to explain how temperature will affect the liquid in your pipeline.

C13 *Thinking about Science and Technology*

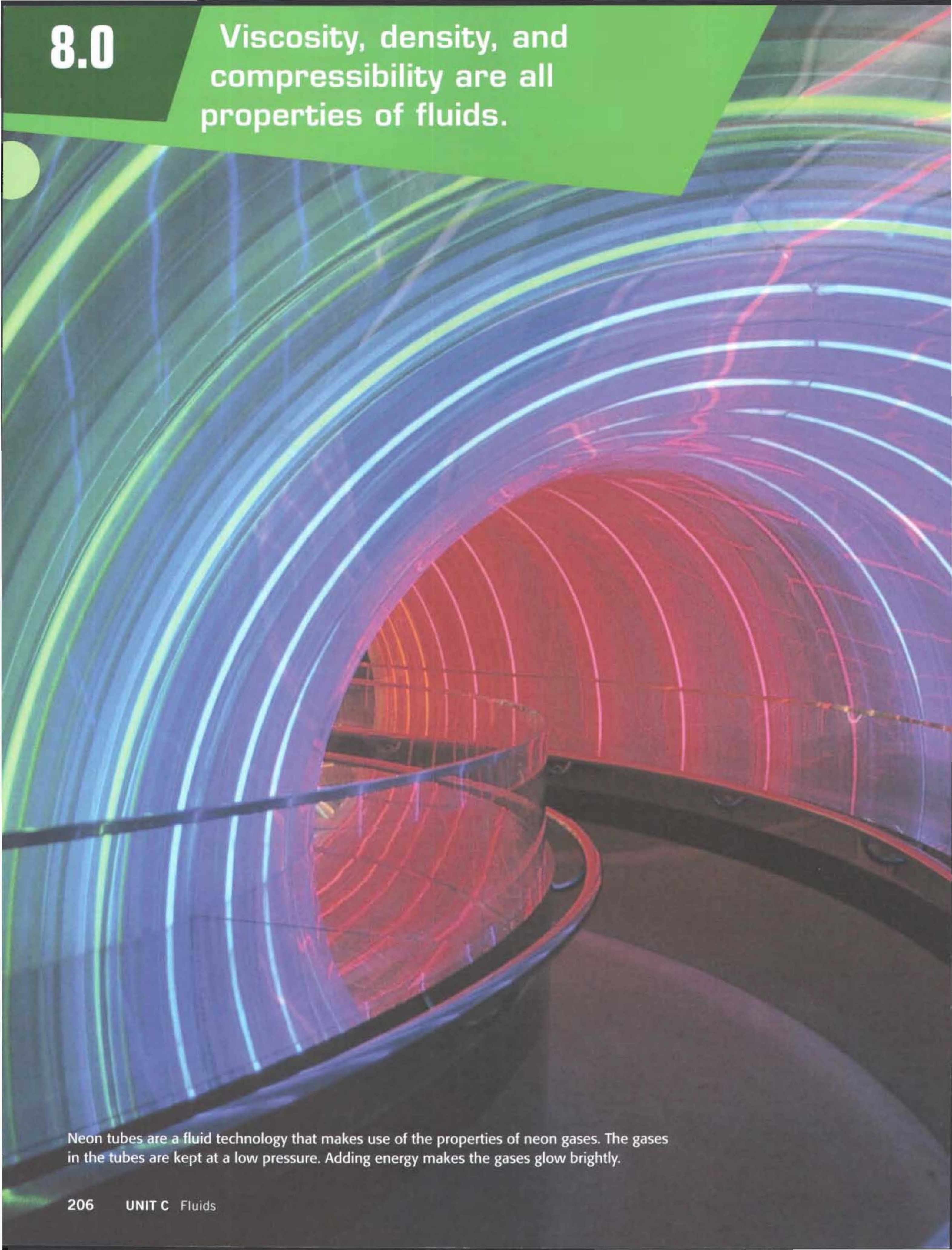
Technology Tools

The goal of technology is to provide solutions to practical problems. With a classmate or as a whole class, discuss the following questions.

1. What are three problems that fluid technology helps to solve?

2. How does a fluid help to solve each of the problems?

8.0 Viscosity, density, and compressibility are all properties of fluids.



Neon tubes are a fluid technology that makes use of the properties of neon gases. The gases in the tubes are kept at a low pressure. Adding energy makes the gases glow brightly.

What You Will Learn

In this chapter, you will:

- compare the viscosity of various fluids
- explain the difference between liquids and gases in terms of their compressibility
- determine the buoyancy of an object
- explain the relationship between pressure, volume, and temperature
- describe the relationship between mass, volume, and density

Skills You Will Use

In this chapter, you will:

- determine the mass-to-volume ratios of different amounts of the same substance
- identify factors that affect the flow rate of fluids
- design an experiment to measure the flow rate of fluids
- investigate and compare the densities of a variety of fluids
- construct and calibrate a hydrometer

Why This Is Important

Fluids can change when their temperature or pressure changes. Understanding density can help you determine whether a fluid and other substance will float or sink.

Before Reading

Thinking Literacy

Activate Prior Knowledge

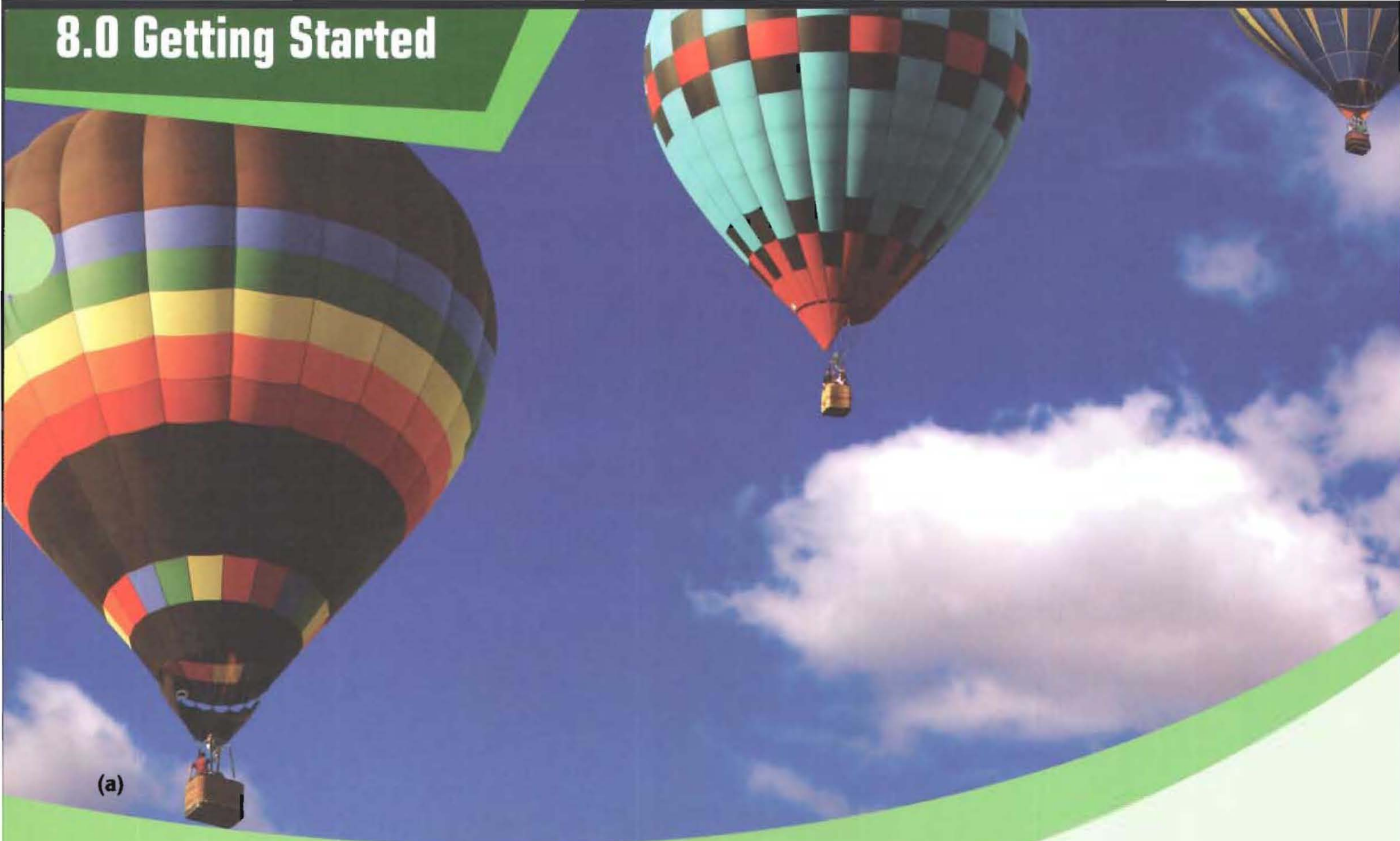
Create a KTW chart with headings "What I Know," "What I Think I Know" and "What I Want to Know." Complete the chart using the key terms below.

