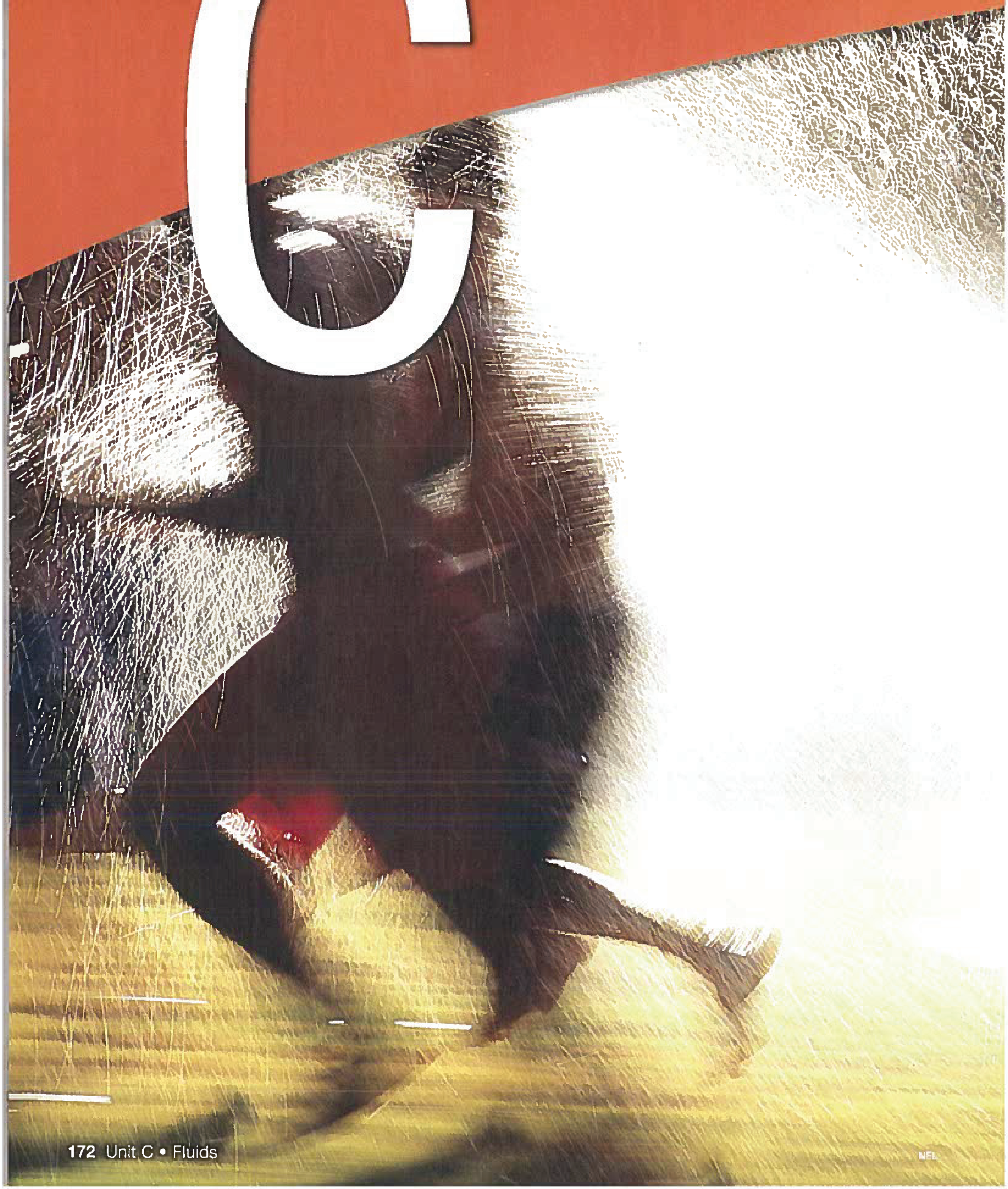
UNIT C FLUIDS



Unit Preview

The air we breathe, the water we drink, and the blood that flows through our veins are all essential to life. Blood transports nutrients and oxygen throughout our bodies. Countless organisms spend their entire lives in rivers, lakes, and oceans. The rest of us live on Earth's surface surrounded by air in the atmosphere.

In water parks and lakes, we swim and play in water. Birds and aircraft use the flow of air over their wings to fly. Earth-moving machinery and industrial equipment use the power of fluids to do work.

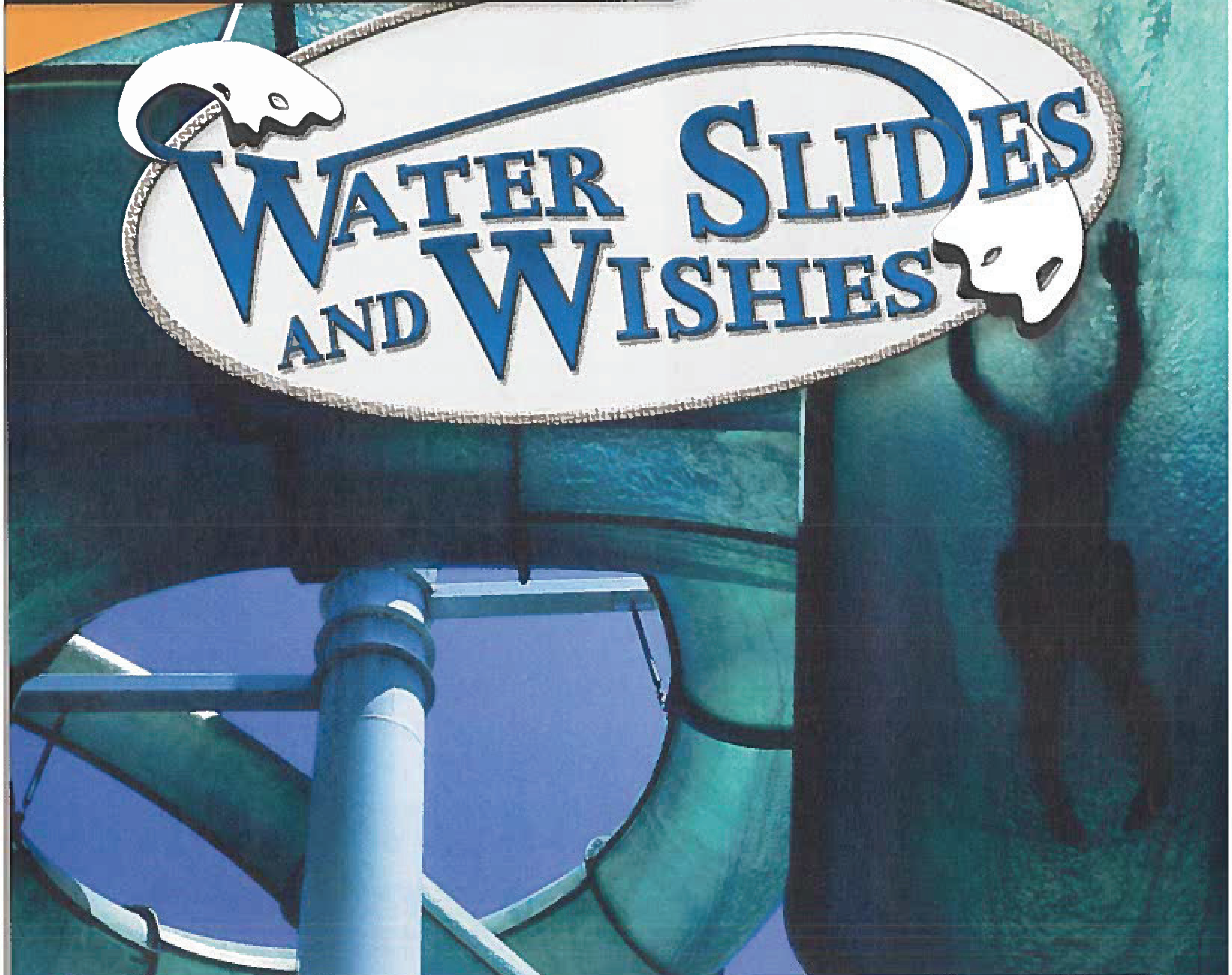
Water and air are fluids—materials that can flow from one place to another—but are they the only kinds of fluids? What properties do fluids possess? How can we put fluids to work? What is the link between fluids in nature and fluids in human-made systems? How do fluids affect society and the environment? What responsibility do we have to use Earth's fluids wisely? You will find answers to these questions as you work through this unit.

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.**

Discover **Science and Technology**

Water Slides and Wishes



I have never liked heights—not ever. Even when I was a little kid, I liked having my feet on the ground. Good, solid ground. So why am I at the top of this massive water slide?

My mom is an engineer; she likes to solve problems and help design new things. Recently, a group of local business owners and politicians started talking about building a water theme park just outside of town.

My mom really liked the idea. I know there was a lot of talk around the dinner table and in town about how the park would help local businesses by attracting tourists. Tourists would bring money to the area and create more jobs. I liked the idea, too. What could be more fun than a water theme park close to my own town? I just wasn't too sure about those really big water slides…

Some townspeople were not as enthusiastic. They liked the town as it was. They also wondered how a water park might affect the local environment. Theme parks like this need massive amounts of water. The visitors would need lots of food and lots of bathrooms! Would our town be able to handle the water and sanitation needs? The pumps and machinery required to move, filter, and clean the water use a lot of energy. How would this affect the town?

The talk went back and forth for more than a year, and I still was not sure how I felt. The closer the town came to making a decision, however, the more excited Mom got. She was thrilled when the firm she works for won the contract. So I started talking it up—all about how great it would be to "ride the slide."

Now it's opening day with free passes for everyone in town. I didn't know how to back out, so I am at the top of this tower. I am at the edge, and, well… wish me luck!

LINKING TO LITERACY

Critical Literacy

Critical literacy involves using language to improve people's lives and to question unfairness in the world. All authors express their beliefs through their writing; readers can analyze what they read by asking themselves why, how, and for whom a text was written. The reader can also look to see whose point of view is represented, and whose point of view is silent.

After reading this text, compare the point of view for each of the following: the mom; the business owners and politicians; some townspeople; the young boy; and, you, the reader.

Consider the following questions:

- Why do different people have different points of view on this issue?
- In the end, the water park is built. Whose wishes were respected? Whose wishes were ignored? Why?
- If you had participated in this issue, what would you have done?

UNIT C

Let's Get Started

Sharing Knowledge about Fluids

Fluids make up a large part of our surroundings. Fluids are also a large part of the bodies of living things. They are so much a part of our lives that we often take little notice of them.

This activity will help you review what you already know about fluids. You will share your knowledge of fluids with your classmates.

1. Copy Table 1 onto a large piece of paper.

Table 1

FLUIDS	
What?	Where?
How used?	Environmental/Societal Impact?

2. In a small group, list all the things you know about fluids under four headings:
   - **What?** Tell what you think fluids are, and give examples of as many as you can.
   - **Where?** Tell where you think fluids are found.
   - **How used?** Describe ways in which you think humans and other living things use fluids and how we can use them to do work.
   - **Environmental/Societal Impact?** Describe some of the harm that you think fluids (including the way we use fluids) cause in the world. Also describe some of the benefits that fluids provide for society and the environment.
3. As a group, decide which points in each quadrant are most important. Highlight the two most important points in each quadrant.
4. Do a gallery walk to see what others have written on their papers. After you return, discuss with your group any adjustments you wish to make. Be prepared to share your thoughts with the class.
5. Store the papers so that you can refer to them again at the end of the unit.
6. On your own, use the results of your discussions to begin building a concept map for Fluids. Figure 1 provides a starting example. You will continue to add to this concept map as you work through the unit.

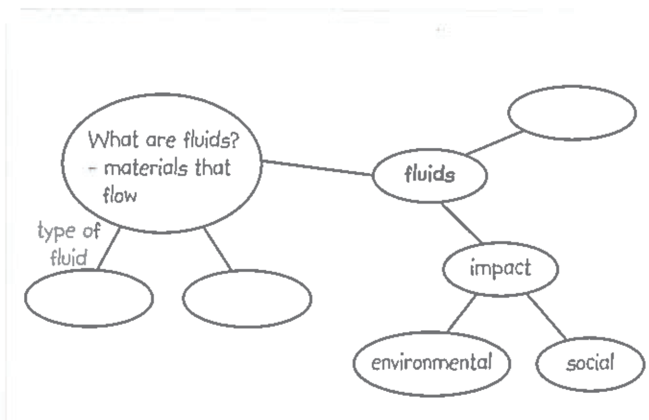


Figure 1

Unit Task Preview

Playing with Fluids

We use the properties of fluids in many ways. Moving huge machinery and designing spray bottles for perfumes both use the properties of fluids. Fluids also play a role in children's toys.

A local public school is holding a toy fair. Your class has been asked to create toys for a display called "Playing with Fluids." In this Unit Task, you are to use the properties of fluids to design a toy that can move on land, through the air, or on or through water. Toys that move in a controlled manner are preferred.

You will also develop a brochure that uses scientific and technological terminology to explain how your toy works. Your brochure will also explain why your toy can be considered "environmentally friendly."

For the contest, you can design and build one of the following devices.

1. **Land Roamer** Vehicles, robots, and walking machines can all move along solid surfaces. Design and build a toy that uses the properties of fluids to move over land.
2. **Water Wonder** Boats, submarines, and diving machines all move using the properties of fluids—either the fluids inside them or the fluids that flow around them. Design and build a toy that uses these properties to move on or through water.
3. **Air Rider** People who design toys or other devices that move through the air must understand and use the properties of gases. Design and build a toy that uses the properties of fluids to move through the air.

Unit Task By the end of the Fluids unit, you will be able to demonstrate your learning by completing this Unit Task. As you work through the unit, think about how you might meet one of these challenges. Read the detailed description of the Unit Task on page 252, and look for the Unit Task icon at the end of selected sections for hints related to the task.

Assessment

You will be assessed on how well you

- plan and design your toy
- build, test, and improve your prototype
- explain your toy in a brochure

CHAPTER

7 Fluids on the Move

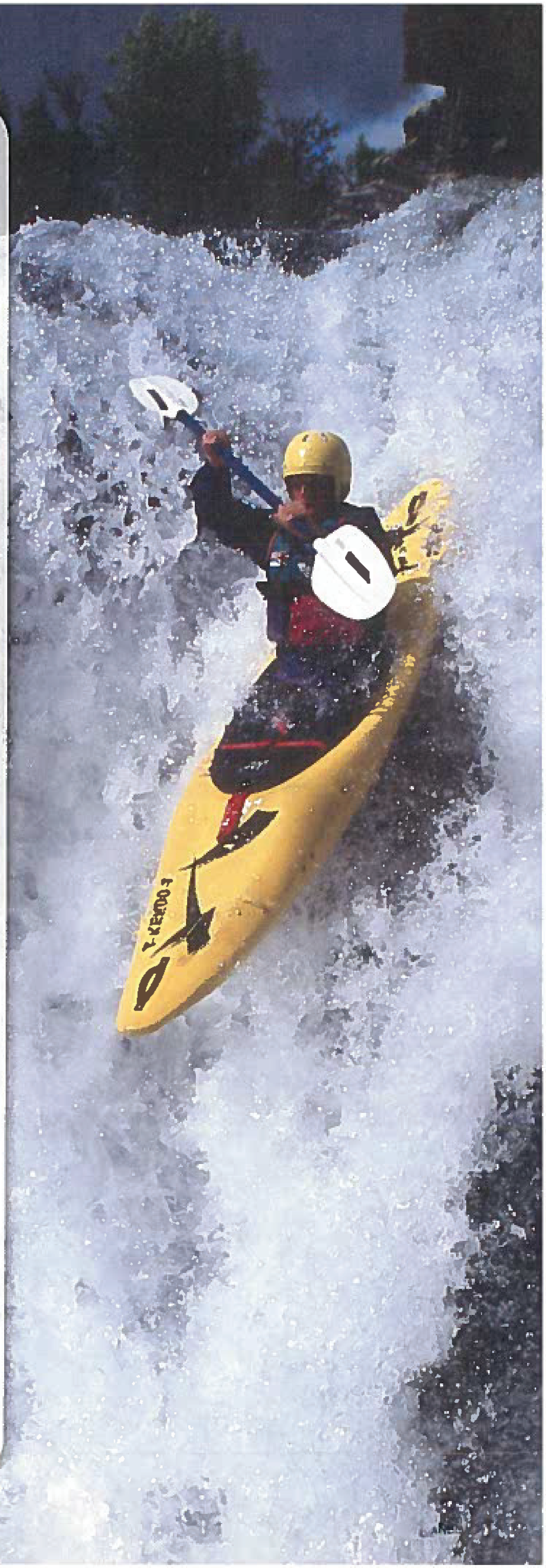
KEY QUESTION: How does the flow of fluids affect our lives?

Looking Ahead

- Fluids are essential to life.
- A key characteristic of fluids is their ability to flow.
- The way fluids flow depends on various factors.
- The skills of scientific inquiry can be used to investigate factors that affect the flow of different fluids.
- Humans control fluid flow (either through objects or around them) to meet certain needs.
- Research skills can be used to investigate applications of fluids.
- The flow of fluids can have positive and negative effects on society and the environment.

VOCABULARY

fluids
particle theory of matter
laminar flow
turbulent flow
eddy
streamlined
flow rate
viscosity
cohesion
surface tension
adhesion
fluid mechanics
fluid dynamics
aerodynamics
hydrodynamics



Rushing and Resting

Fluids can give us pleasure and sometimes cause us pain. Read the following scenes, which show two different reactions to flowing air and water.

His heart pounded in his chest, sending blood to muscles that must not fail as he tipped over the waterfall's edge. Years of building his skills and learning to read the river had brought him to this point. He had watched and practised, advancing from slow, flat water to turbulent, white water. He knew when to tackle the next run of rapids and when to pull into quiet waters behind a rock to rest. He had even attempted a few small waterfalls, but nothing like this. His heart leaped into his throat as he began to fall.

She watched the violent storm from her window. The winds battered nearby trees, while waves crashed upon the shore. Before the electricity went out, she had heard radio reports of a possible tornado touching down near her home. Tornados are rare in Ontario, but they do happen. Her heart beat faster and her breathing increased with each creak and crack of the house. She knew that all she could do was try to stay calm and wait for the storm to pass.

LINKING TO LITERACY

Making Connections

To gain deeper meaning from your reading, practise making connections between what you are reading and your personal life experiences. You can also make connections to other texts you have read or to what you have seen or heard about this topic in the world around you.