Key Terms

- buoyancy
- density
- flow rate
- friction
- pressure
- compressibility
- viscosity

Viscosity, density, and compressibility are all properties of fluids.

8.0 Getting Started



(a)

Figure 8.1 Modern hot air balloons (a) and ancient Chinese floating lanterns (left, b) both rise because of hot fluids.

(b) Chinese lanterns

The scientific principle used to float Chinese lanterns 1500 years ago is the same principle at work in today's hot air balloons (Figure 8.1).

The first successful "modern" hot air balloon was invented by a French scientist in 1783. The passengers of this experimental balloon were a duck, a rooster, and a sheep. These barnyard passengers stayed airborne for 15 minutes. Two months later, the first human flight took place. Balloon technology increased at a quick pace, and within two years a hot air balloon and its two human passengers crossed the English Channel.

The largest part of a hot air balloon is the gas bag or envelope, which is made from strong, lightweight fabrics such as nylon. A basket for carrying passengers is attached to the envelope.

Mounted above the basket is a burner that injects a flame into the mouth of the envelope to heat the air (Figure 8.2). At the very top of the balloon's envelope are vents which are used to release the air from the balloon during a quick descent or once the balloon has landed.

What scientific principle is at work in hot air balloons? When the air inside the envelope of the balloon is heated, the air particles move faster and take up more space compared to the particles outside the envelope. The hot air balloon rises.

When the balloon pilot allows the warm air inside the balloon to cool down, the air particles move more slowly and take up less space. The balloon sinks back down to Earth.

Figure 8.2 A balloonist fires the burner to heat the air.

C14 *Quick Lab*

Full of Hot Air — Teacher Demonstration

Purpose

To model a hot air balloon

Materials & Equipment

- clear adhesive tape
- dry cleaner plastic film bag
- heat source, such as hairdryer or electric popcorn maker
- paper clips

Procedure

1. Use a small amount of clear adhesive tape to seal any openings in the upper end of the bag.
2. Attach several paper clips to the bag around the lower opening. You will need to experiment to decide how many paper clips to add.
3. With a partner, hold the opening of the bag over the heat source to capture the hot air.
4. Let go of the bag. If the bag rises, observe its motion. If it does not rise, continue heating it for a little while longer. If it still does not rise, remove a few paper clips and then heat it again.
5. If the rising bag tips over before it reaches the ceiling, add a few more paper clips to the bottom of the bag. Then, heat and release the bag again.

Questions

6. Explain what causes the bag to rise.
7. Explain what causes the bag to eventually return to the floor.
8. Suggest possible changes you could make to your design that would allow the bag to remain aloft for a longer period of time.

8.1 Viscosity and the Effects of Temperature

Here is a summary of what you will learn in this section:

- Viscosity is the resistance of a fluid to flow. Different fluids have different viscosities.
- As the temperature of a liquid decreases, the viscosity increases. As the temperature of a gas decreases, the viscosity decreases.
- Flow rate is a measure of the speed at which a fluid flows from one point to another. The higher the flow rate, the lower the viscosity.

Figure 8.3 Ketchup has a higher viscosity than fluids like milk and water.

Ketchup, like all fluids, will flow. However, ketchup is designed to flow slowly so that it will stay on foods, as shown in Figure 8.3. Thin fluids, like milk and water, flow much more quickly and easily than ketchup.

The thickness or thinness of a fluid is a property called viscosity. **Viscosity** is the resistance of a fluid to flow. Fluids with high viscosity do not flow as easily as fluids with a low viscosity.

C15 *Starting Point*

Skills A C

Thick or Thin?

One property of fluids is how they move or flow. Think about the fluids you have used in the past few days. What would happen if they did not flow the way they usually do? For example, what would happen if water flowed like a thick syrup or ketchup flowed like oil?

1. Make a chart like the one shown in Table 8.1 to record your descriptions.
2. With your partner, identify five fluids that you have used recently.
3. Describe what the fluids would be like if they were thicker or thinner. Here is an example.

Table 8.1 Five Fluids

Fluid	Thicker	Thinner
Shampoo	Hard to get out of the bottle	I would probably use more to wash my hair

Viscosity and Temperature

Suppose you wanted ketchup to flow faster. What could you do to change its viscosity?

Temperature is one factor that can have a big effect on viscosity. The viscosity of a fluid can change as the fluid is heated up or cooled down. Notice in Figure 8.4 how the viscosity of each liquid changes.

Figure 8.4(a) Olive oil placed in a refrigerator becomes more viscous as it cools.

Figure 8.4(b) Cold maple syrup poured on hot pancakes becomes less viscous as it heats up.

Figure 8.4(c) Hot tar, ready to spread on a road, becomes more viscous as it cools.

Temperature Changes in Liquids

Why does ketchup flow faster if you heat it? Recall that in the particle theory, a liquid is made of particles that can move past each other. When heat is added to the liquid, the particles move faster and spread farther apart. Since the distance between particles has increased, there is less attraction between the particles. This allows the particles to move past each other more freely.

As the temperature of a liquid increases, its viscosity decreases. As a result, the fluid flows more easily. The warmer the liquid, the faster it flows.

As the temperature of a liquid decreases, the particles slow down. The result is that the viscosity increases. The cooler the liquid, the slower it flows.

Figure 8.4(d) Room temperature engine oil poured into a hot engine becomes less viscous as it heats up.

Temperature Changes in Gases

Temperature affects the viscosity of gases differently from how it affects the viscosity of liquids. According to the particle theory, a gas is made of particles that are very far apart. When heat is added to the gas, the particles move faster and collide more often, resulting in greater resistance, or friction. **Friction** is a force that works to slow down motion as a result of surfaces rubbing against each other. The greater the friction, or rubbing, between particles in any fluid, the higher the viscosity. A fluid with a high viscosity has a large amount of internal friction.

As the temperature of a gas increases, friction increases, and so the viscosity of the gas increases (Figure 8.5). The warmer the gas, the slower it flows.

As the temperature of the gas decreases, the particles slow down and collide less often, so there is less friction. The result is that the viscosity decreases. The cooler the gas, the faster it flows.

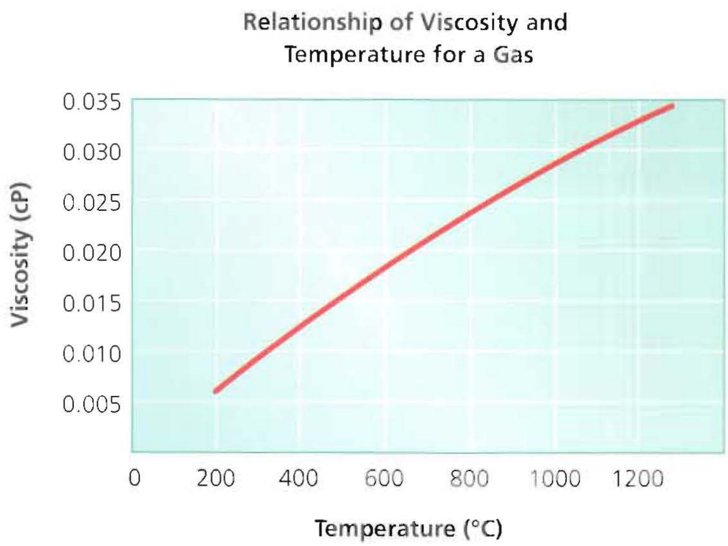


Figure 8.5 As the temperature of a gas increases, its viscosity increases.