1. Examine the photograph and read the stories on this page. Think about similar texts that you may have read in which characters had a river adventure or experienced a severe storm. How do these compare to the stories on this page? Discuss with a partner.
2. Think of a time when you had a heart-pounding experience like the characters in these two stories. What connections can you make between your experience and the ones on this page?
3. What have you learned about tornadoes from books, articles, or the news? How does this information match or not match what you read in the second story?

7.1 Fluids Everywhere

Figure 1 All homes contain many different fluids.

fluids: materials that have no fixed shape and are free to flow, such as liquids and gases

You likely think of water when you hear the word "fluid," since water is a fluid you use many times a day. We drink water and wash with it. We cook and clean with water. We see it in the rain that falls and the rivers, lakes, and oceans that cover Earth. We travel on it in boats and through it when swimming. Yet water is just one of many fluids we encounter daily. Examine your home, and you will find that many kinds of fluids play a role in your life (Figure 1).

We live in a world full of fluids, but not all fluids are liquids. **Fluids** are substances that flow, so gases are fluids, too. The atmosphere that surrounds Earth (Figure 2) is a fluid that is crucial to all life forms on the planet. Unfortunately, we harm the atmosphere when we release dangerous gases into the air from cars, factories, and landfill sites (Figure 3).

Figure 2 Two fluids essential for life—water and air—cover and surround our planet.

Figure 3 Human activity has an impact on the health of fluids.

TRY THIS: Counting Fluids

SKILLS MENU: performing, observing, analyzing, communicating

SKILLS HANDBOOK 2.B.7., 5.F.

In this activity, you will count and classify the fluids in your home. Think about fluids you eat, spray, cook, and clean with.

1. Go from room to room in your home. In a table similar to Table 1 below, list all the fluids you find.

Table 1

Room	Fluid found	Category of fluid	Safety warnings

Get your parents' permission before handling containers of fluids. Handle all containers of fluids safely.

2. Group the fluids into categories according to how we use them (for example, fluids for cleaning, for cooking, for eating, and so on).
3. Make note of any special safety warnings.

A. How many of the fluids you listed were liquids? How many were gases?

B. Compare the number of fluids used for cleaning to those that are food or products used in food preparation.

C. Which fluids could cause harm to you or to the environment if used or disposed of improperly? Explain.

D. Compare your list with those of your classmates. Add any new fluids that are interesting or important.

Fluids for Life

Not only do we use fluids, such as air and water, to stay alive, the human body is mostly made of fluids. Each of us is about 60–70 % water. Table 2 shows other fluids our bodies make and use.

To learn more about the role of body fluids,
Go to Nelson Science

Table 2 Some Fluids in the Human Body

Fluid	How it is used by the body
oxygen	releases energy from food
blood	acts as a transport system (Figure 4) to take materials to cells as well as gather wastes from cells
sweat	cools the body
saliva	lubricates food for swallowing and begins chemical digestion
urine	eliminates dissolved wastes from the body
stomach acid	aids chemical digestion of food

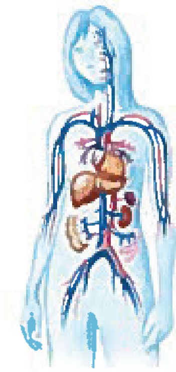


Figure 4 Blood travels throughout the human body via arteries (red) and veins (blue).

Several systems within your body make, use, or move some of the fluids listed in Table 2. These systems include the circulatory system, the respiratory system, and the urinary system. Sometimes technology is needed to maintain the health of our bodies' fluid systems.

Our body cells produce waste continuously. This waste is carried in the bloodstream and could harm or kill us if it were not removed. Kidneys filter waste from the blood and dispose of it in urine. For people whose kidneys do not work properly, a dialysis machine performs this function (Figure 5). Blood flows through a tube into the machine, is cleaned, and then returns to the body. Each dialysis treatment takes four to five hours. Dialysis does not replace all the kidneys' functions.

LINKING TO LITERACY

Reading Tables

To read a table, start by looking at the table title ("Some Fluids in the Human Body"). This tells you the type of information in the table. Next, look at the column headings ("Fluid" and "How it is used by the body"). These tell you where to locate specific information about fluids in the table. Finally, read each row. Here, you will find the details about each fluid sorted by column heading. Information listed across each row is usually connected in some way.

Figure 5 This patient must come to the hospital for dialysis treatment every two or three days to have her blood filtered mechanically.

CHECK YOUR LEARNING

1. What are fluids?
2. Name three fluids that are essential to life. Cite evidence from this section to justify your answer.
3. Blood is a critical body fluid. What role does blood play in the body? How is it usually cleaned, and how is it cleaned during dialysis?

7.2 Characteristics of Fluids

Fluids have certain characteristics that define them as fluids. For example, fluids do not have a definite shape of their own. Instead, both gases and liquids take the shape of their container (Figure 1). Although liquids do not have a definite shape, they do have a definite volume. If you pour 500 mL of a liquid from a tall, thin container into a short, wide container, its volume is still 500 mL.

LINKING TO LITERACY

Compare and Contrast

Read about liquids and gases in the first two paragraphs. Create a chart to compare and contrast them. Use Liquids and Gases as column headings. In each column, list properties of each. Now, work with a partner to discuss what you have written. How are liquids and gases the same? How are they different?

Figure 1 A key characteristic of fluids is that they take the shape of their container.

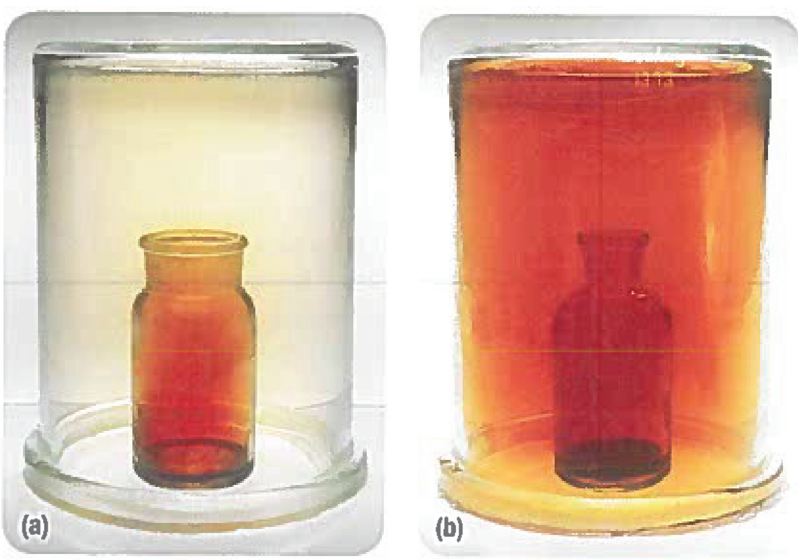


Figure 2 The brown bromine gas in the small bottle slowly moves out of the bottle (a) and fills the large container (b).

Gases, however, will completely fill any empty container they are placed in (Figure 2). Imagine if a frightened skunk entered your classroom. Skunks can spray a very strong-smelling liquid to defend themselves. The liquid quickly evaporates into a gas. Although the spray itself may be only a few millilitres, the smell (which is caused by a gas) quickly fills a room. Very soon, everyone in your school would know by the smell that a skunk is inside. Gases may not have a definite shape or volume, but some have a very definite smell!

The Particle Theory

particle theory of matter: a theory that explains what matter is made of and how it behaves

The **particle theory of matter** helps explain why fluids act the way they do. It states that

- all matter is made of tiny particles
- particles have empty spaces between them
- particles are moving randomly all the time
- particles move faster and spread farther apart when they are heated
- particles attract each other

Solids have a definite shape and volume. Although the particles of a solid are in constant motion, the forces of attraction are so strong that the particles vibrate very small distances around a central point. The particles are more or less locked in place. They cannot slide past one another (Figure 3(a)). This is why solids are generally not fluids.

Particles of liquids are farther apart than particles of solids. They are bound less tightly and are free to move past one another. The forces of attraction among particles of liquids are still strong enough to hold the liquid together (Figure 3(b)).

The particles of a gas are much farther apart, and their force of attraction is extremely small. Gas particles spread out and fill whatever container they are placed in (Figure 3(c)).

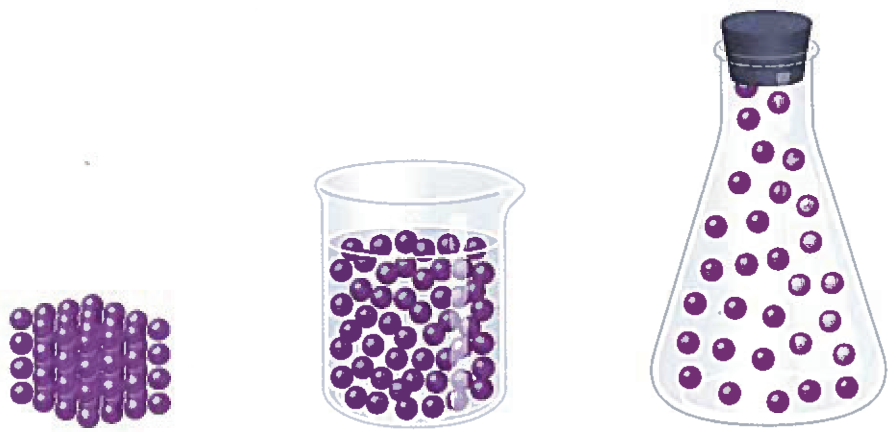


Figure 3 (a) Particles of a solid are tightly packed and locked in place. (b) Particles of a liquid are freer to move about. (c) Gas particles have large spaces between them and are free to spread out to fill their container.

LINKING TO LITERACY

Reading Diagrams

A first look at this diagram may give you little information about particles. The following tips will help you understand this diagram:

- Begin by reading the caption at the bottom of the diagram. The first sentence describes the first picture, a solid. The next sentence describes the second picture, a liquid. And the last sentence describes the third picture, a gas.
- Scan the diagram, left to right, and top to bottom. Make sure you notice all details.
- Reflect: How are the particles different in each picture?
- Make a connection: Think of something that is a solid, something that is a liquid, and something that is a gas. How are particles arranged in each?

TRY THIS: Exploring Goobleck

SKILLS MENU: performing, observing, analyzing, communicating

In 1949, Dr. Seuss introduced the mysterious substance Oobleck to the world in his children's book *Bartholomew and the Oobleck*. Today, you will examine an Oobleck-like substance (we will call it Goobleck) and determine whether it is a liquid or a solid. You will also give reasons why there might be some confusion.

Equipment and Materials: measuring cup; medium-sized bowl; graduated cylinder; spoon; cornstarch; water

1. Create your Goobleck by mixing 45 mL of cornstarch with 30 mL of water in the bowl. Stir slowly and well. When the water and cornstarch are thoroughly mixed, you can begin your investigation.
2. Perform the following actions using slow movements. Push your finger into the mixture. Slowly pour it. Let it run between your fingers. Record your observations with each new action.
3. Now perform the following actions using quick movements. Poke your finger into the mixture. Pick some up and squeeze it. Try breaking some in half. Record your observations with each new action.

A. In what ways did your Goobleck behave like a liquid?

B. In what ways did it behave like a solid?

C. Decide whether you think Goobleck is a liquid or a solid. Justify your answer.

Ability to Flow

Fluids have the ability to flow because the particles of liquids and gases are free to move about. The ability to flow through, around, or over something is a key characteristic of fluids (Figure 4). Fluids can flow through pipelines, around wings, and over rocks.

Figure 4 (a) Oil and natural gas flow through pipelines. (b) Air flow holds airplanes aloft. (c) Water flows in rivers.

You might be thinking, "I can pour salt, sugar, or sand. Do some solids also flow?" Some solids can appear to flow, especially when ground into very fine fragments or grains. Salt, for example, can be poured from one container to another and takes the shape of the box or saltshaker (Figure 5(a)). However, if you look closely at such solids you will see that each fragment still has a definite shape (Figure 5(b)). Solids form piles when poured; fluids do not. Imagine trying to make a pile of liquid water or a pile of oxygen!

To hear an audio clip about a new form of matter,
Go to Nelson Science

Figure 5 Solids in fine granular form may appear to flow (a), but on close inspection we can see their definite shape (b).

Figure 6 The ice in glaciers can "flow" over long periods of time.

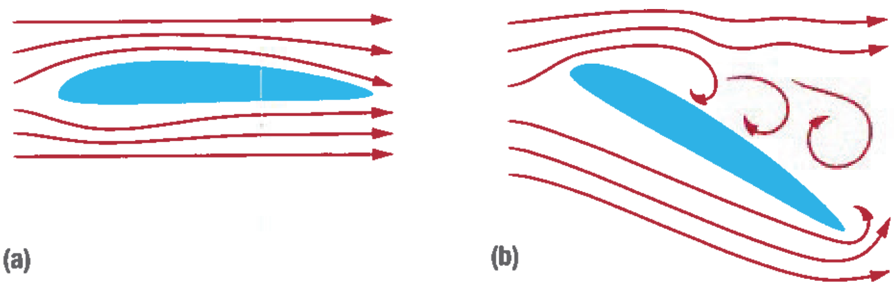
Some solids—such as the ice in glaciers (Figure 6)—are considered fluids. These solids will exhibit fluid-like behaviour when subjected to strong forces over long periods of time. The smooth surface on some glaciers shows that the glaciers are moving (flowing) slower than glaciers with a rough surface. The ability to flow is more commonly discussed with respect to liquids and gases. Fluid solids are very uncommon in everyday life on Earth's surface.

Types of Flow

Fluid flow can be divided into two main patterns—laminar flow and turbulent flow. **Laminar flow** is smooth and regular; **turbulent flow** is choppy and irregular (Figure 7).

laminar flow: a smooth pattern of flow

turbulent flow: an irregular, mixing flow pattern



(a) (b)

Figure 7 (a) Laminar flow around an airplane wing. (b) As the wing tilts more, the airflow becomes more turbulent.

LINKING TO LITERACY

Reading Diagrams

To understand the diagrams on this page:

- Read the text above the diagrams.
- Read the definitions in the margin.
- Next, read the caption at the bottom of the diagrams.
- Scan the diagrams, making sure to notice all the details.
- Follow the arrows to see how they flow around a tilted wing.

Laminar flow is when fluids move in orderly lines or along smooth pathways. In pipes and hoses, laminar flow allows fluids to move quickly with more energy. For objects such as cars, boats, and planes that move through fluids, laminar flow along the vehicle reduces resistance, or drag. Reduced drag makes the vehicle more efficient, since it needs less energy to push through the air.

Now imagine a fast-flowing river rushing down a slope. Different currents and pathways in the water can be seen in the white foam that is churned up as the water mixes with air. Turbulent flow in rivers and streams adds oxygen to the water, which is needed by fish, insects, and other organisms. Whitewater rafters, canoeists, and kayakers enjoy turbulent flow for the thrill it provides (Figure 8). For safety's sake, these thrill-seekers spend time and energy learning to "read" the river to understand the patterns that exist even within turbulent flow. For example, as water flows past rocks in the river, some of it curls back behind the rocks to form a much calmer flow called an **eddy**. Canoeists and kayakers rest in these eddies while planning the next stage of their run down the river (Figure 9).

eddy: an area of slower-moving fluid that occurs behind an obstacle

Figure 8 This kayaker understands how the turbulent flow of the river can be used to increase the thrill of the ride.

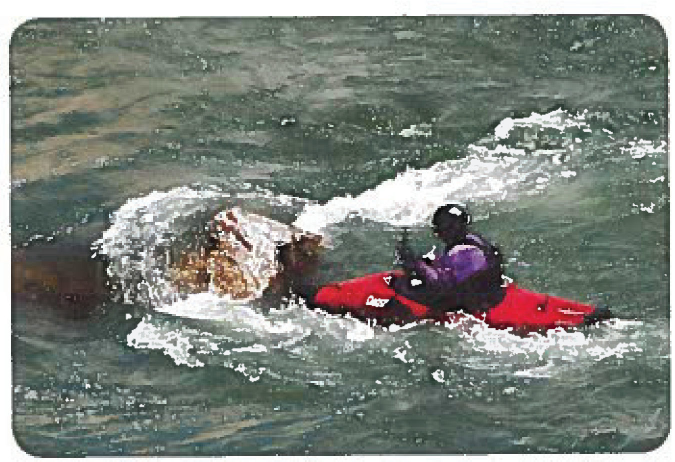


Figure 9 Knowing the patterns that exist within turbulent flow allows this kayaker to find a quiet eddy behind a rock.

Turbulence is not only found in water and air. It can also occur in a person's bloodstream. In a healthy person, blood normally flows smoothly through veins and arteries. However, over time, material called plaque can build up in arteries. Plaque build-up narrows arteries and causes additional friction, which can create turbulence in the blood flow. Turbulent blood flow and plaque may then cause blood clots to form. If the clot gets big enough, or if it moves and becomes lodged in a small artery, it can completely block the artery. This can cause heart attacks and strokes. Understanding turbulence in blood flow helps doctors and medical researchers save lives.

Figure 10 Wind tunnels and smoke trails can be used to investigate patterns of fluid flow around objects like this tennis ball.

Taming Turbulence

Scientists and engineers use their knowledge of flow patterns to reduce or eliminate turbulence so that fluids flow more smoothly. Engineers and designers often use wind tunnels and smoke trails to study air flow around objects (Figure 10). Objects that are **streamlined** have shapes that reduce turbulence and create more laminar flow.

streamlined: a smooth shape designed to decrease resistance to fluid flow

To learn more about streamlining and turbulence,
Go to Nelson Science

Managing fluid flow can create problems as well as solve them. During heavy rains, the increased volume of water can cause turbulent flow in rivers and streams, which can result in erosion of the riverbanks. Concrete linings have been used to create more laminar flow along some waterways (Figure 11). The linings also help prevent soil erosion. What problems can you think of that might be created by this solution? What other solutions might there be?

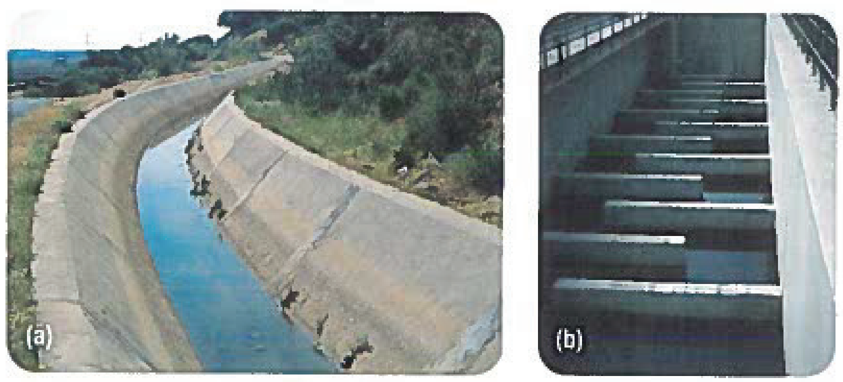


Figure 11 (a) To create a more laminar flow, this waterway is lined with concrete. (b) Concrete baffles help release some of the water's energy by creating more turbulent flow.

CHECK YOUR LEARNING

1. State two characteristics of all fluids.
2. State the particle theory.
3. Use the particle theory to explain why fluids can flow while solids cannot.
4. Draw diagrams to represent the arrangement of particles of a solid, a liquid, and a gas.
5. (a) What is the difference between laminar flow and turbulent flow?
   (b) Give one advantage and one disadvantage each for laminar flow and turbulent flow.
6. In your own words, explain streamlining.

Flow Rate and Viscosity

7.3

You probably noticed that not all fluids flow at the same rate. Water out of a tap, for example, flows much faster than honey flows over your spoon (Figure 1). Flow rate is the term used to describe how quickly fluids move. **Flow rate** measures the volume of fluid moving past a certain point in a given amount of time. We use flow rate to measure fluids moving through or out of a pipe. For example, if it takes 4 seconds to fill up a 1 L container of water from your kitchen tap, the flow rate from the tap is 1 L/4 s or 0.25 L/s. If you turn the tap only halfway, will the flow rate increase or decrease? Flow rate depends on several factors:

- the type of fluid that is flowing (thin fluids flow faster than thick ones)
- the force pushing on the fluid (stronger forces produce faster flow rates)
- the size of the pipe or opening the fluid is flowing through (larger openings allow for faster flow)
- the type of surface over which the fluid is flowing (smooth surfaces allow for faster flow)

flow rate: a measure of how quickly fluids move; measured in a volume per unit time (for example, L/s)

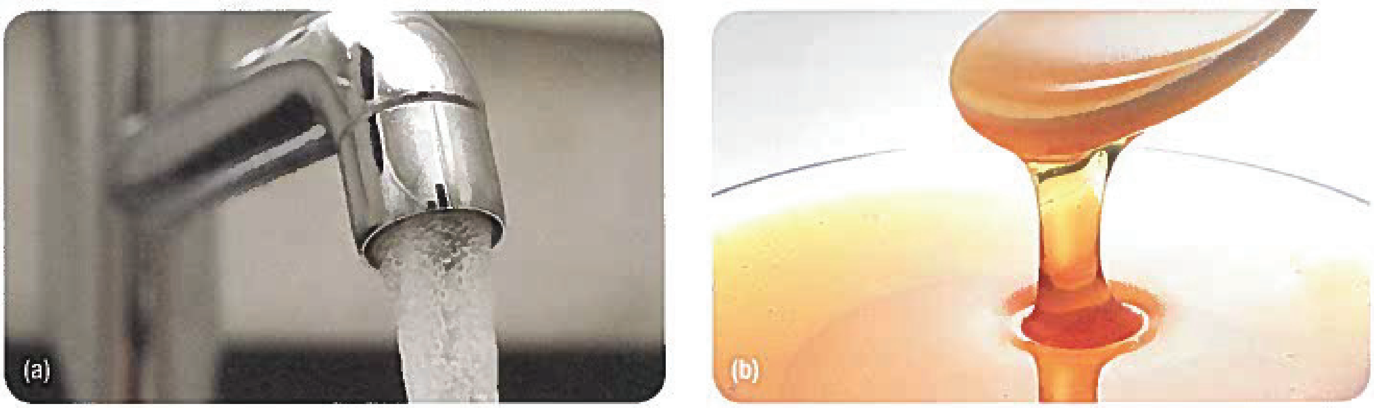


Figure 1 The flow rate of water out of a tap (a) is quite different from the flow rate of honey (b).

TRY THIS: Measuring Drips

SKILLS MENU: predicting, performing, observing, analyzing, evaluating, communicating

SKILLS HANDBOOK 2.B.3., 2.B.7.

A dripping tap wastes water… but how much? In this activity, you will determine the flow rate of a dripping tap.

Equipment and Materials: faucet; container (for example, large can, plastic jar, 600 mL beaker); graduated cylinder or measuring cup; timing device

1. Turn the faucet on so that the tap drips at a steady rate.
2. Estimate how much water the tap will waste in 1 h. Record your estimate.
3. Use your container to collect the water that drips from the tap over a 10 min period. Measure and record the volume of water collected.
4. If time allows, repeat using a faster drip rate.

A. Calculate the volume of water the tap would drip in 1 h.

B. Calculate the flow rate of the dripping tap in litres per hour (L/h) or millilitres per minute (mL/min).

C. How did your results compare with your estimates?

D. There are approximately 12 million people in Ontario. If we assume that there are three people per home, how much water would be wasted every hour if each home had one tap that dripped at the rate yours did?

LINKING TO LITERACY

Compare and Contrast: Photographs

Sometimes, illustrations or photographs are placed side by side to invite the reader to make a comparison. Look at the two photos on the right. Read the captions below the photos. What comparison are you asked to make? Can you explain why these fluids are different?

Viscosity

Some fluids pour more quickly than others. Which fluid pours more quickly, maple syrup or soy sauce (Figure 2)? Thick fluids, such as maple syrup, flow more slowly than thin, runny fluids, such as soy sauce.

Figure 2 What causes some fluids to flow more easily than others?

viscosity: a measure of how easily a fluid's particles are able to slide past one another

The **viscosity** of a fluid refers to its "thickness," or its resistance to flow. A number of factors affect a fluid's ability to flow. Two factors are cohesion and adhesion.

Cohesion

cohesion: a measure of how strongly the particles of a fluid attract each other

Cohesion is the force of attraction between the particles of a substance. Fluids with slow flow rates, such as maple syrup, have particles with greater cohesion. They stick together. We say such fluids are viscous. Some fluids, such as caramel, are so viscous that they fold over on themselves (Figure 3). Less viscous fluids, such as water and milk, show less cohesion. They flow more freely. Gases are the least viscous fluids, since their particles are farther apart.

Less viscous fluids are thin and runny and have faster flow rates. Thicker fluids are more viscous and have slower flow rates.

Figure 3 Fluids with high viscosity, such as caramel, pour slowly.

Surface Tension

surface tension: the strong attraction among the particles that form the surface of a liquid

The cohesion of particles on a liquid's surface is called **surface tension**. Insects such as water striders (Figure 4) use surface tension to their advantage. The force of attraction among the water particles is greater than the force of gravity pulling the strider down on the water's surface. This attraction forms a cohesive "skin" on the water's surface that the insect can walk or skate across.

Figure 4 Surface tension keeps this water strider from sinking into the water.

Sometimes the cohesion of water needs to be reduced. When fighting forest fires, a "wetting agent" can be added to water to reduce cohesion. The wetting agent allows the water to disperse more readily. Water with reduced cohesion spreads out when it hits the trees and ground (Figure 5).

To learn more about cohesion,
Go to Nelson Science

Figure 5 Fire retardants often contain chemicals to reduce cohesion and increase water's ability to spread out and cover the burning material.

Adhesion

Another factor that affects flow rate is adhesion. **Adhesion** is the force of attraction between particles of a fluid and particles of other substances. When you have finished drinking a glass of milk, you may have noticed a thin film of milk on the sides and bottom of the glass (Figure 6). Fluid particles adhere to the sides of containers, pipes, and tubing. Adhesion between water particles and the container is responsible for the curved top surface you see when water touches the sides of a cup, graduated cylinder, or other container. This curved surface is called a meniscus.

Adhesion causes gases and liquids to travel faster near the centre of pipes and tubes than at the edges. The fluid's attraction to the material the pipes and tubes are made of slows down the flow of the fluid. In a similar way, water flows faster at the centre of a stream or river than along the edges.

adhesion: the attraction between the particles of one substance and the particles of another substance

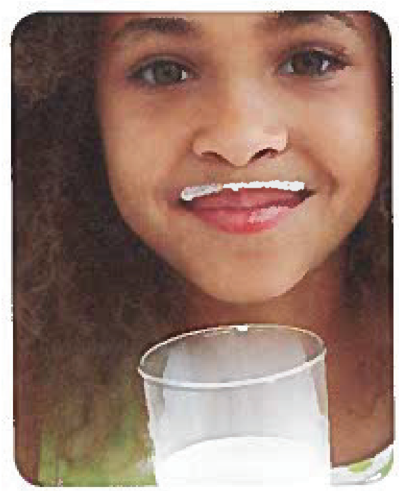


Figure 6 Adhesion causes the milk to stick to both glass and skin.

CHECK YOUR LEARNING

1. (a) In your own words, define "flow rate" and "viscosity."
   (b) Describe the relationship between flow rate and viscosity.
2. In your own words, define "cohesion" and "surface tension."
3. Use the term "viscosity" to explain how wetting agents are used to help fight fires.
4. (a) How does adhesion affect flow rate?
   (b) Give an example in real life that shows adhesion at work.
5. Explain why fluids travel faster near the centre of pipes and tubes than at the edges.

Comparing Flow Rate

Understanding the factors that influence the flow of fluids is important in determining how to best use the fluids. In this investigation, you will examine how viscosity and surface material affect the flow rate of various liquids.

SKILLS MENU

- [ ] Questioning
- [ ] Hypothesizing
- [ ] Predicting
- [x] Planning
- [ ] Controlling Variables
- [x] Performing
- [x] Observing
- [x] Analyzing
- [x] Evaluating
- [x] Communicating

Purpose

To measure differences in the flow rates of different liquids.

Equipment and Materials

- apron
- eye protection
- graduated cylinder (100 mL)
- clear plastic cups
- wax pencil
- retort stand and ring clamp
- 2 plastic funnels
- small beakers
- timing device
- ruler
- board and block
- water
- variety of fluids (ketchup, cooking oil, syrup)
- variety of surfaces (wax paper, sandpaper, foil)


apron

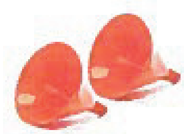

eye protection


graduated cylinder (100 mL)


clear plastic cups

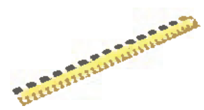

wax pencil


retort stand and ring clamp


2 plastic funnels


small beakers


timing device


ruler


board and block


water


variety of fluids (ketchup, cooking oil, syrup)


variety of surfaces (wax paper, sandpaper, foil)

Procedure

SKILLS HANDBOOK 2.B.4., 6.A.2.

Part A

1. Put on your apron and eye protection. Use a graduated cylinder to measure 30 mL of water.
2. Pour the 30 mL water sample into a small plastic cup and mark the level of water on the side of the cup with the wax pencil. Empty the cup. This will be your catch container.

3. Set up the equipment as shown in Figure 1.

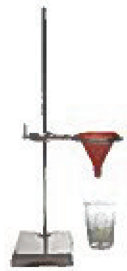


Figure 1 Experiment setup

4. Measure a 40 mL sample of water.
5. Place your finger over the end of the funnel.
6. Pour 40 mL of water into the funnel.
7. Time how long it takes 30 mL of water to flow into your catch container once you remove your finger from the funnel. Record your observations in your notebook, using a table such as Table 1.

Table 1 Flow Rate of Liquids

Fluid used	Volume of fluid collected (mL)	Time for 30 mL of fluid to flow through funnel (s)	Flow rate (mL/s)	Amount of fluid stuck to the funnel (+ to +++++)
water	30			
syrup	30			

8. Dry the funnel and repeat steps 4 to 7 with a second fluid. Record your results.
9. Wash off the finger that you used for the previous fluid. Then use a second clean, dry funnel to repeat steps 4 to 7 with a third fluid. Record your results.
10. Use the results from others in your class for two liquids you do not test. Remember to record whose data you are using.
11. Use soap and water to clean your hands, the funnels, and containers when finished.

Part B

12. Design a method to investigate how the type of surface affects the flow rate of a liquid moving down a slope.
13. Determine the procedure you will use and the equipment and materials you will need. Some possible equipment and materials are in the list on the previous page. Your procedure should include safety precautions. You should also identify the variables you will need to control and how you will control them.
14. Create a table in which to record your observations.
15. Submit your procedure to your teacher for approval. Once you have approval, perform your experiment. When finished, clean all equipment and your work area as directed.

Analyze and Evaluate

SKILLS HANDBOOK 6.D.2.

(a) Create a graph showing the flow rates of the liquids in Part A from slowest to fastest.

(b) Compare your flow rate values with the amount of fluid that stuck to the sides of the funnel. Is there a relationship between how quickly a fluid flows and how much fluid remains behind?

(c) Rank the surface materials from the least resistant to fluid flow to the most resistant to fluid flow. Explain why the type of surface makes a difference to fluid flow.

Apply and Extend

(d) Research how flow rate is used in an industry, such as construction (for example, building foundations and driveways) or the food industry (for example, making candy, ice cream, and baked goods).

Go to Nelson Science

(e) When might you want to increase the flow rate of a fluid you use in daily life? When might you want to decrease the flow rate?

Warming Things Up

There is an old saying: "As slow as molasses in January." Molasses is a thick liquid sweetener (Figure 1), but what does January have to do with it? Does molasses behave differently in January than it does in June?

In this experiment, you will investigate the properties of fluids by examining the effect that changing temperature has on the viscosity of a liquid.

SKILLS MENU

- ☐ Questioning
- ☒ Hypothesizing
- ☒ Predicting
- ☒ Planning
- ☒ Controlling Variables
- ☒ Performing
- ☒ Observing
- ☒ Analyzing
- ☒ Evaluating
- ☒ Communicating

Figure 1 Molasses is a thick, brown syrup left over when sugar is refined.

Testable Question

What effect does a change in temperature have on the viscosity of a fluid flowing down a slope?

Hypothesis/Prediction

SKILLS HANDBOOK 2.B.3.

Make a hypothesis regarding the effect of temperature on the viscosity of a liquid. Your hypothesis should include a prediction and reasons for your prediction.

Experimental Design

In this investigation, you will design an experiment to see how a change in temperature affects the viscosity of a fluid. Your teacher will provide you with liquids at different temperatures.

Equipment and Materials

- apron
- eye protection
- warm water bath
- various fluids (for example, syrup, cooking oil, ketchup)
- ice bath

You may choose other equipment and materials from the following list or from those supplied by your teacher:

- thermometer
- small beakers or test tubes
- plastic cups
- timing device
- syringe
- wax paper, plastic wrap, or foil
- board and block


apron


eye protection


warm water bath


various fluids (syrup, cooking oil, ketchup)


ice bath


thermometer


small beakers or test tubes


plastic cups


timing device


syringe


wax paper, plastic wrap, or foil


board and block

Procedure

SKILLS HANDBOOK 2.B.2., 2.B.4.

1. Make a list of the equipment and materials you will need to perform your experiment.
2. Write a procedure you will follow to conduct your experiment. The following questions may help guide you:
   - How many trials will you conduct with each liquid?
   - What variables will you have to control?
   - How will you control them?
   - What will you measure and how will you measure it?
   - How will you record your observations?
3. Make a note of any safety considerations and ask your teacher to check and approve your procedure before you continue.
4. Conduct your experiment and record your results.

Analyze and Evaluate

SKILLS HANDBOOK 2.B.7., 6.D.2.

(a) In your experiment, what was your dependent variable? What was your independent variable?

(b) Graph the results of your experiment using the most appropriate type of graph. On which axis should your independent variable be plotted?

(c) Did your observations support your hypothesis? Explain using evidence from your experiment.

(d) Answer the Testable Question.

Apply and Extend

(e) Oil sands, such as those in Alberta, consist of deposits of sand and clay that are surrounded by a sticky oil called bitumen (Figure 2). Why does heating these sands make it easier to separate the oil from them?

Figure 2 About 2 tonnes of oil sand are required to produce 1 barrel of oil.

(f) The food industry uses many fluids that contain water. The viscosity of these fluids actually increases as the fluids are heated. Use the particle theory to explain how the viscosity of these fluids could increase when the fluids are heated.

7.6 Controlling Fluid Flow

fluid mechanics: the study of fluids and how they behave when at rest and when moving

fluid dynamics: a part of the study of fluid mechanics concerned with how fluids move

aerodynamics: a part of fluid dynamics concerned with how gases move

hydrodynamics: a part of fluid dynamics concerned with how liquids move

Since fluids play an important role in our lives, we need to understand them and learn to control their flow. **Fluid mechanics** is the study of how fluids behave, both at rest and in motion. Part of the study of fluid mechanics is **fluid dynamics**—the study of fluids in motion. The field of fluid dynamics ranges from complex tasks, such as designing computer simulations of high-speed airflow around the space shuttle (Figure 1), to more everyday tasks such as developing a teapot spout that does not drip. Fluid dynamics is subdivided into two major areas. **Aerodynamics** is the study of moving gases, and **hydrodynamics** is the study of moving liquids.

Figure 1 Aerodynamics engineers use programs designed to simulate high velocity airflow around vehicles like the space shuttle.

Aeronautics and Fluid Control

Many modern terms related to air travel come from sailing. Airplanes evolved from air ships, and we still use the term "spaceship" or "starship." Aeronautics is the study of the science of flight. Aeronautics literally means "to sail in the air." Aeronautical research deals with the science of air and space travel such as wing design to control airflow over and around wings. Figure 2 shows two other aspects of aeronautical research.

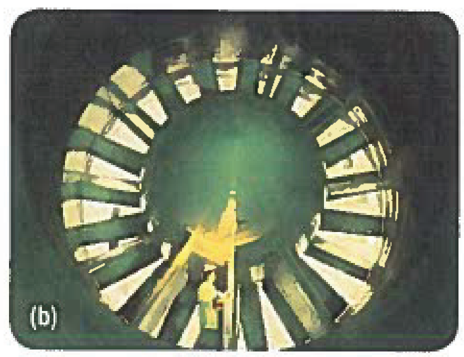


Figure 2 Aeronautical research includes (a) design of parachutes and paragliders and (b) wind tunnel design used to study and control airflow around objects.

Fluid Control in the Food Industry

One simple yet challenging task for the food industry is to get fluids to flow where and when we want them to, and to stop flowing when we are finished with them. Figure 3 shows a design developed to control fluid flow in the kitchen.