C16 *During Reading*

Thinking Literacy

Monitoring Comprehension with "Fix-up" Strategies

There are a number of things good readers do when they realize their understanding of a concept is breaking down. Many of these strategies happen naturally – you slow down the pace of your reading, reread, read ahead to see if it helps you make sense, or pause more often to think.

The reading comprehension strategies (making connections, visualizing, predicting, inferring, looking for patterns in the writing, using the text features) you have been using in previous chapters can also help you "fix up" your comprehension.

As you read about friction and viscosity on this page and the next page, keep track of the "fix-up" strategies you use to help you make sense of the text. Share the strategies you used with a partner. Did you use the same strategies in the same places as your partner? Discuss the differences.

Viscosity and Flow Rate

Different substances have different viscosities because they are made of different particles with different forces of attraction between them. One way to compare the viscosity of different fluids is to compare their flow rates. The **flow rate** of a fluid is a measure of the speed at which a fluid flows from one point to another. Flow rate is determined by measuring the amount of fluid that flows past a given point in a given time. The greater the viscosity, the lower the flow rate.

Suggested Activity •
C17 Design a Lab on page 214

Density

The amount of mass contained in a given volume is called **density**. Density describes how closely packed together the particles are in a substance. A substance is most dense when it is a solid and least dense when it is a gas. A solid is denser than a gas because the particles in a solid are much closer together (Figure 8.6).

Take It **Further**

Motor oil labels may contain viscosity ratings, such as 5W-30 or 10W-40. Investigate what these viscosity ratings mean. Start your research at ScienceSource.

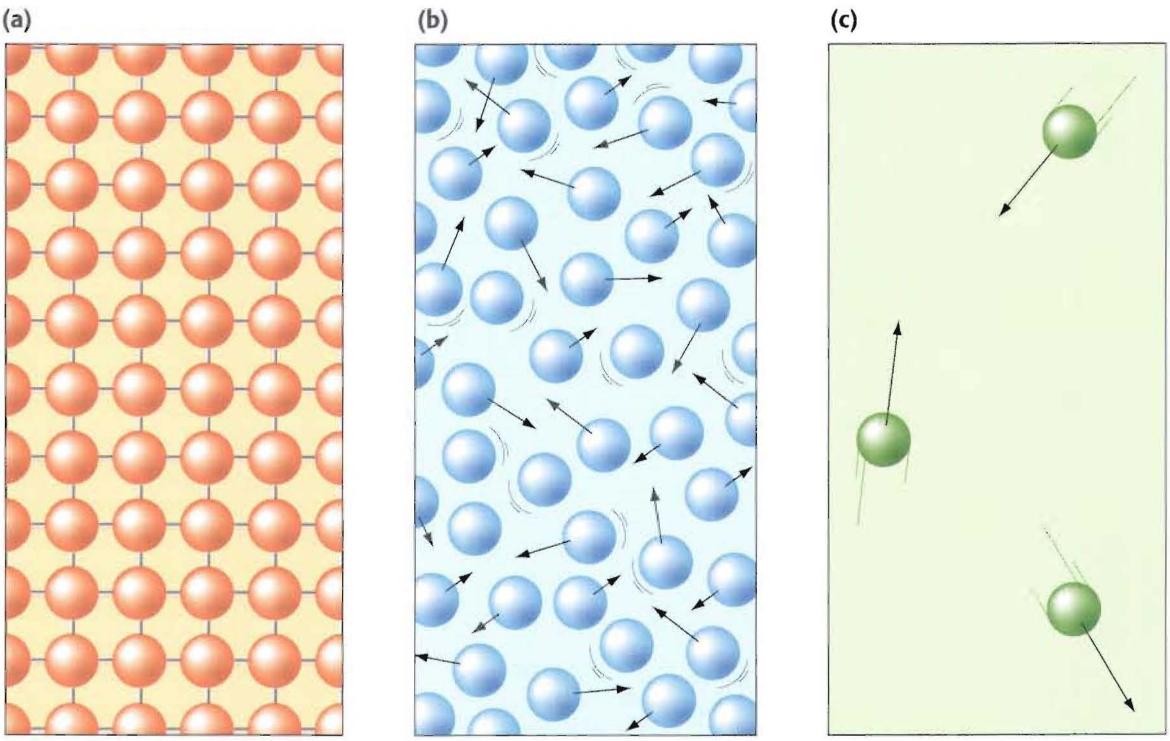


Figure 8.6 The particles in a solid (a) and a liquid (b) are packed closer together than the particles in a gas (c).

C17 *Design a Lab*

Toolkit 2

SKILLS YOU WILL USE

- Designing a fair test
- Using appropriate equipment and tools

Flow Rate of Fluids

Introduction

You can design an experiment to record the time it takes a fluid to travel a given distance. The distance divided by the time is the fluid's flow rate. Several factors can affect the flow rate of a liquid (Figure 8.7). These may include:

- changing the temperature of the liquid
- changing the angle, or tilt, of the slope the liquid flows down
- changing the diameter of the tube through which the liquid is poured

Question

How does the factor you identify affect the flow rate of pancake syrup?

Design and Conduct Your Investigation

1. With your group, decide which factor you are going to test.
2. Make a hypothesis about how the factor will affect the flow rate of pancake syrup.
3. Decide what materials you will need to test your hypothesis.
4. Plan your procedure. Think about these questions.
   (a) What evidence are you looking for to support your hypothesis?
   (b) What steps will you follow to collect the data you need?
   (c) How will you make sure the test you are planning is fair?
   (d) How will you make sure the test you are planning is safe?
   (e) How will you record your results?
5. Write up your procedure. Be sure to show it to your teacher before going any further.
6. Carry out your experiment.
7. Compare your results with your hypothesis.
   (a) Did your results support your hypothesis?
   (b) If not, what possible reasons might explain the difference?
8. Present your findings to the class or in a form suggested by your teacher.

Figure 8.7 Molasses has a lower flow rate and higher viscosity than water.

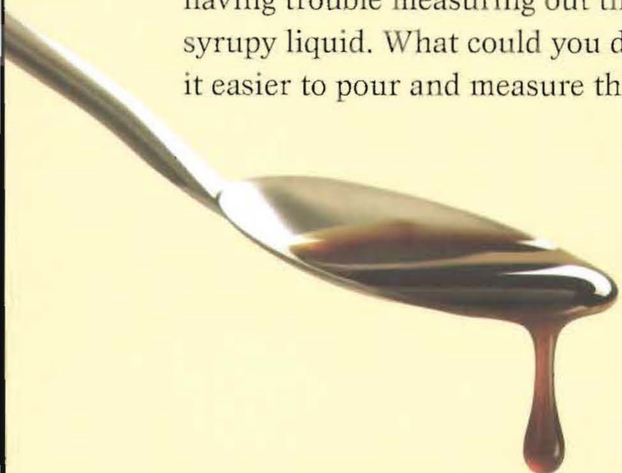
8.1 CHECK and REFLECT

Key Concept Review

1. Write a short paragraph to describe viscosity. Include at least two examples of fluids and the words "flow," "fluid," "particles," and "viscosity."
2. Draw a diagram to show what happens to the particles when a liquid is heated.
3. Draw a diagram to show what happens to the particles when a gas is heated.

Connect Your Understanding

4. You are making cookies that call for 3 tablespoons of molasses, but you are having trouble measuring out the thick, syrupy liquid. What could you do to make it easier to pour and measure this fluid?



5. Describe two substances that are useful because of their viscosity.
6. You are given three samples of the same shampoo at three different temperatures: 35 °C, 50 °C, and 75 °C.
   (a) Which sample has the highest viscosity?
   (b) Which sample has the highest flow rate?
   (c) Which sample has the highest density?

Practise Your Skills

7. In a fair test, you should change only one variable so that you can see the effects of the variable you changed. Suppose you were investigating the flow rates of various liquids by measuring the time that each took to flow down a ramp.
   (a) What variable would you change during the tests?
   (b) What variables would you keep the same?

For more questions, go to ScienceSource.

C18 *Thinking about Science and Technology*

Measuring the Flow Rate of Gas

You can determine the flow rates of liquids by pouring them down an inclined plane. However, many technologies, such as a firefighter's air tank and helium used to blow up balloons, use gases rather than liquids as the fluid that flows through the system.

1. When might it be important to know the flow rate of a gas?
2. How is the flow rate of a gas controlled as it leaves a storage container?
3. How might understanding the flow rate of a gas be useful in preventing environmental disasters?