Controlling fluid flow is especially important during the processing of some foods. For example, margarine and shortening are made by bubbling hydrogen gas through liquid oils (usually vegetable oil). If the hydrogen gas mixes with the oil too quickly, a substance called "trans fat" may be produced. Trans fats have been related to heart disease, so controlling the flow of hydrogen is critical.

Figure 3 A dripless cooking oil bottle

Another example occurs with ethylene gas. This gas can be used to control the ripening of fruit. Fruit is often picked and transported before it is ripe because unripened fruit is firmer and less easily damaged. The fruit is then stored in a ripening room, where it is exposed to ethylene gas. Controlling airflow into and out of the ripening room is crucial. Too much ethylene gas too early in the ripening process will cause the food to spoil.

Controlling Water Flow

Dams are used throughout the world to control the flow of water. Water is stored behind the dam during times of heavy precipitation. Water is released during times of lower precipitation.

Many dams are also used to generate electricity (Figure 4). The weight of water behind the dam pushes water to the turbines through large pipes called penstocks. The water spins the blades of the turbines, which are connected to generators. The spinning turbine blades cause huge magnets in the generators to spin, producing electricity.

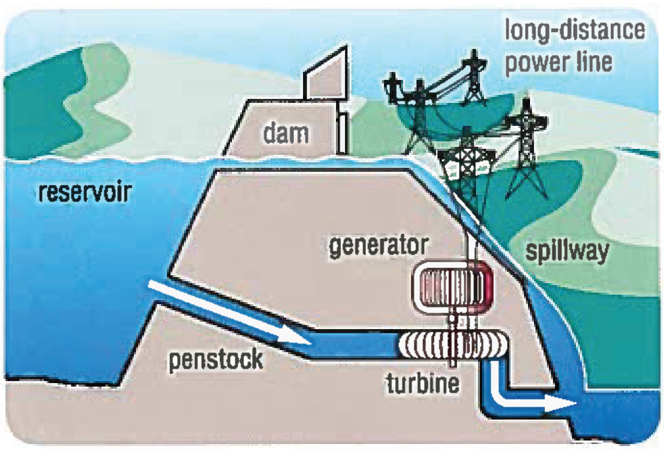


Figure 4 About 60 % of Canada's electrical power is produced by hydro-electric power plants.

LINKING TO LITERACY

Reading Diagrams

Diagrams usually provide information in two ways: an illustration and written words (labels and captions). Here are a few tips to help you "see" all of the information in a diagram:

- Look for things you recognize first. What do you already know about dams? Then, look to understand things that may not be as familiar.
- Scan the diagram. Make sure you notice all details.
- Follow connections, arrows, or lines between words and parts of the illustration. Can you locate the turbine?
- Read the caption.

The impact of dams on the environment continues to be debated. Dams do not emit the type of air pollution that coal- and gas-burning power plants do. Nor do they create the potentially dangerous radioactive wastes of nuclear power plants. However, there are negative impacts. The most obvious drawback is loss of land due to flooding. The construction of dams has flooded forests, wetlands, agricultural land, and lands used by First Nations peoples for fishing and hunting (Figure 5).

Figure 5 Major hydro-electric projects, such as the James Bay Project, have social and environmental impacts as well as economic ones.

Dams, and flooding related to dams, can also affect fish populations, contribute to bacteria growth, and cause the release of chemicals, such as mercury, into the water. Better dam design, construction of fish ladders, and careful management of water flows can reduce some of these impacts. However, some negative environmental impacts are unavoidable. Dam construction will always require careful consideration and responsible decision-making. This becomes even more important when people construct dams in areas where natural disasters such as earthquakes are common.

Controlling Blood Flow

Blood flow is one of the most important fluid movements within your body, yet we rarely give it much thought. However, some people need medical assistance to maintain the flow of blood throughout the body:

- Blood thinners are medicines given to people whose blood forms clots (Figure 6) too easily. Clots inside arteries and veins can cause heart attacks and strokes.
- Some people have a condition called hemophilia. They may bleed excessively when injured, since their blood does not clot as it should. These people often take medicine to promote clotting.
- Artificial hearts have saved the lives of thousands of people whose own hearts were no longer strong enough to continuously pump blood throughout the body.

To learn more about how doctors can treat heart problems,
Go to Nelson Science

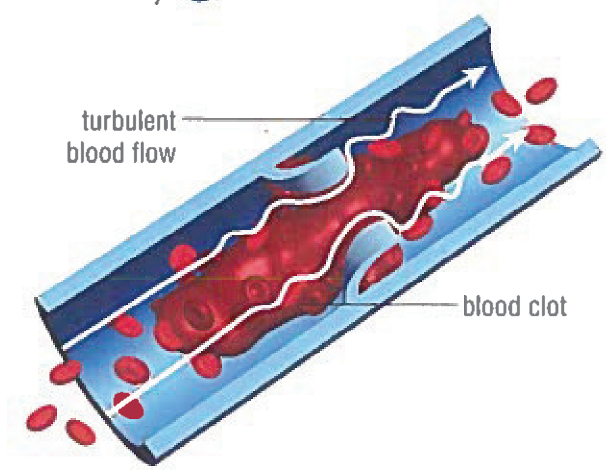


Figure 6 A blood clot in this vein slows the flow of blood back to the heart.

CHECK YOUR LEARNING

1. What is meant by fluid mechanics?
2. What is the relationship between fluid dynamics, hydrodynamics, and aerodynamics? Draw a concept map to show the relationship between the three terms.
3. Describe two applications each of hydrodynamics and aerodynamics.
4. Why is it important to control the presence of ethylene gas when ripening fruit?
5. Describe two aspects of dams that depend on the proper flow of fluids.
6. How has technology allowed us to control the flow of blood in humans?
7. Name two economic benefits of fluid flow and two environmental costs that are a result of human control of flowing fluids.

AWESOME SCIENCE

Streamlined to the Max!

When fluids flow around an object in a pattern that forms smooth lines, we say the object is "streamlined." Vehicle designers and engineers strive to design forms that offer little resistance to the flow of air or water around them. Streamlining increases speed and ease of movement. It also makes the vehicle more efficient, as it requires less fuel to push through the fluid. The search for the most streamlined shapes has continued for decades, and the search continues today.

FuelVapor Technologies is a small British Columbia company that has designed a vehicle called the "alé" (Figure 1). Although the vehicle's mass and wheel arrangement legally make it a motorcycle, it seats two people side-by-side and includes many features found in cars, such as airbags and seatbelts. Its streamlined shape helps reduce fuel consumption.

Figure 1 The three-wheeled alé produces significantly less emissions than more traditional gasoline-driven vehicles.

Streamlining is also important to water vehicles. *Earthrace* (Figure 2) not only races across the surface of the ocean, it also races through it! Its wave-piercing design allows it to maintain a flat pathway as it cuts into and through waves, rather than moving up and down with them. *Earthrace* was designed to be the fastest ship to completely circle the globe. On June 27, 2008, *Earthrace* set a new world record for time taken to completely circle the globe—60 days, 23 hours, and 49 minutes. The previous record was 74 days, 20 hours, and 58 minutes. *Earthrace* beat the old record by almost 14 days!

Figure 2 *Earthrace's* streamlined, wave-piercing design allows it to travel smoothly through the water as well as on it.

To learn more about these and other streamlined vehicles,
Go to Nelson Science

Investigating Fluid Mechanics

This activity gives you the opportunity to study an area of fluid mechanics and some related careers that are of interest to you.

SKILLS MENU

- [x] Questioning
- [ ] Hypothesizing
- [ ] Predicting
- [x] Planning
- [ ] Controlling Variables
- [x] Performing
- [ ] Observing
- [x] Analyzing
- [x] Evaluating
- [x] Communicating

Purpose

To investigate applications of fluid mechanics, then communicate your findings to inform and interest others.

Equipment and Materials

- library books
- computer with Internet access
- magazines
- apprenticeship, college, and university brochures
- television shows (for example, sports, medicine, forensic science)

library books

computer with Internet access

magazines

apprenticeship, college, and university brochures

television shows (for example sports, medicine, forensic science)

Procedure

SKILLS HANDBOOK 3.

1. Identify a few areas of fluid mechanics that are of interest to you and think about how fluids are used in those areas. Talk with a partner to help generate ideas. In your notebook, jot down what you already know about that area. Also jot down the questions you may want answered (Figure 1).

Figure 1 (a) Why do golf balls have dimples? (b) How do toilets work?

2. If necessary, broaden your search into other areas. See Table 1 (on the next page) for some suggestions to help you get started. These are just some ideas; take time to explore areas of interest to you.

Table 1 Applications of Fluid Mechanics

Industry	Related applications
aeronautical research	• flight simulators • aircraft design
shipping	• double-hull design for oil tankers • marine engineer
hydrodynamic engineering	• glacier research • pipelines, pumps, and valves
food services	• cooking • equipment design (Figure 2)
construction	• plumbing • home heating and air conditioning
sports	• fluid flow around golf balls, baseballs, and so on • fluid flow around racing equipment (for example, cars, bikes, and boats)
medicine	• artificial hearts • air flow in lungs and bronchi (Figure 3)

Figure 2 Commercial bakeries often use large-scale kitchen equipment to mix doughs and batters.

Figure 3 Airflow in lungs can be greatly reduced if the lung tissue has been damaged by tar from cigarettes.

3. Narrow your focus to a single area. Using several different sources, research ways in which the properties of fluids are used and the types of jobs available in your area of interest.
4. In your area of interest, identify one or two applications of fluid mechanics that you would like to explore more thoroughly.

Analyze and Evaluate

SKILLS HANDBOOK 7.B., 8.

(a) Use a web or other organizer to help you sort your information. Consider the following questions when developing your organizer:
- What needs are being met by the applications you have chosen?
- Which applications seem most interesting or most important to you? Why?
- What careers are available in your area of study? Consider apprenticeship, college, and university pathways.
- Have you learned enough to explain your area of interest clearly to others in your own words? What else do you need to find out?

(b) Identify the main ideas, any trends or patterns that you notice, or key information your audience will need. Prioritize the points you wish to make, and use this to create an outline for your writing.

(c) Decide how you will communicate your information (for example, brochure, poster, presentation software).

(d) Create your communication piece and be prepared to share it.

Apply and Extend

(e) What does the future hold for your application? What other needs still need to be met in your area of study?

(f) What might some of the consequences be if these needs are not met?

Fluid Spills

SKILLS MENU
- Defining the Issue
- Researching
- Identifying Alternatives
- Analyzing the Issue
- Defending a Decision
- Communicating
- Evaluating

People benefit from the oil that flows quietly through underground pipes. It provides energy for heating, transportation, and industrial use. Pipeline construction and maintenance creates jobs. Pipelines are just one way of transporting fluids, and oil is just one of the many kinds of fluids that we depend on and need to transport daily. However, accidents sometimes occur during the transport of fluids.

On July 24, 2007, a work crew in Burnaby, British Columbia, broke through an underground oil pipeline (Figure 1). Oil shot out of the rupture like a small geyser for about 25 minutes before work crews could stop the flow. Although this spill was a relatively small one, it damaged homes, cars, and lawns. It also caused damage to the local water system when oil flowed into Burrard Inlet, contaminating the water and shoreline.

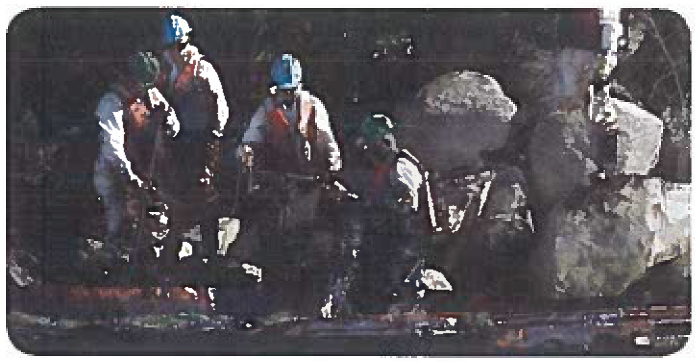


Figure 1 A Burnaby, British Columbia, neighbourhood feels the effects of a spill from a punctured oil pipeline.

LINKING TO LITERACY

Reading Between the Lines

Think about the sentence that says, "People benefit from the oil flowing quietly through underground pipes." What does this sentence tell you? What information might you need to "read between the lines" because it is not openly stated in the sentence?

Although people benefit from this situation, oil does not always flow quietly through underground pipes. What might the cost of oil flowing in above ground pipes be for people, wildlife, and the environment?

For more information on the Burnaby spill,
Go to Nelson Science

The Issue

Companies and the public both benefit from the transportation of fluids. What should the responsibility and cost breakdown be when fluid spills occur? Who should pay? Should the payment and the cleanup be the sole responsibility of the person or company who made the mistake?

Local and provincial politicians are invited to a town-hall meeting to hear concerned citizens' suggestions about fluid transport happening in the community. Young people are invited to create posters and brochures to help inform the audience of some of the issues. As a Grade 8 student who is concerned with the environment, you have been chosen to offer some thoughts.

Your audience will consist of homeowners, farmers, cottage owners, boaters, and fishers. There may be other stakeholders (those who are affected by an event), and part of your job is identifying them.

Goal

Your goal is to determine who should be responsible for the cleanup of an oil spill, and to communicate this information to people in your community.

Gather Information

SKILLS HANDBOOK 3.J.

From the list below, choose a spill that is most likely to occur in your area:

- a poorly maintained or damaged oil or natural gas pipeline spews its contents onto its surroundings
- derailment of a train spills liquid chlorine or other industrial fluids
- an overturned transport truck spills liquid fertilizer onto the roadway and into the local water system
- spillage from a waste lagoon of a large farm or meat processing plant contaminates nearby property

Begin your research. Ask yourself some questions to help generate ideas: How do these spills occur? Has this happened before in my community? Who should be responsible for cleaning it up? What are the costs? What is the process for cleaning up the environment? What damage cannot be repaired?

Go to Nelson Science

Identify Solutions

You will need to identify the information that is important for your audience. There will likely be several ways that responsibility could, or should, be shared. Examine different solutions and the advantages and disadvantages of each.

Make a Decision

Choose the best solution for the kind of spill you have chosen to discuss. Identify the likely damage of such a spill, the method of cleanup required, and the ways that costs should be shared.

Communicate

SKILLS HANDBOOK 8.

Create a communication tool that could be displayed at the meeting. Consider making a poster, a brochure, or a self-timed electronic presentation. Your work must

- catch the attention of your audience
- clearly define and show the type of spill you are discussing
- briefly describe some of the major hazards of such a spill
- clearly communicate how costs should be shared
- briefly state your reasons for how costs should be shared

LINKING TO LITERACY

Persuasive Texts: Providing Evidence to Support Your Opinions

Your communication tool will need to be convincing. How do authors persuade their readers of their position?

They

- present information in a logical, organized way
- clearly express their opinions
- provide evidence to support their opinions
- clearly show the causes and effects of actions
- use words such as "care" or "concern" that draw on the reader's emotions

Be sure to check that you have included all of these details in your communication tool. First, state your position. Then, list and describe evidence that supports it. End with a concluding statement to restate and confirm your beliefs.

CHAPTER 7 SUMMARY

Fluids on the Move

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.

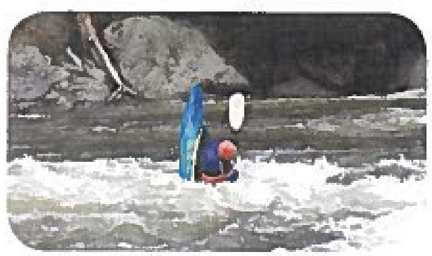
Looking Back

Fluids are essential to life.

- Fluids include all liquids and gases.
- Air and water are two fluids essential to life on Earth.
- Fluids are part of all living things.

A key characteristic of fluids is their ability to flow.

- Fluids have no definite shape and can flow.
- Flow can be laminar (smooth) or turbulent (rough and irregular).
- Streamlined objects reduce turbulence and create more laminar flow.



The way fluids flow depends on various factors.

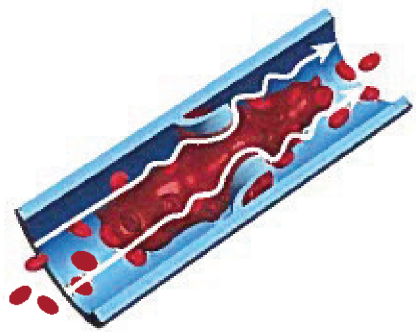
- The particle theory can be used to explain the behaviour of fluids.
- Viscosity is a measure of how thick or thin a fluid is and can change with temperature.
- Flow rate can be used as a measure of the viscosity of a fluid.
- Fluid particles are attracted to each other (cohesion) and to the sides of their containers (adhesion).

The skills of scientific inquiry can be used to investigate factors that affect the flow of different fluids.

- Inquiry skills can be used to investigate how fluids flow at different rates.
- Experimentation skills can be used to determine how the type of surface affects the flow rate of a fluid moving down a slope.
- Experimentation skills can be used to determine how temperature affects the viscosity of different fluids.

Humans control fluid flow (either through objects or around them) to meet certain needs.

- Fluid mechanics is the study of how fluids behave when in motion or at rest.
- Aerodynamics is the study of moving gases; hydrodynamics is the study of moving liquids.
- The need to control fluid flow occurs in many aspects of life.



Research skills can be used to investigate applications of fluids.

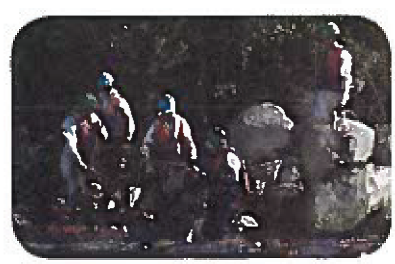
- Research skills can be used to explore different applications of fluid mechanics and careers associated with fluid mechanics.

The flow of fluids can have positive and negative effects on society and the environment.

- Fluid flow plays a role in many aspects of our daily lives, from health care to sports, from the food industry to transportation.
- Managing fluid flow is an important part of many careers and hobbies.
- Well-managed fluid flow can provide benefits, such as flood control, generation of electricity, and efficient motion.
- Poorly managed fluid flow creates considerable costs—both financial and environmental.

VOCABULARY

fluids, p. 180
particle theory of matter, p. 182
laminar flow, p. 185
turbulent flow, p. 185
eddy, p. 185
streamlined, p. 186
flow rate, p. 187
viscosity, p. 188
cohesion, p. 188
surface tension, p. 188
adhesion, p. 189
fluid mechanics, p. 194
fluid dynamics, p. 194
aerodynamics, p. 194
hydrodynamics, p. 194



CHAPTER 7

REVIEW

The following icons indicate the Achievement Chart categories: K/U Knowledge/Understanding T/I Thinking/Investigation C Communication A Application

What Do You Remember?

1. What are fluids? Give three different examples of fluids. K/U
2. Most solids cannot flow. Use the particle theory to explain why solids are not considered to be fluids. K/U
3. List four types of fluids found in the human body and describe one function of each. K/U
4. Make a t-chart to compare differences between laminar and turbulent flow. Provide examples for both. K/U
5. Define flow rate. What units are used to measure flow rate? K/U
6. Use the particle theory to explain why 10 mL of liquid cannot fill a 20 mL container. K/U
7. List the five main statements of the particle theory. K/U
8. Is the science that studies wind patterns around wings on aircraft (Figure 1) called aerodynamics or hydrodynamics? Name two other applications related to this field of study. K/U A

Figure 1

9. The words "cohesion" and "adhesion" look very similar. Use the meanings of the words to show why it makes sense that these words should look alike. What might the parts "co," "ad," and "hesion" refer to? K/U
10. "The greater the viscosity of a fluid, the slower the flow rate." Do you agree or disagree? Support your answer based on your work with fluids in this unit. K/U
11. Describe three ways in which fluid flow is important in the food industry. K/U A
12. Describe one way that streamlining plays a role in your daily activities. K/U A
13. Should the practice of lining waterways with concrete continue? Justify your answer using concepts from this chapter. K/U A

What Do You Understand?

14. One of the Big Ideas of the unit is "Fluids are essential to life." Comment on this statement and use this text and your notes to justify your answer. K/U T/I C
15. Does warming a viscous fluid generally increase or decrease its flow rate? Use the particle theory to explain why this might be so. K/U
16. One of the Looking Ahead statements reads, "The way fluids flow depends on various factors." Choose three of these factors and briefly describe them. K/U C
17. If the particles of a substance show considerable adhesion as well as cohesion, is this fluid likely to have a fast or slow flow rate? Justify your answer. K/U
18. Many modern terms related to air travel come from sailing. Using concepts from this chapter, describe three ways in which travelling through air and travelling through water share similar characteristics. K/U A
19. When you tip a syrup bottle upside down, it takes a long time for all the syrup to move down. Explain this, using the ideas of viscosity, cohesion, and adhesion. K/U A

20. Look at the graph in Figure 2. It shows the length of time three fluids took to flow through a funnel at different temperatures.

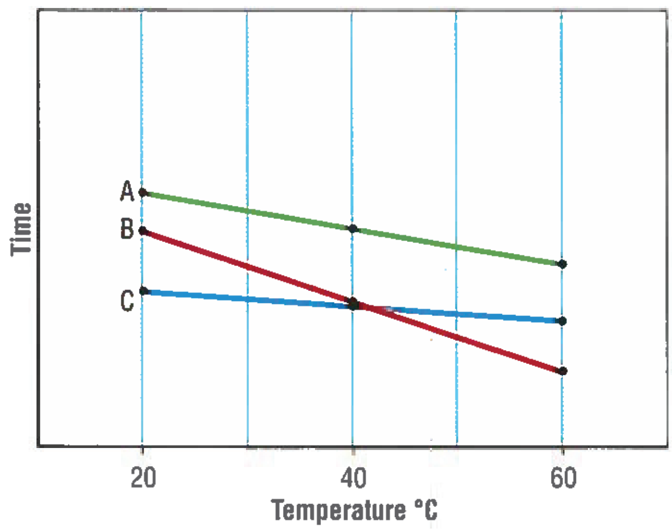


Figure 2

(a) Which fluid is most viscous? Justify your answer.

(b) Which fluid is most affected by changing temperature? Justify your answer. T/I C

21. The phrase "as slow as molasses in January" comes from a time when molasses was used as a common liquid sweetener in cooking. What does the phrase have to do with concepts learned in this chapter? K/U

22. In many situations in which fluids are moving, designers want to reduce drag. Describe a situation in which drag is important. Why is drag so important in this situation? K/U A

23. Bicycle and car racers often stay very close to the person in front of them. Using concept of fluid flow, explain why this strategy is useful. K/U A

Solve a Problem!

24. Squeezing a mustard container results in 60 mL of mustard coming out in 5 seconds. Calculate the flow rate of mustard. T/I A

25. You are scheduled to have a bicycle race with your friends. The day of the race is very windy. What can you do to give yourself an edge? T/I A

Create and Evaluate!

26. Use information from this chapter to add to your concept map from "Let's Get Started." Include the seven points in the Looking Ahead section on the first page of the chapter and the words in the vocabulary list. Evaluate your graphic organizer against those of your classmates. Ask a classmate to evaluate yours. Discuss your perspectives. K/U C

27. Research the importance of fluid flow in your favourite sport. Present your findings in a poster, brochure, slide show, or another creative manner. A C

Go to Nelson Science

Reflect on Your Learning

28. How did working with Goobleck help you learn about the properties of fluids?

29. In what ways has the material in this chapter changed your understanding of fluids?

30. (a) Which concepts in this chapter do you find the easiest to understand? Explain why.

(b) Which concepts in this chapter do you find the most difficult to understand? Explain why.

(c) What action could you take to help you understand these concepts better?

31. Think back to the Key Question on the first page of this chapter.

(a) In a brief paragraph, answer the Key Question. You may use diagrams.

(b) Write one or two more questions about the topic of this unit that you would like to explore.

CHAPTER 8

Density and Buoyancy

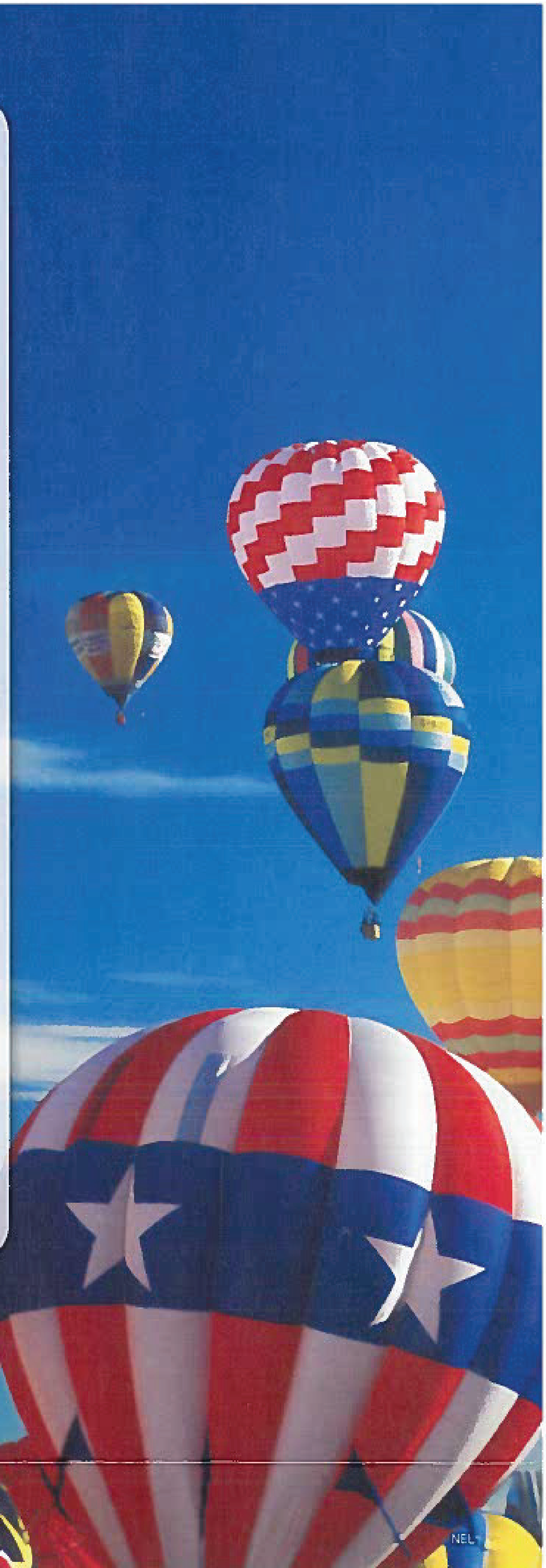
KEY QUESTION: How do the properties of fluids affect fluid behaviour and determine fluid use?

Looking Ahead

- Density is a specific property of fluids that can be used to our advantage.
- The skills of analysis can be used to determine the mass-to-volume ratio of a substance.
- The skills of scientific inquiry can be used to determine the density of different liquids.
- Buoyancy is the upward force that all fluids exert on objects.
- Humans and other organisms make effective use of the density and buoyancy of natural and human-made objects.

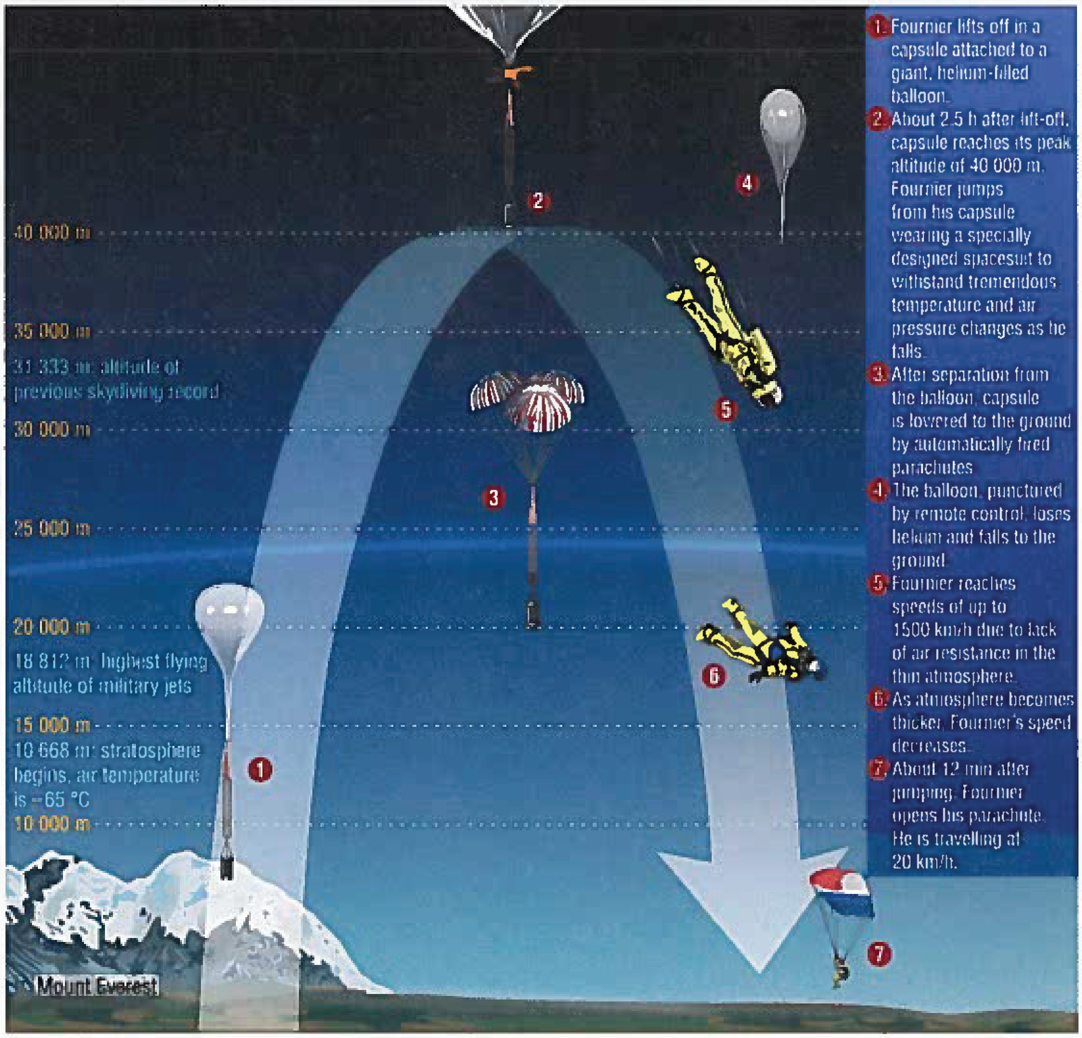
VOCABULARY

weight
mass
volume
displace
density
characteristic property
buoyancy
swim bladder
ballast tanks



The Ultimate Jump

On Monday, May 26, 2008, in North Battleford, Saskatchewan, 64-year-old Michel Fournier was to set the world's highest skydive record. The attempt was aborted, but Mr. Fournier has vowed to try again. The figure below illustrates Mr. Fournier's jump plan.



LINKING TO LITERACY

Understanding Visual Texts

Examine the illustration on this page. Begin by scanning it from side to side and top to bottom. Follow the arrow to gather details about Mr. Fournier's proposed trip.

1. Identify and describe the various types of equipment that Mr. Fournier would have used for his dive.
2. From what height was he to begin his dive?
3. What possible reasons might cause a skydiver to abort this type of dive?

8.1 Weight, Mass, and Volume

Would you weigh the same on the Moon as you do on Earth? Your **weight** is a measure of how strongly gravity pulls on you. Therefore, weight will change depending on where it is measured. You would weigh much less on the Moon because the force of gravity is not as strong as on Earth. **Mass**, however, is a measure of the amount of matter in an object or substance. If you went to the Moon, your weight would change, but your mass would not (Figure 1).

weight: the force of gravity acting on an object

mass: the amount of matter that makes up an object or substance

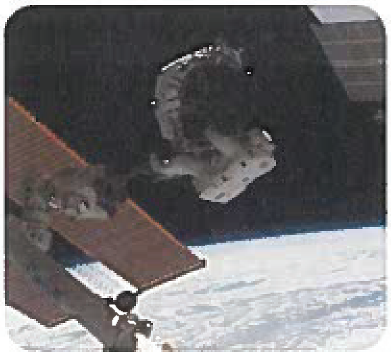


Figure 1 This astronaut is able to manipulate huge pieces of equipment because of their minimal weight in space.

Which do you think has greater mass: a kilogram of gold or a kilogram of polystyrene foam? Since mass measures the amount of matter in a substance, their mass is the same—1 kg. However, you need a lot more foam than gold to make up a kilogram. So, although the mass is the same, the volume of foam will be greater. **Volume** is a measure of how much space an object occupies.

volume: the amount of space an object or substance takes up

You can find the volume of a regular solid by multiplying its three dimensions together:

$$\text{volume} = \text{length} \times \text{width} \times \text{height}$$

This gives a measurement in cubic units (m^3, cm^3, and so on). Gases are often measured in cubic metres (m^3). The basic unit for measuring liquid volumes is the litre (Figure 2). A container measuring 10 cm × 10 cm × 10 cm holds 1000 cm^3 or one litre (L) of water. Since a litre is also equal to 1000 mL, 1 cm^3 equals 1 mL. We use millilitres to measure small volumes of fluids.

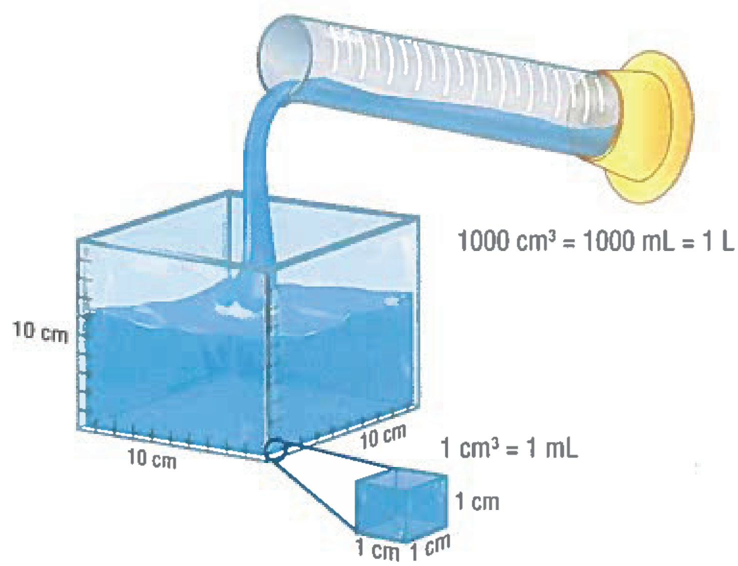


Figure 2 A litre of liquid would fill a container 10 cm long, 10 cm wide, and 10 cm high. So, 1 L = 1000 cm^3. Since 1 L also equals 1000 mL, then 1 mL = 1 cm^3.

LINKING TO LITERACY

Gaining Meaning from Context

Important words are highlighted in yellow and are bolded. You may be familiar with some of these terms, such as weight, mass, and volume. As you come across words you are not familiar with, make a note of these words in your notebook.

See if you can guess the meaning of unfamiliar words just by reading the sentence or paragraph where they are located. Write the definition in your notes. Often, a reader can learn the meaning of a new word from the text in which it is placed.

Finding Volume by Displacement

How can we measure volume when the object does not have a regular shape? You may have noticed that whenever you take a bath, the water rises as you settle into the tub. Since you and the water cannot occupy the same space, your body **displaces** water (pushes it out of the way), which causes the water level to rise. This property can be used to find the volume of irregularly shaped objects and is called the "finding volume by displacement" method.

displace: to take the place of

TRY THIS: Finding Volume by Displacement

SKILLS MENU: performing, observing, communicating

SKILLS HANDBOOK 6.A.2.

In this activity, you will measure the volume of small objects using the finding volume by displacement method. Remember that the apparent increase in water volume is equal to the volume occupied by the object.

Equipment and Materials: graduated cylinder; small objects that do not float, such as marbles or a standard weight

1. Fill the graduated cylinder approximately half full.
2. In your notebook, record the volume, making sure you have the water surface at eye level and you are reading from the bottom of the meniscus (Figure 3).
3. Place a small object in the graduated cylinder. Read and record the new water level. This is the volume of the water plus the volume of the object.

A. Use your values from steps 2 and 3 to calculate the volume of the object alone. In your notebook, record the volume of the object. Remember to use the proper units.