8.2 Density and Buoyancy

Here is a summary of what you will learn in this section:

- Density is the ratio of mass to volume.
- The solid state of a substance is usually denser than the liquid state. The liquid state is denser than the gas state.
- The upward force exerted by a fluid is called the buoyant force.
- Archimedes' principle states that the buoyant force on an object is equal to the weight of the fluid displaced by the object.

Figure 8.8 Some fluids are denser than others.

If you drop a grape into water, what happens? The grape sinks. However, if you drop the grape into corn syrup, it floats. Why does a substance float in some fluids, but sink in others?

- If the density of a substance is greater than the density of the fluid, the substance will sink.
- If the density of a substance is less than the density of the fluid, the substance will float.
- If the density of a substance is the very same as the density of a fluid, the substance will "hover" in place.

A grape floats on corn syrup, a plastic building block floats on water, and a cork floats on oil (Figure 8.8).

C19 *Starting Point*

Skills A C

Dense and Denser

You have six identical jars full of different materials in front of you.

Table 8.2 Different Densities

Contents of Jars	
1. water	4. aquarium stones
2. sand	5. shampoo
3. corn syrup	6. wood chips

1. Without opening the jars, rank them in order of highest density to lowest density.
2. What ranking did you choose? Be prepared to explain your reasons for the order of your ranking.
3. Keep your ranking handy. You may test these substances later in C21, Calculating Mass-to-Volume Ratio on page 222. You can then compare your ranking with the results of your investigation.

Sink or Float?

If all metals have a greater density than water, how is it possible for metal boats to float on water? The answer is that a boat consists of more than just metal. If you consider the density of the air inside the boat and the density of all the objects in the boat, you would find that the combined density of all parts of the boat is less than the density of the water (Figure 8.9).

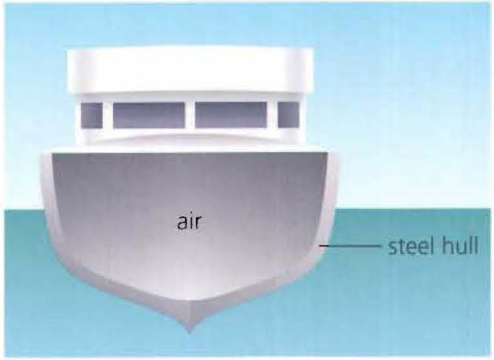


Figure 8.9 The average density of the boat is less than the average density of the water, so the boat floats.

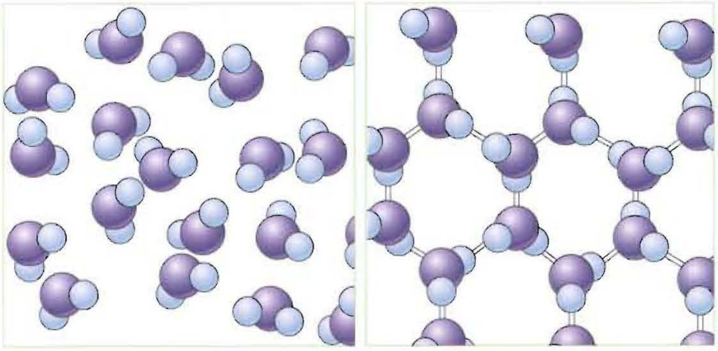
The submarine described in the Unit Opener floats when its tanks are filled with air because the combined density of all parts of the vessel, including the air, is less than the density of water. When the tanks are filled with water, the combined density of the water in the tanks and all other parts of the vessel is greater than that of the surrounding water, so the submarine sinks.

Density and Temperature

A substance can have different densities, depending on its temperature. For example, imagine swimming in a lake on a hot summer day. The water on the surface of the lake is noticeably warmer than the water below it. The warm water floats on the cold water because it has a lower density than that of cold water.

You may have noticed that the air in a room is warmer toward the ceiling and cooler toward the floor. The warmer air has a lower density, so it rises above the cooler, higher density air along the floor.

According to the particle theory, particles in a substance move more quickly when energy is added. As a substance warms up, the particles move faster and farther apart. This causes the volume to increase even though the number of particles stays the same. With the same number of particles in a larger volume, the density decreases. A substance generally has a greater density in its solid state than in its liquid state and gas state. One exception to this is water (Figure 8.10).



(a) Water **(b)** Ice

Figure 8.10 The particles in water move slightly farther apart as the water freezes, so ice is less dense than liquid water.

Calculating Density

Density is the ratio of mass to volume. The unit for measuring the density of liquids is usually grams per millilitre (g/mL). For gases, the most commonly used unit is kilograms per litre (kg/L). The unit for measuring the density of solids is usually grams per cubic centimetre (g/cm^3). You can calculate the density of a substance by dividing its mass by its volume.

$$\text{Density } (D) = \frac{\text{mass } (m)}{\text{volume } (V)}$$

Sample problem: A 2.0 mL sample of oil has a mass of 1.76 g. What is its density?

$$D = \frac{m}{V}$$

$$= \frac{1.76 \text{ g}}{2.0 \text{ mL}}$$

The density of oil is 0.88 g/mL.

Suggested Activity
C21 Inquiry Activity on page 222

Comparing Densities

The graph in Figure 8.11 shows the densities of some common substances. A substance with a greater slope on the graph has a greater density than a substance with a shallower slope. Notice in the graph that gold, iron, and aluminum have greater densities than water. This means that these metals will sink in water. Which fluids are less dense than water? Vegetable oil, rubbing alcohol, and gasoline will all float on water. Some solids, such as pine wood, are less dense than some liquids. That is why wood floats on water or oil.

Suggested Activity
C22 Problem-Solving Activity on page 224

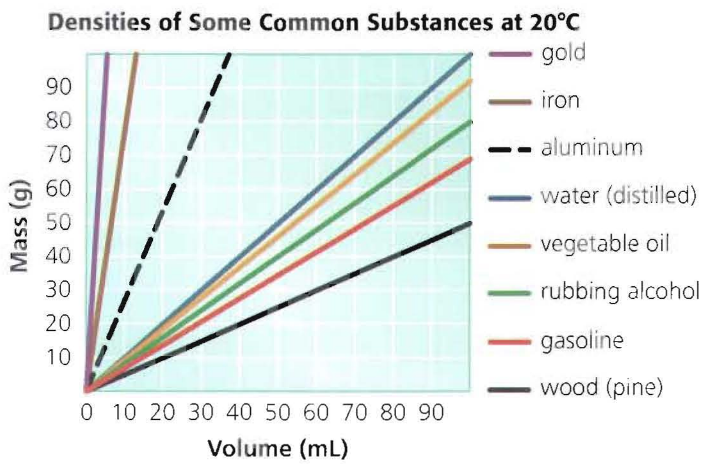


Figure 8.11 Notice which substances are less dense than water.

C20 Learning Checkpoint

Calculate and Compare

1. A 15-mL sample of gasoline has a mass of 11 g. What is the density of the gasoline?
2. What is the density of a 2.5-cm^3 glass marble that has a mass of 7.5 g?
3. The mass of 5.0 mL of rubbing alcohol is 4.0 g. The mass of an 8.0-cm^3 block of wood is 5.6 g. Which of these materials has the greater density?

Use the graph in Figure 8.11 to answer the following questions.

4. Which substances have a lower density than rubbing alcohol?
5. If gasoline and vegetable oil were poured into the same container, which substance would be on top?
6. What is the mass of 30 mL of aluminum?

Forces in Fluids

A **force** is a push or pull that acts on an object. For example, weight is the amount of downward pull on an object due to the force of gravity. The measuring unit of force is the newton (N). One newton is approximately equal to the force you would exert to hold up a baseball.

Buoyancy

You have just learned that an object sinks when its density is greater than the density of the fluid it is in. **Buoyancy** is the tendency of an object in a fluid to rise or sink due to density differences with its surroundings. What is the connection between the object's density and the forces that act on it in a fluid?

Earth's gravitational force attracts matter downward toward Earth's centre. A fluid, however, exerts an opposite force that pushes matter upward. The upward force exerted by a fluid is called the **buoyant force** (Figure 8.12).

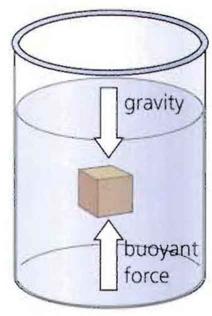


Figure 8.12 Gravity and the buoyant force act on an object in a fluid.

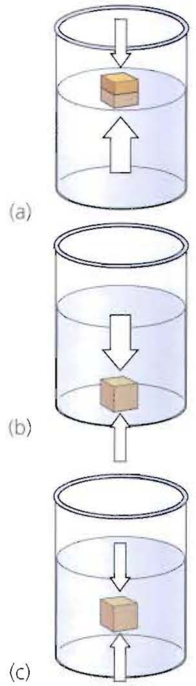


Figure 8.13 An object rises in a fluid (a). An object sinks in a fluid (b). An object floats in a fluid (c).

Buoyancy and Gravity

If you want to know whether an object will sink or float, you need to consider all the forces that are acting on the object (Figure 8.13).

- An object will *rise* in a fluid when:
  - the density of the object is less than the density of the fluid
  - the buoyant force on the object is greater than the force of gravity on the object

- An object will *sink* in a fluid when:
  - the density of the object is greater than the density of the fluid
  - the buoyant force on the object is less than the force of gravity on the object

- An object will *float* in a fluid when:
  - the density of the object is equal to the density of the fluid
  - the buoyant force on the object is equal to the force of gravity on the object

Archimedes' Principle

More than two thousand years ago, a Greek mathematician and inventor named Archimedes discovered an important principle about buoyancy (Figure 8.14). Archimedes' principle states that the buoyant force on an object is equal to the weight of the fluid displaced by the object.

Imagine two identical pieces of aluminum foil. If you take one piece of aluminum foil and crumple it up tightly, it will sink in water. But if you fold the second piece into the shape of a boat, it will float. It will even support a "cargo" of some pennies or paper clips. Even though both pieces of aluminum foil have the same mass, the piece shaped like a boat takes up a much greater volume and displaces more fluid. Therefore, the buoyant force acting on the boat and its cargo is greater, so it floats.

Figure 8.14 Archimedes (287–212 B.C.) discovered that the buoyant force depends on the weight of the displaced fluid, not on the weight of the object.

Applications of Buoyancy

Buoyancy is also an important factor in natural fluid systems. For example, a sperm whale has an oil-filled organ above its skull (Figure 8.15). When the whale is preparing to dive deep, it allows cold seawater into the organ, which solidifies the oil and increases its density. When the oil is allowed to warm, it becomes a liquid, and the whale's density is decreased so that it can rise to the surface.

Transportation technologies such as hot air balloons, airships, and research platforms use the concept of buoyancy in their design (Figure 8.16). Ships can travel around the world thanks to the buoyant force of water. But what happens when the density changes in the water through which they travel?

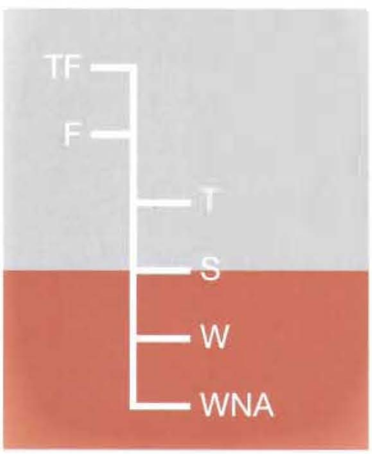
Figure 8.15 By changing the temperature of its oil, a sperm whale can dive deep or rise to the surface for air.

Figure 8.16 FLIP is a research platform that floats out to sea. The platform becomes vertical when water is pumped into its tanks.

Plimsoll Line

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

Because of density variations in the world's oceans and rivers, all cargo ships have a Plimsoll line painted on their hulls. The **Plimsoll line** shows how heavily a ship can be safely loaded in different water conditions as shown in Figure 8.17. The marks on the left indicate where the waterline should be in fresh water. The marks on the right indicate where the waterline 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 8.17 The Plimsoll line shows how heavily a ship can be loaded in different densities of water.

Take It Further

Airships have the ability to change their density in order to ascend and descend. Find out how airships change their density. Begin your search at ScienceSource.

DI Anchor Activity

C21 *Inquiry Activity*

Toolkits 2, 7

SKILLS YOU WILL USE
- Measuring
- Recording and organizing data

Calculating Mass-to-Volume Ratio

Question

How can you calculate the densities of a variety of solids and liquids?

Materials & Equipment

- 250-mL beaker
- graduated cylinder
- triple beam or electronic balance
- water, sand, aquarium stones, shampoo, wood chips, corn syrup
- graph paper

Hypothesis

Write a hypothesis about how to calculate the densities of solids and liquids.

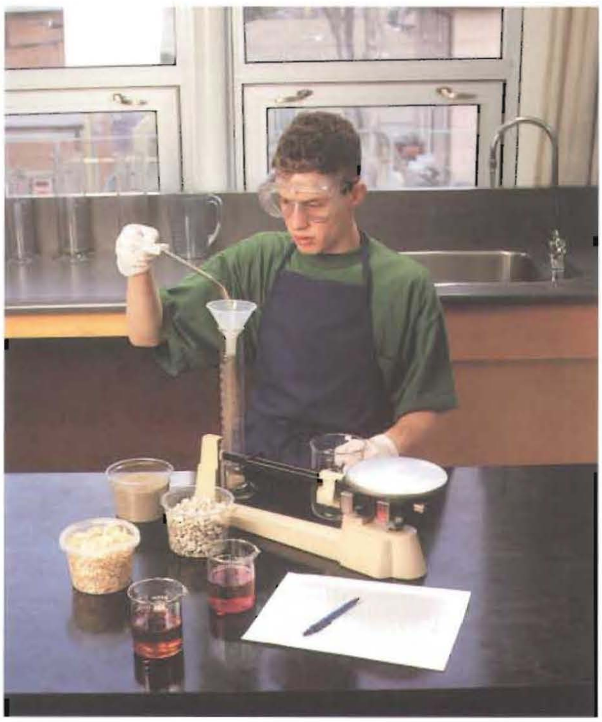


Figure 8.18 Steps 3 and 4. Carefully pour 50 mL of a substance into the beaker and record its volume and mass.

Procedure

Part 1 – Collecting Data

1. In your notebook, make a table using headings like the ones shown below to record your data. Give your table a title. Use a row in your table for each substance.

Table 8.3 Data Table

Substance	Volume of Substance (mL)	Mass of Beaker (g)	Mass of Beaker and Substance (g)	Mass of Substance Only (g)

2. Measure the mass of the beaker and record it in your table. (See Toolkit 7 for information on measuring mass.)
3. Pour 50 mL of one substance (other than corn syrup) into the beaker (Figure 8.18). Record the volume in the table. (See Toolkit 7 for information on measuring volume.) Clean up any spills immediately.
4. Place the beaker containing the substance on the balance and measure the mass. Record the mass in your table.
5. Repeat steps 3 and 4 for the substance with volumes of 100 mL, 150 mL, 200 mL, and 250 mL. Wash and dry the beaker. Return the substances as directed by your teacher.
6. Repeat this procedure for each of the other substances. The final substance you test should be the corn syrup.
7. Clean your equipment and return it to the proper location.

Part 2 – Graphing Your Data

8. When you have finished taking the measurements, enter your data into a spreadsheet program. Find the mass of each substance by subtracting the mass of the beaker from the total mass of the beaker and substance together as shown in Figure 8.19.

Figure 8.19 How to calculate the mass of the substance

9. Set up a line graph with mass on the vertical axis and volume on the horizontal axis like Figure 8.20. Plot your results for the first substance. Draw a straight line through or close to the points on the graph. Label the line.

10. Plot your results for the other substances on the same graph. Label each line.

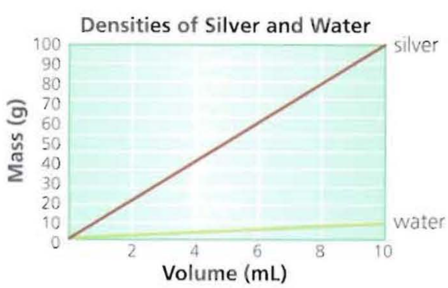


Figure 8.20 An example of step 9 for silver

Analyzing and Interpreting

11. Compare the slopes of the lines in your graph.

(a) Which slope is the steepest?