B. Why is it important to read the water volume with your eye at the same level as the surface of the water?

C. Why is it important to read the water level from the bottom of the meniscus?

D. Why is this method called "finding volume by displacement"?

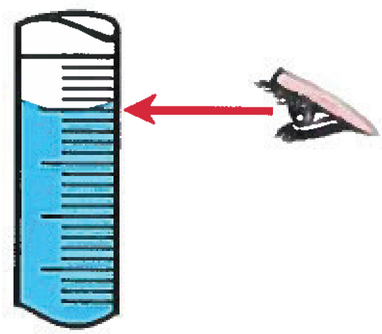


Figure 3 Read a meniscus at eye level.

When objects are too big to fit in a graduated cylinder, volume by displacement is measured using an overflow can (Figure 4). An overflow can has a spout near the top which allows displaced water to escape. If an object floats slightly, thin rods can be used to push it just under the water. Here is a suggested procedure for measuring volume by displacement:

- Place a container under the spout.
- Fill the can until it begins to overflow (be careful of spills).
- Wait until the flowing stops.
- Dispose of the water in the container and carefully place the container back under the spout.
- Slowly put the object into the can.
- Collect and measure the volume of the displaced water.

Figure 4 Collecting water from an overflow can

CHECK YOUR LEARNING

1. What in this section was already familiar to you? What was new information? How do you plan to remember this new information?
2. In your own words, describe the relationship between weight, mass, and volume. Use a diagram or chart if this is helpful.
3. Describe three ways of determining the volume of an object.

Comparing Mass and Volume

If you double the mass of a substance, does its volume double? Do the mass and volume of a substance always relate to each other in the same way? You will find answers by examining the relationship between mass and volume.

SKILLS MENU

- ☐ Questioning
- ☐ Hypothesizing
- ☐ Predicting
- ☐ Planning
- ☐ Controlling Variables
- ☑ Performing
- ☑ Observing
- ☑ Analyzing
- ☑ Evaluating
- ☑ Communicating

Purpose

To determine the mass-to-volume ratio of different amounts of the same substance.

Equipment and Materials

- graduated cylinder (100 mL)
- balance or scale
- beaker (250 mL)
- water
- corn syrup
- 40 pennies

graduated cylinder (100 mL)

balance or scale

beaker (250 mL)

water

corn syrup

40 pennies

Procedure

SKILLS HANDBOOK 6.A.2., 6.A.3.

Part A

1. In your notebook, make a table similar to Table 1.

Table 1 Observation Table

Substance	Volume of substance (mL)	Mass of empty graduated cylinder (g)	Mass of cylinder + substance (g)	Mass of substance (g)	Mass-to-volume ratio (g/mL)
water	20				
water	40				
water	80				

2. Use the balance or scale to measure the mass of a clean, dry graduated cylinder. Record the mass in your table.
3. Pour 20 mL of water into the cylinder. Measure the mass of the cylinder plus the water. Record the mass in your table.

Water on the floor can be very slippery. Immediately clean up any spilled material as you work through this activity.

4. Calculate the mass of the water only and record this value in your table.
[mass of water = (mass of cylinder + water) – (mass of cylinder)]

5. Repeat steps 1 to 4 using 40 mL of water. Then repeat using 80 mL of water.
6. Empty and dry the graduated cylinder.
7. Get a beaker of corn syrup (approximately 80 mL) from your teacher.
8. Repeat steps 1 to 6 using corn syrup in place of water. Remember to record all of your measurements in your table.
9. When finished, return the corn syrup to the beaker. Thoroughly clean and dry the graduated cylinder.

Part B

10. Measure the mass of 20 pennies. Record this measurement in your table.
11. With a graduated cylinder, use the volume by displacement method described in Section 8.1 to measure the volume occupied by 20 pennies (Figure 1). Record this value in your chart. Remember to use the proper units for the volume of a solid.

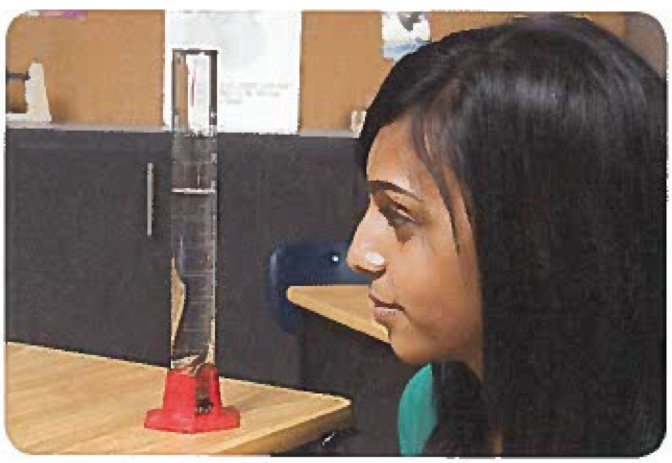


Figure 1 Remember to read the graduated cylinder at eye level.

12. Repeat steps 10 and 11 with 30 pennies, and then with 40 pennies. Record your measurements.

Analyze and Evaluate

SKILLS HANDBOOK 6.D.2.

(a) Determine the mass-to-volume ratio for each substance using each set of measurements. Write these values in the last column in your table.

(b) Based on your observations, does changing the volume of a particular substance change its mass-to-volume ratio? State your evidence. Does this seem reasonable to you? Explain.

(c) Based on your observations, does changing the mass of a particular substance change its mass-to-volume ratio? State your evidence. Does this seem reasonable to you? Explain.

(d) Make a line graph to show the three sets of data on one graph. Let the horizontal axis represent volume. Let the vertical axis represent mass. Use a different colour or line pattern for each substance. Examine the graph. What do you notice?

(e) If you extended each line, would they meet at the point (0,0)? Should these line extensions touch the (0,0) point? Justify your answer.

Apply and Extend

(f) Do you think mass-to-volume ratios could be used to identify unknown substances? Explain your thinking.

8.3 Density

In the last activity, you discovered that no matter how much substance you used, the mass-to-volume ratio stayed the same. "Density" is the term used for this mass-to-volume ratio in science and technology. So, **density** is a measure of the amount of matter in a given volume of a substance.

density: a measure of the mass per unit volume of a substance

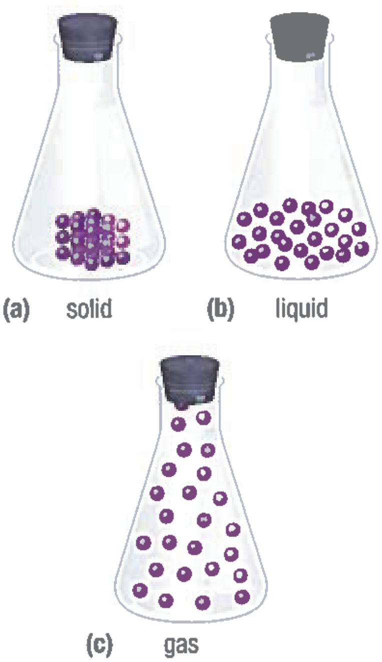


Figure 1 Particles of a solid (a) are usually more closely packed than particles of a liquid (b), which are more closely packed than particles of a gas (c). Therefore, solids are generally denser than liquids, which are denser than gases.

Density and the Particle Theory

Think back to the gold and polystyrene foam—gold has the greater density. For any given volume, there would be many more gold particles than foam particles.

We can use the particle theory to help explain density, since density depends on two things—the mass of the particles and how tightly those particles are "packed" (Figure 1). Since particles of solids are usually closer together than the particles of a liquid, solids are often denser than liquids. The spaces between gas particles are larger than those in solids and liquids, which means that there are considerably fewer particles in a given volume of gas. Gases are much less dense than liquids and solids.

Density is also affected by the type of particles a substance is made of. Different substances have different densities. Even though oil and water are both liquids, water is much denser. Helium is much less dense than air.

Calculating Density

Density is determined by the following equation:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

The common units of measurement for density of solids and liquids are g/mL or g/cm^3, and for gases, kg/m^3.

SKILLS HANDBOOK 6.B.

SAMPLE PROBLEM: Determine the Density of Cooking Oil

An empty container has a mass of 50 g. When 75 mL of oil are placed in it, the total mass is 120 g. Calculate the density of the oil.

Given: mass of container = 50 g
mass of container + oil = 120 g
volume of oil = 75 mL

Required: density of oil

Analysis: $\text{density} = \frac{\text{mass}}{\text{volume}}$

Solution: mass of oil = (mass of oil + container) − (mass of container)
= 120 g − 50 g
= 70 g

$$\text{density} = \frac{\text{mass}}{\text{volume}} = \frac{70\text{ g}}{75\text{ mL}} = 0.93\text{ g/mL}$$

Statement: The density of the oil is 0.9 g/mL.

Practice: Calculate the density of a diamond if the volume of the diamond is 0.50 cm^3 and its mass is 1.75 g.

Density is considered a characteristic property of matter. A characteristic property is one that is specific to a particular substance and can be used to distinguish one material from another (Table 1). For example, two samples of pure gold will always have the same density. The temperature at which a liquid boils (boiling point) and the temperature at which a liquid freezes (freezing point) are two other characteristic properties of matter.

characteristic property: a property that makes a particular substance distinct from others

Table 1 The Density of Some Common Materials

Fluids	g/cm³ or g/mL	kg/m³
air	0.001 3	1.3
carbon monoxide	0.001 45	1.45
gasoline	0.737	
distilled water (at 4 °C)	1.0	
sea water	1.03	
mercury (a liquid metal)	13.55	
Solids		
wood (balsa)	0.12	
ice	0.92	
lead	11.34	

The Wonder of Water

Notice in Table 1 that ice is less dense than water. Normally, fluids become more dense as they cool because the particles move more slowly and are closer together. This is also true of water, but only until it reaches 4 °C. Pure water is most dense at 4 °C. As cooling continues, water particles begin to move farther apart and eventually form ice (Figure 2). As the water particles move apart, the volume increases. Since the mass remains the same (the number of water particles does not increase), the density decreases. Pure water is least dense at 0 °C. This is why ice forms at the top of lakes and why ice floats in liquid water. If water behaved the same way as other liquids, our lakes would freeze solid in the winter from the bottom up, killing the plants and animals living there.

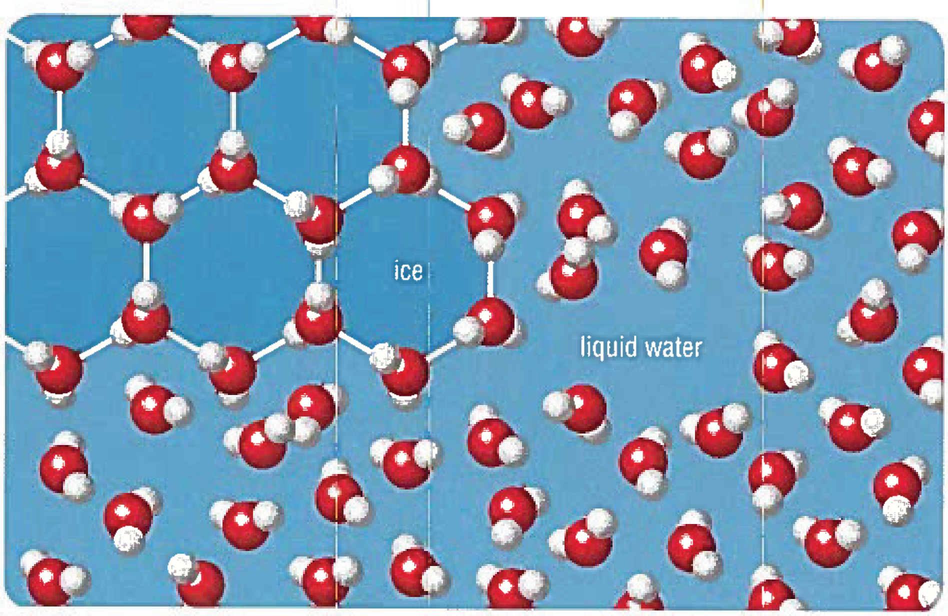


Figure 2 Liquid water is more dense than ice because its particles are more closely packed.

LINKING TO LITERACY

Making Inferences

Read *The Wonder of Water* and examine the diagram to the left. Read the caption below the diagram. Think about what happens to water as it freezes.

Now, make an inference about what happens to water poured into an ice cube tray and placed in a freezer. Discuss your thoughts with a partner.

CHECK YOUR LEARNING

1. Explain the mathematical relationship between mass, volume, and density.
2. Use the particle theory to explain the difference in density between most solids, liquids, and gases. You may use sketches in your explanation.
3. What units can be used to measure density?
4. Which solids in Table 1 are less dense than water?
5. Why is density a characteristic property of matter?

Measuring Density: Making a Hydrometer

SKILLS MENU

- [ ] Questioning
- [ ] Hypothesizing
- [ ] Predicting
- [x] Planning
- [ ] Controlling Variables
- [x] Performing
- [x] Observing
- [x] Analyzing
- [x] Evaluating
- [x] Communicating

Canadian maple syrup is loved throughout the world. It takes about 40 L of maple sap to make 1 L of syrup. The sap is heated to evaporate its water content (Figure 1). That is a lot of water that has to be evaporated! Syrup makers rely on measurement and their experience to tell when the syrup is ready. When maple syrup reaches the right sugar-to-water ratio, it has a very specific density. Syrup makers use a hydrometer—a tool that precisely measures the density of liquids—to tell them when the syrup is ready for market.

In this activity, you will create a homemade hydrometer that you can use to measure the density of various liquids.

Figure 1 Maple sap is boiled for hours before it becomes syrup.

Purpose

To make a hydrometer and to test the density of various liquids with it.

Equipment and Materials

- commercial hydrometer
- graduated cylinder (100 mL)
- permanent fine point marker
- distilled water
- coloured salt solution
- vegetable oil
- modelling clay
- plastic straw
- tap water
- liquid detergent
- corn syrup

commercial hydrometer

graduated cylinder (100 mL)

permanent fine point marker

distilled water

coloured salt solution

vegetable oil

modelling clay

plastic straw

tap water

liquid detergent

corn syrup

Procedure

1. In your notebook, make an observation table similar to Table 1.

Table 1 Observation Chart of Relative Densities

Substance	Density using commercial hydrometer (g/mL)	Estimated density (g/mL)	Reason for estimated density (g/mL)	Density measured using straw hydrometer (g/mL)
distilled water		N/A	N/A	1.0
salt water		N/A	N/A	
vegetable oil		N/A	N/A	
tap water	N/A			
liquid detergent	N/A			
corn syrup	N/A			

2. Use the commercial hydrometer to measure and record the density of distilled water. Pour the distilled water into the graduated cylinder until it is about half full. Make sure the hydrometer is floating freely before reading the value. Record this value in your table. Wipe the hydrometer and graduated cylinder clean between each measurement, and repeat with coloured salt solution and vegetable oil.

Clean up any spills as soon as they occur.

3. Roll some modelling clay into a ball about 1.5 to 2 cm in diameter. Push one end of a straw into the clay, so that the clay blocks the opening at that end.
4. Place the straw in a graduated cylinder of distilled water. It should float upright with more than half the straw below the surface. If it does not, adjust your hydrometer by adding or removing modelling clay until it floats as described. This is your straw hydrometer.
5. Carefully note the level at which the straw hydrometer floats in the distilled water. Remove the straw hydrometer, and mark the water level on the straw with the permanent marker. Label that level "A."
6. Continue to calibrate your hydrometer by repeating step 5 for salt solution and for vegetable oil. Mark those levels "B" and "C" respectively.
7. Estimate the densities of the remaining liquids. Record your estimates and your reasoning.
8. Check your estimates by using your straw hydrometer to measure the density of the liquids.

Analyze and Evaluate

(a) Using specific examples from your data, describe how your estimates compare with your measured density values. Why do you think your estimates were (or were not) different from the measured values?

(b) Which of the tested liquids are more dense than water? Which are less dense? Use the particle theory to explain your answer.

(c) Use the commercial hydrometer to measure the density of tap water, liquid detergent, and corn syrup. How do these results compare with your results using the straw hydrometer?

Apply and Extend

SKILLS HANDBOOK 2.B.3.

(d) What do you think will happen if you slowly pour equal amounts of corn syrup, distilled water, coloured salt solution, and vegetable oil into a tall, narrow container? Record your prediction as a sketch. Test your prediction using 20 mL of each of the fluids. Explain your observations.

(e) Explain how a hydrometer indicates the right time to stop the boiling process when turning maple sap into maple syrup.

To find out more about how hydrometers are used in the food industry and other industries,

Go to Nelson Science

8.5 Buoyancy

buoyancy: the upward supportive force on an object in a fluid

Have you ever seen a toy wooden boat float on a pond? Why does the boat float? When an object is placed in a fluid, the fluid presses on the object in all directions (Figure 1). The force that presses upwards is known as buoyancy. **Buoyancy** is the upward force that a fluid exerts on an object. It determines whether an object sinks or floats.

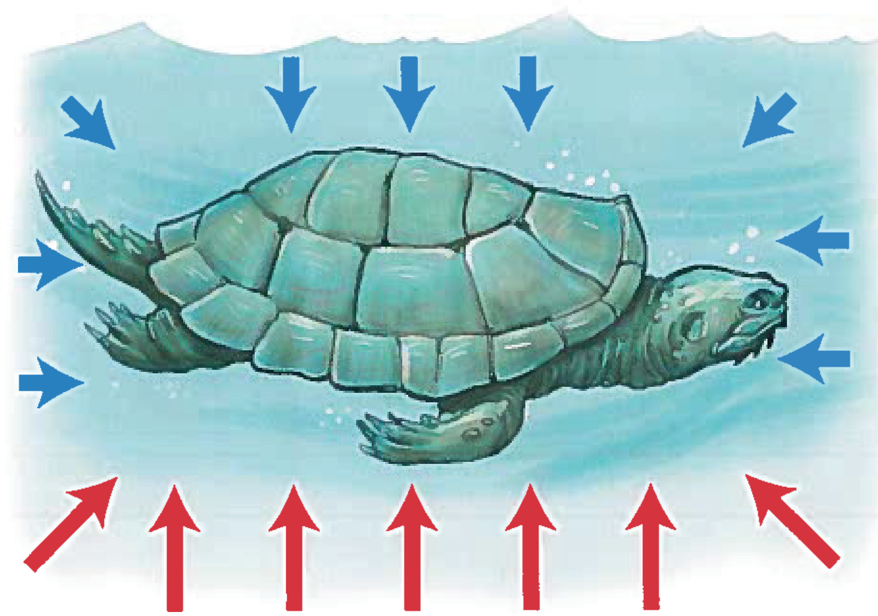


Figure 1 The upward force exerted by the liquid (shown by the red arrows) is called "buoyancy" or the "buoyant force."