(b) Which slope is the shallowest?

12. (a) Find the ratio of mass to volume for each substance by dividing the mass of the substance by the volume. This ratio is the density of each substance. For example:

- 200 mL of a substance has a mass of 400 g. The mass-to-volume ratio is

$$\frac{400\text{ g (mass)}}{200\text{ mL (volume)}}$$

$$\text{Density} = \frac{400\text{ g}}{200\text{ mL}} = \frac{2.00\text{ g}}{1\text{ mL}}$$

(b) Record the mass-to-volume ratios in your data table.

(c) What is the relationship between the average ratio for each substance and the slope of each line on your graph?

Skill Builder

13. Use your graph to determine the answers to the following questions.

(a) What would be the mass in grams of 150 mL of corn syrup?

(b) What would be the volume in millilitres of 225 g of sand?

(c) What would be the mass in grams of 300 mL of shampoo?

Forming Conclusions

14. Write a summary paragraph that explains how you calculated the densities of the substances used in this investigation. Your summary should include the words "substance," "volume," "mass," "graph," "slope," "ratio," and "density." Include your graph with your summary.

Toolkit 3

SKILLS YOU WILL USE
- Designing, building, and testing
- Recording results

Homemade Hydrometer

Recognize a Need

A hydrometer is a device that uses buoyancy to measure the density of a liquid (Figure 8.21). In this activity, you will work in groups to design and build your own hydrometer. By using solutions of known densities, you will be able to calibrate your hydrometer. Your group will then use the calibrated hydrometer to determine the densities of unknown liquids.

Problem

How can you build a hydrometer to compare the densities of different liquids?

Materials & Equipment

- 4 tall clear containers (canning jars or 1-L clear plastic bottles with the tops cut off)
- plastic straw
- modelling clay
- fresh water
- 3 different saltwater solutions prepared by your teacher labelled A, B, C
- fine-tipped permanent marker
- 2 unknown solutions

Criteria for Success

- Hydrometer is calibrated using four known densities.
- The constructed hydrometer can be used successfully to estimate the density of unknown liquids.

Brainstorm Ideas

1. Before you begin, read Toolkit 3 about the problem-solving process.
2. Consider the materials listed here or think of other materials you could use that are easy to get.

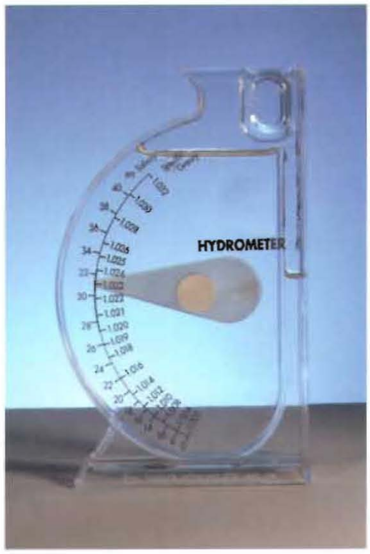


Figure 8.21 This commercial hydrometer can be used to measure the salt content in an aquarium.

3. Working by yourself or in a small group, generate ideas for designing and building a hydrometer.
4. Make a sketch of what your hydrometer will look like when you complete it. Show the sketch to your teacher for approval.

Build a Prototype

Part 1 – Fresh Water

5. Assemble the materials you need and build your hydrometer. Or you can follow steps 6 through 17 to build one using the materials and equipment listed on the left.
6. Press a small ball of modelling clay onto the end of the straw to form a plug. The straw and clay will become your hydrometer.
7. Fill your container full of fresh water.
8. With the clay end touching the water, carefully lower the hydrometer into the fresh water. Add or remove clay so that approximately 2 cm of the straw tip remains above the water.

9. Use a permanent marker to draw a line on the straw at the water level and label it "1." Your hydrometer is calibrated for the density of fresh water, which is 1.0 g/mL.

Part 2 – Salt Water

10. Remove the hydrometer from the fresh water and place it in the container that contains saltwater solution A.

11. Make a mark on the straw where the straw meets the water line and label this "2."

12. Remove the hydrometer from the solution A container and place it in the container that contains saltwater solution B.

13. Make a mark on the straw where the straw meets the waterline and label this "3."

14. Remove the hydrometer from the solution B container and place it in the container that contains saltwater solution C.

15. Make a mark on the straw where the straw meets the waterline and label this "4."

16. The densities corresponding to each of the marks on your hydrometer is given below.

Table 8.4 Density Values

Solution	Mark	Density (g/mL)
Fresh water	1	1.0
A	2	1.008
B	3	1.017
C	4	1.025

17. Make a sketch of your hydrometer showing the four marks. Label the density indicated at each mark.

Test and Evaluate

18. Your teacher will give you two unknown liquids. Use the hydrometer you built and calibrated to determine the densities of the unknown samples. You will need to estimate if the liquid comes between two of the lines on your hydrometer. Record your results.

19. Compare the densities you obtained with those of your classmates. How do your results compare with those of your classmates?

20. If your teacher has a commercial hydrometer, compare your results to the actual values.

Communicate

21. After you have determined the densities of the unknown samples, write a short report that describes:
    (a) what you did
    (b) your results
    (c) one new thing you learned in this activity

8.2 CHECK and REFLECT

Key Concept Review

1. In which state of matter is a substance the least dense?
2. What is the relationship of temperature to density?
3. What two opposing forces are acting on an object as it floats in a fluid?

Connect Your Understanding

4. The table below shows mass and volume data for mineral oil.

Table 8.5 Mineral Oil Data

Mass (g)	Volume (mL)
0.8	1.0
1.6	2.0
2.4	3.0
3.2	4.0

(a) What happens to the mass of the mineral oil as the volume changes?

(b) What is the density of mineral oil?

(c) What happens to the density as the mass and volume change?

Practise Your Skills

5. Suppose you were to graph the mineral oil data from question 4 on a graph with mass on the vertical axis and volume on the horizontal axis. Would the slope of the line for the mineral oil be shallower or steeper than the one for water? (The density of water is 1.0 g/mL.)
6. Draw a diagram to help you explain how a heavy ship can float on water.
7. What is the density of each of the following substances?

   (a) 2.0 mL of mercury with a mass of 27.1 g

   (b) 0.5 mL of silver with a mass of 5.25 g

   (c) 2.5 mL of lead with a mass of 28.5 g
8. If you had 100 mL of each substance in question 7, which one would have the greatest mass?

For more questions, go to ScienceSource.

C23 *Thinking about Science and Technology*

Worldwide Shipping

Improvements in technology have enabled larger and safer shipping around the world. Consider each of the following questions from the viewpoint of society and of the environment. Make a chart to record your ideas.

1. (a) What are some benefits that result from worldwide shipping of oil in oil tankers?

   (b) What are some problems that result from worldwide shipping of oil?
2. (a) What are some benefits that result from worldwide shipping of produce (vegetables and fruit)?

   (b) What are some problems that result from worldwide shipping of produce?

	Society	Environment
Benefits of shipping oil		
Problems from shipping oil		
Benefits of shipping produce		
Problems from shipping produce		

8.3 Pressure in Fluids

Here is a summary of what you will learn in this section:

- Pressure is the amount of force applied to a given area.
- Pressure increases with depth.
- Fluids will naturally move from an area of higher pressure to an area of lower pressure.
- Gases can be compressed easily. Liquids are very difficult to compress.

When you swim underwater, you might notice the pressure of the water around you, especially if you swim along the bottom of a deep pool. But did you know that there is also pressure around you when you are out of the water?

Pressure is the amount of force applied to a given area. Air is a fluid, and it exerts pressure around you all the time. Air pressure is the reason why your ears may "pop" when you change altitude quickly. When the air pressure outside changes, the air pressure inside your middle ear has to adjust, resulting in the popping sound (Figure 8.22).