A block of solid metal will sink in water, yet a boat made of the same amount of metal will not. Why does the buoyant force of water keep a boat afloat but not the metal block? Why does the shape of the metal determine whether it will sink or float?

LINKING TO LITERACY

Critical Thinking: Cubing

Cubing helps you get more meaning from the texts you read.

Make a cube. Write one of the following words on each side: describe, analyze, apply, compare, associate, argue for/against. In a small group, discuss this section. Roll the cube. If you roll:

- describe: talk about what buoyancy is like
- analyze: talk about how buoyancy works
- apply: talk about ways you could use buoyancy
- compare: talk about how buoyancy is the same or different from something else
- associate: talk about what "buoyancy" brings to mind
- argue for/against: talk about what is good or not good about buoyancy

TRY THIS: Building a Metal "Boat"

SKILLS MENU: performing, observing, analyzing

SKILLS HANDBOOK 6.A.2., 6.A.3.

In this activity, you will make a model metal "boat" and compare the weight of the water it displaces with the weight it can hold.

Equipment and Materials: cup or beaker; ruler; scissors; balance or scale; overflow can; pennies; heavy-duty aluminum foil; water

1. Measure and record the mass of the cup or beaker.
2. Cut two 15 cm × 15 cm squares of aluminum foil.
3. Keep folding one of the squares in half, squeezing out the air between each fold. Keep folding the foil until you have a small, flat shape. Measure and record its mass.
4. Place the folded foil in the filled overflow can. Measure and record the mass of the displaced water.
5. Dry the cup or beaker and replace it under the spout.
6. Make a small boat with the other foil square. Refill the overflow can, place your aluminum boat in it, and carefully add pennies to the boat until it is just about to sink. Collect the displaced water. Measure and record its mass.
7. Remove the boat with the pennies in it and measure its mass. Record this value in your notebook.

A. Use the equation *weight = mass (kg) × 9.8 N/kg* to calculate the weight of
   (i) the folded aluminum
   (ii) the water displaced by the folded aluminum
   (iii) the aluminum boat with pennies in it
   (iv) the water that the boat (with pennies in it) displaced

B. Compare these four weights. What do you notice?

The Try This activity shows that the weight of floating objects is equal to the weight of the water that they displace. The force of gravity acting downward on a floating object is equal to the buoyant force of the water acting upward on the object (Figure 2). The flattened foil displaces a small amount of water, so the buoyant force acting on it is very small and cannot support the weight of the foil. However, the boat-shaped foil displaces more water, so the buoyant force is much larger. The buoyant force on the foil boat supports the foil plus many pennies as well. This is why large metal ocean freighters can carry so much cargo: the displacement of so much water by the large, hollow shell results in a very large buoyant force.

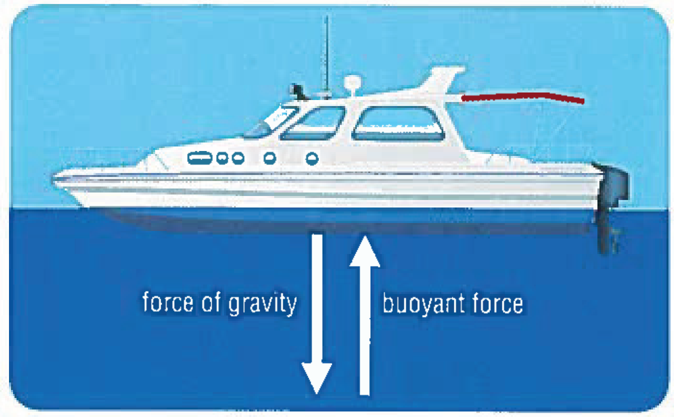


Figure 2 The buoyant force equals the weight of the water displaced by the object.

Hydrometers float at different levels in different liquids because the liquids push upward on the hydrometer with different forces. In other words, each fluid has a different buoyancy. Salt water, for example, is more dense than fresh water, so it provides a greater buoyant force. That is why ships have a Plimsoll line painted on their sides (Figure 3). The markings show at what level the ship will float in different types of water. Freshwater markings are on the left and saltwater markings are on the right.

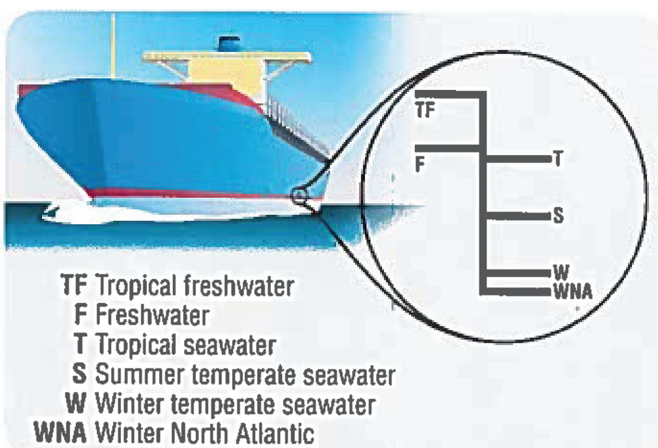


Figure 3 A Plimsoll line allows observers to easily see whether a ship is floating high enough in the water to withstand rough seas without getting swamped.

Unit Task How will you be able to use the concepts of density and buoyancy in designing your toy?

CHECK YOUR LEARNING

1. Define buoyancy and add a visual to the explanation.
2. What is the relationship between density and buoyancy for objects and substances?
3. Explain how a dense substance, such as metal, is able to float on a less dense substance, like water. Use an example from this section in your explanation.
4. Why does a ship float at different levels depending on the type of water it sails in?

SCIENCE WORKS

Underwater Treasures

After the *Titanic* sank in 1912, it rested undisturbed 640 km off the coast of Newfoundland for more than 80 years. When it was found, underwater salvage operations recovered more than 2000 smaller artifacts from the wreck. Then, amazingly, a 20-ton piece of the hull was raised 4 km to the surface. This could never have been achieved without the buoyant force of water. Large, diesel-filled flotation bags were attached to the piece of hull and used to buoy the immense object to the surface. Whole ships can be salvaged in this manner.

Flotation bags were also used to make an artificial reef off the coast of Florida. In May of 2001, the *Spiegel Grove*, a 155-metre retired U.S. Navy ship was to be scuttled so that it would sit upright on the bottom of the ocean. However, it sank prematurely and landed upside-down with its hull sticking out of the water. A month later, airbags were used with tugboats to roll the ship onto its side (Figure 1). In 2005, Hurricane Dennis shifted the ship right-side-up.

Figure 1 The buoyancy of water was used to roll the *Spiegel Grove* onto its side so that it would be totally submerged.

Imagine salvaging an underwater forest. That was the dream of Chris Godsall of Victoria, British Columbia. Approximately 300 million trees have been flooded by hydro dams around the world, and it was his vision to find a way to capture this lost wood. The remotely controlled Sawfish (Figure 2) developed by his company is the world's only deepwater logging machine. Eight video cameras and sonar help the operator locate trees. The Sawfish's 1.4 m chainsaw can harvest larger trees than land-based machines, thanks to water's natural buoyancy. An inflatable, reusable airbag is attached to each water-soaked tree. Then, the buoyant force of water brings the tree to the surface.

Figure 2 The Sawfish uses the buoyancy of water to manoeuvre, handle cut trees, and bring them to the surface.

To learn more about underwater salvage,
Go to Nelson Science

Density and Buoyancy in Action

8.6

Density and buoyancy are closely related characteristics of fluids that help us understand how plants and animals—including humans—make use of fluids.

Oil and Water

Oil is usually less dense than water, so it floats on the surface of water. This property of oil is both harmful and helpful during oil spills. The oil is harmful to aquatic and shore plants and animals. It may contaminate their food, make it difficult for them to breathe, and destroy the insulating effect of fur or feathers.

However, the fact that oil is less dense than water is helpful in cleaning up oil spills. Floating booms are used to encircle oil spills on the surface of the water (Figure 1). Then, collection devices scoop, soak, or suck up much of the captured oil.

Figure 1 This floating boom has trapped most of the spilled oil.

Airships, Balloons, and Blimps

On May 6, 1937, the German airship *Hindenburg* completed its twenty-first crossing of the Atlantic Ocean. While docking in New Jersey, U.S.A., it caught fire and burned within seconds (Figure 2). The 245-metre-long craft was filled with hydrogen gas—less expensive and less dense than helium, but extremely explosive. Thirty-six people died in the disaster—thirty-three of them when they jumped from the burning airship.

Today, "lighter-than-air" craft are used mainly for advertising and recreation. Some, like the Goodyear blimps, are helium-filled airships that propel themselves through the air. Most, however, are hot air balloons filled with air heated by burners and attached to a basket or other type of passenger compartment. The balloon is open at the bottom. The heated air rises into the balloon, forcing the cooler, heavier air out the opening. The hot air inside the balloon is much less dense than the colder outside air and makes the balloon buoyant (Figure 3).

To learn more about the Hindenburg and other "lighter-than-air" craft,
Go to Nelson Science

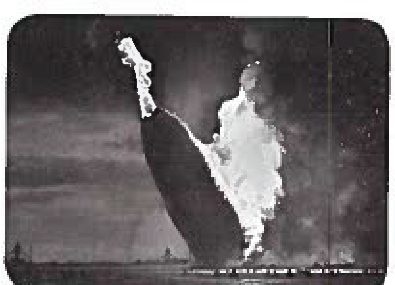


Figure 2 The *Hindenburg* disaster reduced the number of large air ships used for commercial transportation.

Figure 3 Designers must consider density and buoyancy when creating specialized hot air balloons.

The Importance of Buoyancy

Water hyacinth (Figure 4) is a floating plant used in pond gardens. Water hyacinth's buoyancy is due to numerous air chambers in its stem. Humans use this idea of flotation chambers in a wide range of devices, such as life preservers, float plane pontoons, and pool chairs.

Figure 4 The rounded portions of the water hyacinth stem contain air, making this water plant less dense than the water it lives in.

The Buoyancy of Fish and Submarines

Most bony fish maintain their position in the water with the use of a **swim bladder**, a thin-walled sac in their bodies that contains mainly oxygen (Figure 5). Fish can alter the volume of water they displace and their overall density by adjusting the amount of oxygen in the bladder. This changes their buoyancy in the water. The more oxygen in the bladder, the higher they float; the less oxygen, the more they sink. This helps fish save energy while maintaining their depth in the water. The oxygen comes from the dissolved oxygen in the water and enters and leaves the bladder through the fish's blood.

swim bladder: a controllable, balloon-like chamber that allows fish to alter their buoyancy

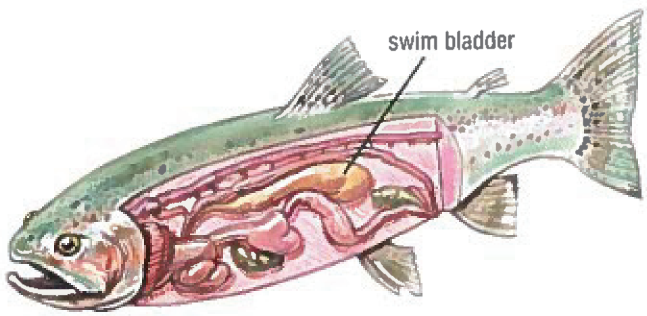


Figure 5 The oxygen in a fish's swim bladder comes from the dissolved oxygen in the water.

Submarines work in a similar manner to the swim bladder. Submarines contain ballast tanks in place of the bladders. **Ballast tanks** are specialized chambers that can be filled with air or water to control the depth of the submarine. To make the submarine descend, valves are opened to take on more water in the ballast tanks (Figure 6). To surface, air from compressed air tanks is forced into the ballast tanks, displacing the water and reducing the ship's mass-to-volume ratio. This reduction in density causes the buoyant force of the surrounding water to carry the submarine to the surface.

ballast tanks: compartments in a ship or submarine that take in water to keep the ship stable or help a submarine dive below the surface

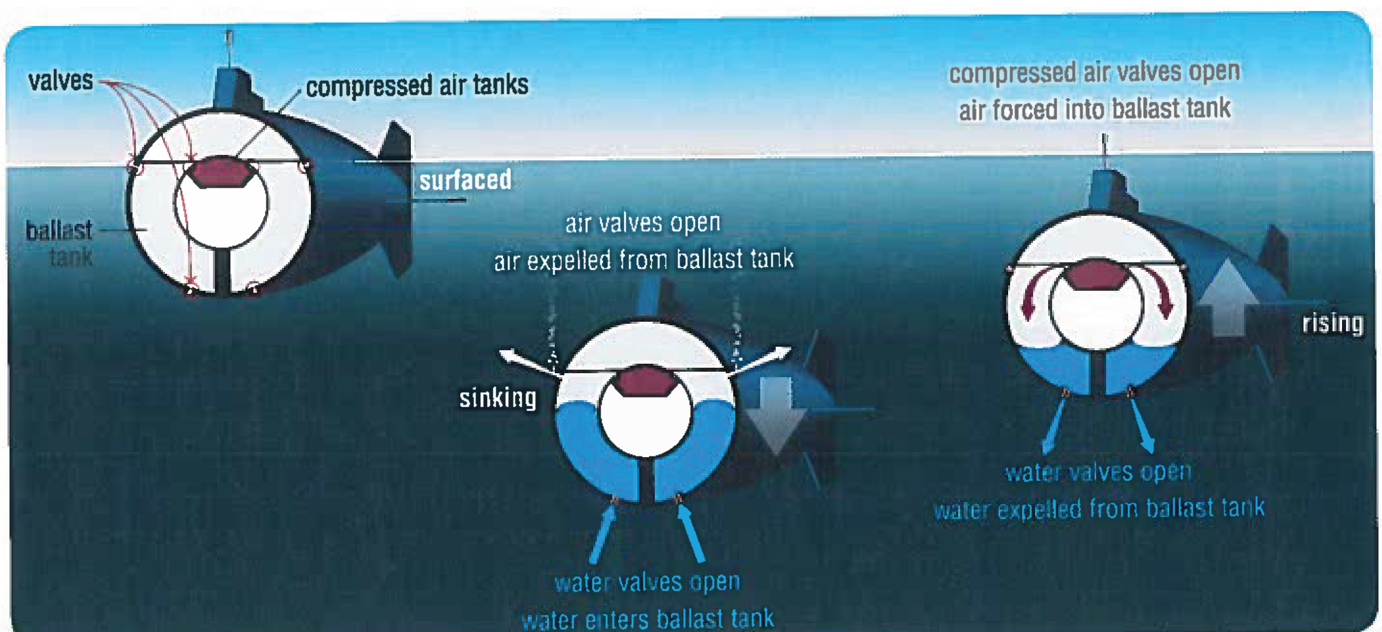


Figure 6 A submarine's ballast tank works like a fish's swim bladder.

By controlling the amount of air in these specialized chambers, submarines and fish can change their density, causing positive, negative, or neutral buoyancy. When positive buoyancy occurs, the object begins to float upward; negative buoyancy causes the object to sink. Neutral buoyancy occurs when the submarine or fish remains in one place, neither rising nor sinking.

TRY THIS: Building a Cartesian Diver

SKILLS MENU: performing, observing, analyzing, communicating

SKILLS HANDBOOK 4.C.1.

The Cartesian diver, along with other toys based on it, has entertained science students and children around the world for hundreds of years. In this activity, you will build your own Cartesian diver.

Equipment and Materials: scissors; 2 L plastic pop bottle (labels removed) with lid; plastic drinking straw; metal paper clips; modelling clay (optional); container of water

1. Cut a plastic drinking straw in half. Bend the straw in half. Secure the bent straw by using a paper clip.
2. Loop four or five additional paper clips over the clip keeping the straw bent (alternatively, add a small lump of modelling clay to the paper clip). This is your diver.
3. Place the diver into the container of water. The diver should just float on the surface of the water (Figure 7). If it does not, add or remove weight (paper clips or modelling clay) from the diver until it floats.
4. Fill the 2 L bottle almost to the top with water. Place the diver in the bottle and put the lid on tightly.
5. When you squeeze the sides of the bottle, you force more water into the straw. Observe what happens to the diver. How can you get the diver to demonstrate positive, negative, and neutral buoyancy?

A. In your notebook, make a labelled drawing of your Cartesian diver in a bottle.

B. Record your observations as you squeeze and release the bottle.

C. Explain how a Cartesian diver can demonstrate positive, negative, and neutral buoyancy. Use sketches if you wish.

Figure 7 Your diver should just float on the surface of the water.

Cartesian divers, submarines, and fish with swim bladders all demonstrate a common principle: objects that displace a greater volume of fluid are more buoyant than those that displace less fluid.

Unit Task Buoyancy is often considered when designing air and water toys. How might you use buoyancy in designing your toy?

CHECK YOUR LEARNING

1. What is the most important idea you learned in this section? Explain the reasons for your choice.
2. Describe two instances in which humans might have used examples from nature when designing devices that use the properties of density and buoyancy.
3. Is the density of oil helpful or harmful when dealing with oil spills? Explain your answer.
4. (a) Explain how ballast tanks work. You may use a diagram in your explanation.

   (b) How is a fish swim bladder similar to a submarine ballast tank?

CHAPTER 8

SUMMARY

Density and Buoyancy

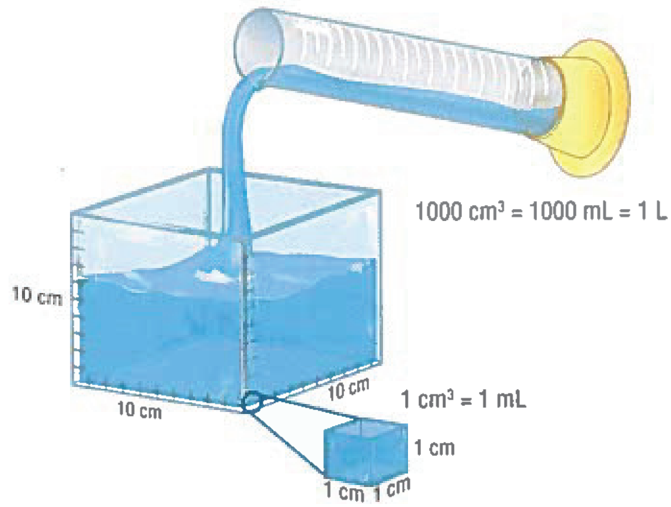
BIG Ideas

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

Looking Back

Density is a specific property of fluids that can be used to our advantage.