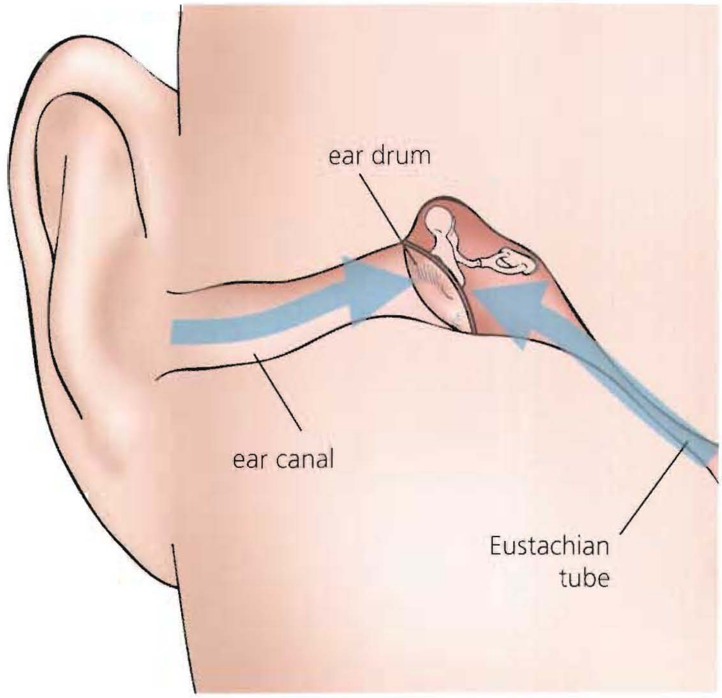


Figure 8.22 The air in the middle ear (Eustachian tube) is sometimes at a different pressure than the air in the outer ear (ear canal).

C24 *Starting Point*

Skills A C

Pressure Can — Teacher Demonstration

Observe as your teacher does the following.

1. Fill a large bowl with ice water.
2. Pour a spoonful of water into a clean, empty soft drink can. Place the can on a hotplate. Heat until the water boils and steam leaves the top of the can.
3. Using a pair of tongs, turn the can upside down and immediately plunge it into the ice water.
4. Observe what happens to the can. Give a possible explanation for your observation.

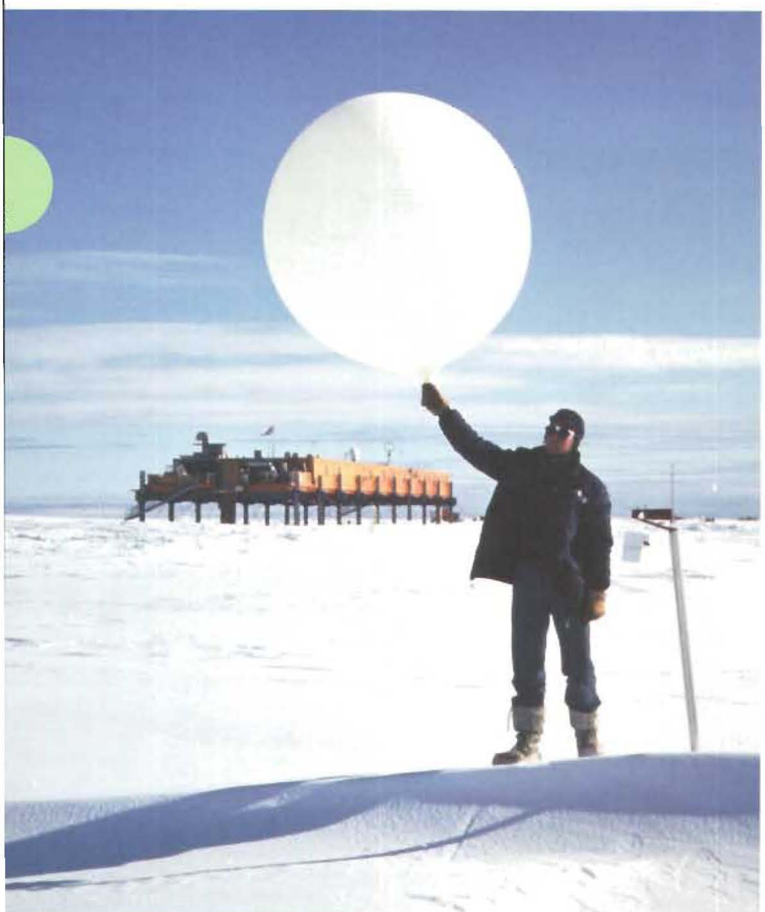


Figure 8.23 A weather balloon measures weather conditions at high altitudes. This weather balloon is being released in Antarctica.

Changes in Pressure

Air pressure changes with altitude. How does the air pressure around you right now compare with the pressure at the top of a mountain?

The layers of air in Earth's atmosphere extend more than 160 km above Earth's surface. Close to the surface, we experience air pressure as a result of all those air particles above us being pulled toward Earth by the force of gravity. There is less air pressure if we travel to higher altitudes because there are fewer layers of air above us and the air there is less dense.

You can observe an effect of this change in air pressure on a weather balloon that is released from Earth's surface (Figure 8.23). As a weather balloon passes through upper layers, there is less air pressure acting on it from the outside, so it expands as it rises. Eventually, the balloon will expand so much that it will burst.

Take It **Further**

An ultrahigh-pressure water system forces water out of a hose with 275 000 kPa of pressure. This water jet can be used for cleaning, blasting, sanding, and processing materials. Find out more about applications of ultrahigh-pressure water systems. Begin your research at ScienceSource.

Pressure and Depth

Pressure in a fluid also changes with its depth. For example, the weight of water in the upper part of a swimming pool presses down on the water in the lower part of the pool. The greater the depth of water, the greater the pressure at that point. This is why you feel a greater pressure when swimming on the bottom of a pool than you do when swimming at the surface.

You can observe an effect of this change in pressure by making two holes in a container of water, one above the other (Figure 8.24). Water at the depth of the lower hole has a greater pressure on it than water at the higher hole. The greater pressure results in the water being released with more force from the lower hole.

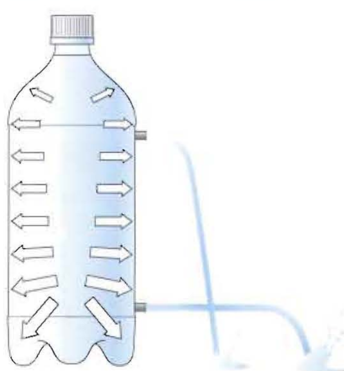


Figure 8.24 The greater the depth, the greater the pressure.

Pressure and Fluid Flow

If a fluid is allowed to move, it will always go from an area of higher pressure to an area of lower pressure. You make use of this property when you use a straw to drink from a juice box. Your mouth creates an area of lower pressure. The juice in the box is at a higher pressure, so it travels up the straw and into your mouth (Figure 8.25).

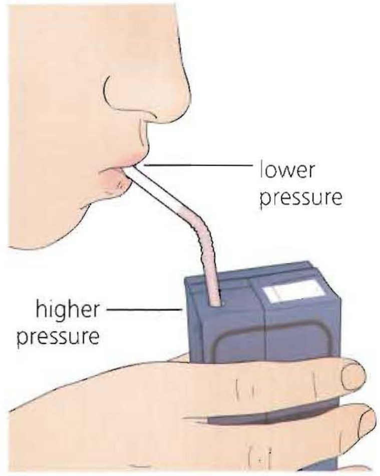


Figure 8.25 The fluid travels up the straw from an area of higher pressure in the box to an area of lower pressure in your mouth.

Pressure and Temperature

What happens to pressure inside a container when the temperature of a fluid is increased? The pressure exerted by a fluid is the sum of all the forces exerted by the individual particles in the fluid. When the temperature is increased, the particles move faster and strike the walls of the container more often and with more energy. At a constant volume, an increase in temperature results in an increase in pressure. If the volume of the container cannot increase, its pressure increases, possibly resulting in an explosion.

Compression

Suggested Activity • C25 Inquiry Activity on page 230

An important part of understanding how to use fluids in devices is knowing how they react under pressure. If you kick a soccer ball, you force the air particles inside into a smaller volume (Figure 8.26). The shape of the ball changes temporarily because the air particles inside it are compressed. **Compression** is a decrease in volume caused by a force.

There is a large amount of space between the particles in a gas like the air in the soccer ball. There is much less space between the particles in a liquid. This means that gases are much more compressible than liquids are. When a force is applied to the particles, much more compression takes place in the gas than in the liquid. In fact, very little compression occurs in liquids.

Compressibility is the property of being able to be compressed. Materials in a liquid state are said to be **incompressible**, which means they cannot be compressed easily. As you will see in Chapter 9, this property of liquids is very useful.

Figure 8.26 Your foot compresses the air inside the soccer ball as you kick it.

C25 *Inquiry Activity* Toolkit 2

SKILLS YOU WILL USE
- Using appropriate equipment and tools
- Drawing conclusions

Compressing Fluids

Question

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

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
- four 1-kg masses
- water
- empty container

Figure 8.27 Step 1. The plunger should be three-quarters of the way up the tube.

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 (Figure 8.27).
2. Before you press the plunger down, predict how far the plunger will go. Record your prediction.
3. Press the plunger down and record the change in volume in the syringe.
4. Unclamp the tubing. 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.
6. Record the volume in the syringe before you push down the plunger. Press down the plunger and record the change in volume in the syringe.

Part 2 – Compressing Water

7. Make a data table like the one below for recording your data. Give your table a title.

Table 8.6 Data Table

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

8. Use the burette clamps to attach a modified syringe (with platform) to a support stand, as shown in Figure 8.28.

Figure 8.28 Step 8. Be sure to follow safe work procedures. Clamp the syringe tightly at right angles to the stand.

9. 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.

10. Place a 1-kg mass on the centre of the platform that is attached to the syringe. (This mass applies a 10 N force.) Measure and record the volume of air in the syringe.

11. Repeat step 10 by adding another 1-kg mass so that you have 2-kg mass (20 N).

12. Repeat step 11 for 3 kg (30 N) and 4 kg (40 N). Place the masses in the centre of the platform.

13. Remove all of the masses.

14. 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. Re-attach the syringe with the burette clamps. Place an empty container under the syringe. Repeat steps 10, 11, and 12.

15. Clean your equipment and return it to the appropriate location. Wash your hands after you finish the activity.

Analyzing and Interpreting

16. How did your predictions compare with your results?

17. (a) Which fluid compressed more?
    (b) Why do you think this happened?

18. How did the force affect the compression of the air and the water?

Skill Builder

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

Forming Conclusions

20. Use the particle theory of matter 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.

8.3 CHECK and REFLECT

Key Concept Review

1. What term describes the amount of force applied to a given area?
2. Why might your inner ears "pop" when you are driving through the mountains?
3. Explain why gases are easier to compress than liquids.
4. Use the terms "decreases" or "increases" to complete the following statements.
   (a) As you go deeper in a fluid, the pressure of the fluid ____________.
   (b) A sealed container is cooled. The pressure of the fluid inside the container ___________ .

Connect Your Understanding

5. Suppose a dam developed a hole from which the water started to leak out. Why would it be harder to stop the leak if the hole was near the bottom of the dam as compared to near the top?
6. On a cold winter day, you discover that the football you left outside is soft (has low pressure).
   (a) How could you increase the pressure inside the ball without adding more air?
   (b) Explain why you think your solution would work.

Practise Your Skills

7. Picture a device, such as a vacuum cleaner, that uses the motion of fluids in its design. Make a sketch of the device and show the direction that the fluid moves. Using your sketch, explain
   (a) where the areas of low pressure and high pressure exist
   (b) how the device creates areas with different pressure

For more questions, go to ScienceSource.

C26 *Thinking about Science and Technology*

Pipes and Plumbing

The pipes in your home's plumbing system bring fresh water to your taps and carry waste water away. The word "plumbing" comes from a Latin word meaning lead. At one time water pipes were made from lead. However, in the early 1900s, researchers discovered that lead is a poison. It builds up in the body and affects the nervous system.

1. What environmental factors would you have to consider in choosing material for building water pipelines?
2. What other factors would you have to consider in choosing material for building water pipelines?

Meteorologist

We live in a fluid world. A blanket of air extends above us for almost 160 km. Approximately three-quarters of Earth's surface is covered in water. These two fluids interact, causing changes in temperature and pressure and creating the variations in our weather. A meteorologist is a person who studies these interactions, and collects and analyzes data to forecast our weather.

Meteorologists use data collected from several locations to make a weather forecast. Weather forecasts can be for the same day, for short term, or for long term. Same-day forecasts usually are done by making simple observations. Data collected from radar and satellites are used when making short-term forecasts. Computer models are used for long-term forecasts. Some of the measurements that meteorologists use when making a forecast include temperature, wind, humidity, and air pressure.

Weather forecasting can save lives by giving advance warning of storms or sudden changes in temperature. Meteorologists provide weather forecasts that are essential for air and ocean travel. Agriculture and tourism also depend on the services of meteorologists.

On a global scale, meteorologists analyze the input of industrial projects and human activities on climate and air quality. Meteorologists also take part in studies involving the effect of air pollution on climate.

To become a meteorologist in Canada, you must first have a university degree in meteorology, mathematics, or physics. After your degree, you need to complete a nine-month training course provided by Environment Canada.

Figure 8.29 A meteorologist evaluates data on pressure systems for Hurricane Katrina on August 29, 2005.

Pressure Systems

Why is it important for meteorologists to measure air pressure? When the pressure in an area is higher than the pressure in surrounding air, a high-pressure system occurs. A high-pressure system usually provides us with sunny, dry weather. When the pressure in an area is lower than the surrounding air, a low-pressure system occurs. Clouds and precipitation usually accompany a low-pressure system.

Questions

1. List four types of data a meteorologist uses when forecasting the weather.
2. Describe the type of weather accompanied by
   (a) low-pressure system
   (b) high-pressure system
3. Suppose you had all the skills of a trained meteorologist. Explain how you would use these skills to improve the quality of life for people in your community.

8.0 Chapter Review

Assess Your Learning

Key Concept Review

1. (a) What is viscosity? K

   (b) Why is viscosity an important property of matter? K

2. How does temperature affect the viscosity of a fluid? K

3. What does density measure? K

4. Describe how you find the density of an object. K

5. How does the particle theory of matter help you explain why cold water is denser than hot water? C

6. What units are usually used for measuring the density of the following substances? K

   (a) solids

   (b) liquids

7. Use the particle theory to explain the differences in compressibility between liquids and gases. K

8. Use your answer for question 7 to identify which material in each pair below would compress more than the other. Provide a brief reason for each answer. A

   (a) a helium balloon or a water balloon

   (b) a solid rubber bicycle tire and an inflated mountain bike tire

   (c) plastic bubble pack or a baby's liquid-filled teething ring

   (d) a golf ball or a soccer ball

9. What does Archimedes' principle state? K

10. A full juice can has a hole at the top and another hole near the bottom. K

    (a) How will the juice flow out of the two holes?

    (b) Why is there a difference?

After Reading Thinking Literacy

Reflect and Evaluate

Revisit your KTW chart from the start of this chapter. Did you find answers to all the things you wanted to know?

Summarize your learning in the 3-2-1 organizer below:

3 important things I learned

2 fix-up strategies I used to monitor my comprehension

1 question I still have

ACHIEVEMENT CHART CATEGORIES

K Knowledge and understanding   T Thinking and investigation   C Communication   A Application

Connect Your Understanding

11. You have two fluids of unknown density. How could you find out which is denser without mixing the fluids?

12. Using the information you learned in this chapter, state whether air would flow into or out of a low-pressure system. Explain.

13. Explain why deep-sea fish are not crushed by the pressure of all of the water above them.

Practise Your Skills

14. (a) What is the density of a shampoo if 6 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 54 mL?

(c) What is the density of gasoline if 90 mL of gasoline has a mass of 62 g?

(d) If you had 50 mL of each of shampoo, vegetable oil, and gasoline, which of the three would have the least mass?

Unit Task Link

In your Unit Task, you will investigate the effect that a variable of your choice has on the movement of fluid in a pipeline. What properties of liquids will be part of your hypothesis? Be sure to include key ideas like viscosity, density, and pressure when you continue work on your task.

C27 Thinking about Science and Technology

Propane Tanks

Many people use propane tanks to fuel their barbecues. When a propane tank is filled, the propane gas is compressed into a liquid. When you open the valve on the tank, the propane is released as a gas.

1. Why should propane barbecues only be operated outdoors, in well-ventilated conditions?

2. There is a policy in some high-rise apartment buildings that propane barbecues are not allowed on balconies.

   (a) Why do you think that is?

   (b) Do you agree with the rule? Why or why not?

   (c) Do you think residents should be allowed to vote and decide if barbecues will be allowed? Explain.