- Mass is a measure of the amount of matter in an object or substance.
- Volume is the amount of space an object occupies.
- Density is a measure of the mass per unit volume.
- Density is a characteristic property of matter; it is used in various industries and can even be used to identify unknown substances.



The skills of analysis can be used to determine the mass-to-volume ratio of a substance.

- The mass of different substances can be measured.
- The volume of different substances can be calculated or measured. One method of measuring volume is the finding volume by displacement method.
- The mass-to-volume ratio, or density, of substances can be calculated and can be used to identify unknown substances.

The skills of scientific inquiry can be used to determine the density of different liquids.

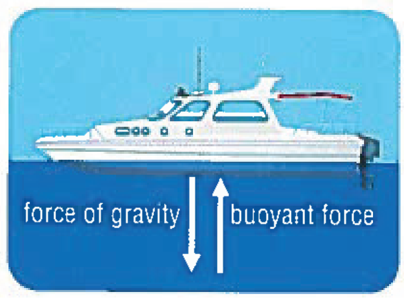
- The density of liquids can be measured using a hydrometer.
- A simple, homemade hydrometer can be constructed and used to measure the density of liquids.

Buoyancy is the upward force that all fluids exert on objects.

- All fluids, whether liquids or gases, exert an upward force on objects.
- The buoyant force that water exerts on an object is equal to the weight of the water the object displaces.
- Density and buoyancy are closely related.
- Substances and objects that are less dense than the fluid in which they are placed exhibit positive buoyancy. (They float.)
- Substances and objects that are denser than the fluid exhibit negative buoyancy. (They sink.)
- Substances and objects that are equal in density to the fluid exhibit neutral buoyancy. (They remain suspended in the fluid.)

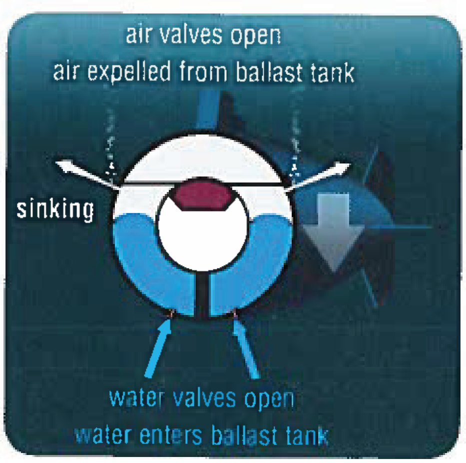
VOCABULARY

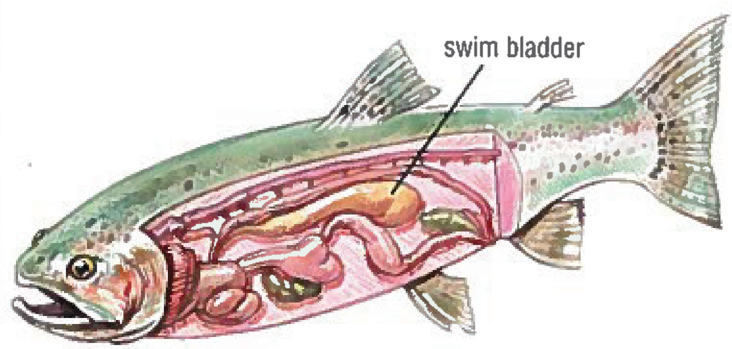
weight, p. 208
mass, p. 208
volume, p. 208
displace, p. 209
density, p. 212
characteristic property, p. 213
buoyancy, p. 216
swim bladder, p. 220
ballast tanks, p. 220



Many natural and human-made objects make effective use of density and buoyancy.

- Many living things use density and buoyancy to survive.
- Humans often make use of density and buoyancy when designing devices and procedures.
- Some human-made devices (for example, submarines) mimic similar objects found in nature (for example, a fish's swim bladder).





CHAPTER 8 # REVIEW

The following icons indicate the Achievement Chart categories: K/U Knowledge/Understanding; C Communication; T/I Thinking/Investigation; A Application

What Do You Remember?

1. Describe two different ways to determine the density of an object or material. K/U
2. What is the meniscus and how should it be used when measuring the volume of water in a graduated cylinder? K/U
3. Use a flow chart or other graphic organizer to explain how to correctly use an overflow can. K/U C
4. Use the particle theory to explain density. K/U
5. What is meant by positive buoyancy, neutral buoyancy, and negative buoyancy? K/U
6. What is meant by a characteristic property of matter? K/U
7. What are some of the advantages and disadvantages of determining volume by the water displacement method? K/U
8. Are the *Hindenburg* and the Goodyear blimp (Figure 1) examples of hot air balloons? Explain. K/U

Figure 1

9. Why must hot air balloons carry a heat source with them? K/U
10. Describe two positive applications of buoyancy and two negative effects of buoyancy. K/U A
11. How are a Plimsoll line, density, and buoyancy related? K/U
12. Compare and contrast the way that fish and submarines use density and buoyancy to control their position in the water. Consider using a Venn diagram to make your comparison. K/U C
13. Use Table 1 in Section 8.3 to answer the following questions:
    (a) Which solids would float on water?
    (b) Which solids would sink in water but float on mercury?
    (c) If 0.5 m^3 of an unknown substance has a mass of 0.65 kg, what is the substance likely to be? K/U

What Do You Understand?

14. Imagine that you have travelled to a planet that is much smaller than Earth and has less gravitational pull. You have taken a block of metal with you. Compare the mass, weight, volume, and density of the object on Earth and on the smaller planet. K/U T/I
15. (a) Does the swim bladder of a fish generally keep the fish positively, neutrally, or negatively buoyant?
    (b) How does this compare to the use of ballast in a submarine? Explain your answer. K/U A
16. Two metal objects, A and B, each have a mass of 200 kg. Object A displaces 100 kg of water. Object B displaces 1000 kg of water. Which one is more likely to be a boat? Explain your reasoning. T/I A
17. You are the captain of a fully loaded ship sailing from warm tropical waters into the cold North Atlantic. As you sail north, will you need to dump some of your ballast water so that the ship can travel safely? Explain your answer. T/I A

18. Use words and pictures to show how a submarine uses ballast and compressed air to (a) rise, (b) descend, and (c) remain at one level in the water. K/U C

19. Would a ship in Lake Ontario (fresh water) float higher or lower in the water than in the Atlantic Ocean (salt water). Give reasons for your answer. A

Solve a Problem!

20. If 30 mL of a fluid has a mass of 63 g, what is its density? Will it float or sink in water? Explain. T/I A

21. You would like to raise a very delicate piece of sunken equipment to the surface, but you must do it slowly. In the flotation bags, you can use either air or diesel oil. Which would you use? Explain your reasoning. T/I A

22. You are a manufacturer of carbon monoxide detectors. One of your employees suggests that the detectors should come with instructions to install them close to the floor. Another says that it does not matter. Use Table 1 in Section 8.3 and your knowledge of fluids to develop a response to your employees. K/U T/I A

Create and Evaluate!

23. Continue to build upon the concept map you began at the start of this unit. Share what you have written with a partner and evaluate each other's work. Make any modifications you think are necessary. K/U C

24. Create a graphic that clearly shows why 1 cm^3 is equal to 1 mL. Evaluate your graphic. What are some of its limitations? K/U C

25. Most of us have little control over oil spills. However, we do have control over the fluids that enter our storm drains when we wash cars (Figure 2), change the oil, or discard such things as cleaning fluids and paint. Research what happens to fluids that enter storm drains, and create a poster to convince others to treat these drains with care. What are some limitations of a poster campaign? Suggest a more effective way of communicating this to the members of your school community. T/I A C

Go to Nelson Science

Figure 2

Reflect on Your Learning

26. Which aspect of fluid properties have you found most interesting so far? Why do you think this is so interesting?

27. Think back to the Key Question on the first page of this chapter.
    (a) In a brief paragraph, answer the Key Question. You may use diagrams.
    (b) Write one or two more questions about the topic of this unit that you would like to explore.

CHAPTER 9

Fluids Under Pressure

KEY QUESTION: How do pressurized fluids affect our lives and the lives of other living things?

Looking Ahead

- Under pressure, some fluids behave differently than others.
- Systems use fluids to accomplish tasks.
- The skills of scientific inquiry can be used to study how fluids are used in hydraulic systems and pneumatic systems.
- Pressurized fluid systems occur in nature as well as in human-made devices.
- Technological problem-solving skills can be used to create a working model of a hydraulic or pneumatic device.
- Human use of fluids technology has social and environmental costs and benefits.

VOCABULARY

compress
compressibility
pneumatic system
hydraulic system
pressure
atmospheric pressure
Pascal's Law
valve
internal combustion engine

Hydrants, Hoses, and Hope

Shortly after midnight, the fire was still not completely out. Jason and Shauna continued to watch the scene. Two hours earlier, their neighbour, Mrs. Nguyen, had pounded on their door, asking to call 911. While she was cooking a late-night snack, some cooking oil had splashed onto the gas stove and caught fire. She tried to put the fire out with water but that made things worse. Getting herself and her pets out of the house became the priority.

The fire trucks arrived soon after. The firefighters rolled the hoses out and connected them to the fire hydrant down the street. Within minutes, water was flowing from the pumper trucks into hoses and onto the burning house. Hoses on extension ladders rained water down upon neighbouring homes to prevent the fire from spreading.

When the fire was under control, the firefighters entered the house to begin cleanup. They were wearing masks connected to air tanks on their backs. It was not only the smoke from burning materials the firefighters had to worry about; many household items give off poisonous fumes when heated or burned.

Mrs. Nguyen, although comforted by paramedics and friends, was devastated at her loss. Part of the house had been saved, but it would be many months before she could move back in. Still, the firefighters had done their work. They had salvaged some of her house and, most importantly, made sure that Mrs. Nguyen and her pets were safe. There was hope.

LINKING TO LITERACY

Recounts

A recount lists, in order, a series of small events that happened to a person or character. There are three types of recounts: personal, factual, and imaginative. The text on this page is a *factual recount* because it reports the facts of an incident as they occurred. Sometimes, to capture a reader's interest, the writer begins with the last event of the recount, and then describes what happened before this event.

1. Create a sequence chart to list each of the events in this recount in order. Begin with a blank sheet of paper. Draw a text box and write the event that came first. Then draw a second box and write the second event. Connect the first box to the second box with an arrow. Continue adding text boxes and arrows until you have listed all of the recount's events.

9.1 Putting the Squeeze on Fluids

compress: to pack closely together; squeeze

Does a water-filled balloon bulge and move in the same way as an air-filled balloon when it is squeezed (Figure 1)? Air and water tend to flow from one place into another when you try to **compress** them or squeeze them into a smaller space.

LINKING TO LITERACY

Making Connections: Text-to-Self

This text asks you to make a text-to-self connection. Think about the last time you squeezed a balloon and felt the air move from one part of the balloon to another.

Making a connection to the text, or thinking about a "time when…" helps you make sense of the scientific principle that is being explained.

Figure 1 Compressing a fluid is difficult when the sides of the container are free to move.

TRY THIS: Compressing Fluids

SKILLS MENU: performing, observing, analyzing, communicating

In this activity, you will use a syringe (Figure 2) to observe the effects of compressing a volume of air and then the same volume of water.

Equipment and Materials: eye protection; 20 mL syringe; water

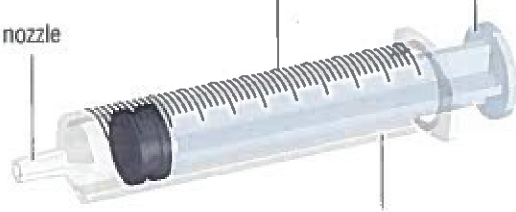


Figure 2 A syringe

Wear eye protection to work with fluids under pressure.

1. Draw 20 mL of air into the syringe and cap the nozzle with your thumb so that no air escapes.
2. Press the plunger slowly and firmly while keeping the end sealed. Watch for any change in the volume of air. If air escapes from the end of the syringe, cap the end more tightly or use less force on the plunger.
3. Keep the end sealed, and release the plunger. Observe any changes in volume. Record your actions and observations.
4. Repeat steps 1 to 4 using water. Record your observations in your notebook.

A. Offer a possible explanation for any observed change in fluid volume.

The Try This activity demonstrates that air (a gas) can be compressed into a smaller volume much more easily than water (a liquid) can. Why is that?

The particles of a gas are much farther apart than those of a liquid, allowing us to force the particles of a gas closer together. There is less space between the particles of liquids so they have very little compressibility, while solids have almost none at all. **Compressibility** is the ability of a substance to become more compact when squeezed.

compressibility: the ability to be squeezed into a smaller volume

Types of Fluid Systems

Systems designed to put the squeeze on fluids can be divided into two main types. **Pneumatic systems** (Figure 3) use pressurized air or other gases to do work. **Hydraulic systems** (Figure 4) use pressurized liquids (often oil) to do work. These systems must keep their fluids contained within them in order to work. They are called closed systems. Closed systems are ones in which no material enters or leaves the system.

Hydraulic and pneumatic fluid systems consist of several components:

- a pump (sometimes including cylinders and pistons) forces fluids through a system
- conductors (tubing, hoses, or pipes) provide a pathway to carry the fluid
- valves keep the fluid moving in the desired direction at the desired time
- a pressure gauge monitors pressure within the system

Each component has its own job to do (Figure 5).

pneumatic system: a system that uses gases under pressure

hydraulic system: a system that uses liquids under pressure

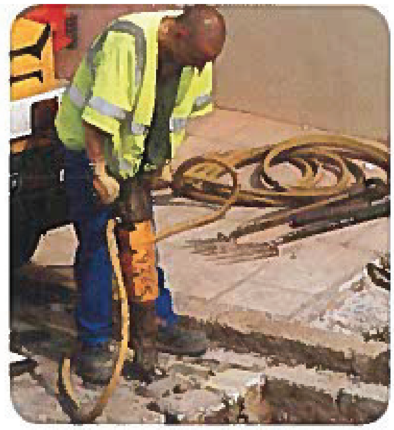


Figure 3 Pressurized air provides the power for this pneumatic hammer.

Figure 4 Rescue workers use hydraulic cutters and spreaders to rescue crash victims.

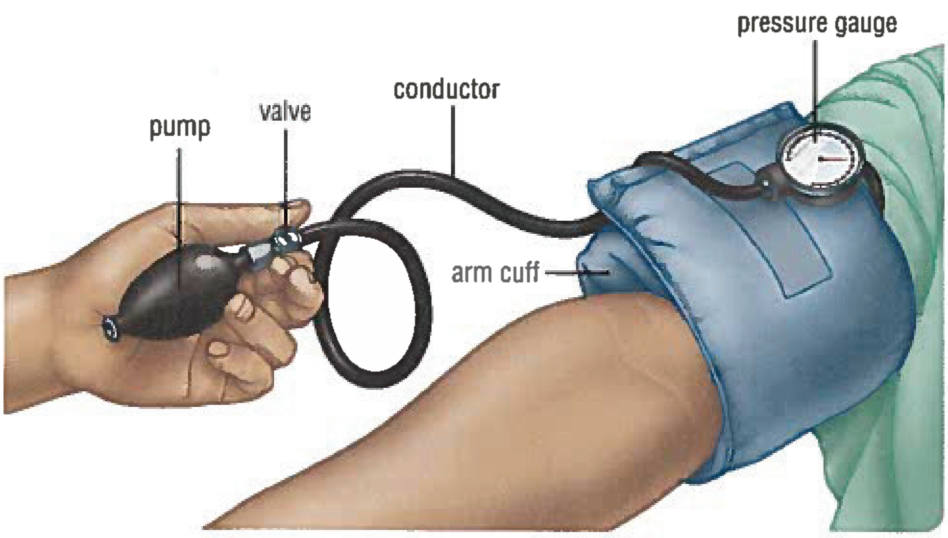


Figure 5 A blood pressure gauge uses the pressure of air to measure the pressure of liquid blood in the body.

Unit Task How might you address the compressibility of different fluids when planning for the Unit Task?

To learn more about how hydraulic and pneumatic systems work,

Go to Nelson Science

CHECK YOUR LEARNING

1. Define "compressibility" in your own words. Give an example from your daily life.
2. Using the particle theory, explain why liquids are less compressible than gases.
3. (a) What is a hydraulic system?
   (b) What is a pneumatic system?
4. What are the components of both hydraulic and pneumatic fluid systems?

9.2 CONDUCT AN INVESTIGATION

Investigating Fluids in Closed Systems

In this activity, you will connect a variety of syringes together to observe the effects of air and water in different systems.

SKILLS MENU

- [ ] Questioning
- [x] Hypothesizing
- [x] Predicting
- [ ] Planning
- [ ] Controlling Variables
- [x] Performing
- [x] Observing
- [x] Analyzing
- [x] Evaluating
- [x] Communicating

Testable Question

What effect does changing the type of fluid (for example, air or water) have on the ability of a fluid system to transfer force?

Hypothesis/Prediction

SKILLS HANDBOOK 2.B.3.

Read over the rest of the investigation. Make a hypothesis regarding the ability of air and water to transfer force. Your hypothesis should include a prediction and reasons for your prediction.

Experimental Design

In this investigation, you will use syringes to observe how a pneumatic system is able to move plungers in syringes of different sizes. You will then compare those observations while using the same syringes to create a hydraulic system.

Equipment and Materials

- eye protection
- two syringes (30 mL)
- syringe (10 mL)
- 5 cm of vinyl tubing
- 50 cm of vinyl tubing
- wax crayon or masking tape
- water


eye protection


two syringes (30 mL)


syringe (10 mL)


5 cm of vinyl tubing


50 cm of vinyl tubing


wax crayon or masking tape


water

Wear your eye protection and follow instructions carefully. Stop applying pressure when a plunger is moving close to the open end of the syringe.

Procedure

1. Read the rest of the procedure and decide how you will record your observations. Design an observation table that you can use.
2. Put on your eye protection. Begin with two 30 mL syringes. Use a wax pencil or masking tape to label one of the syringes "A" and the other "B."
3. Pull the plunger of syringe A to the 30 mL mark, and push the plunger of syringe B all the way in. Connect them with the 5 cm piece of tubing.

4. Slowly push plunger A all the way in. Observe and record what happens to plunger B. How far did each plunger move? What is the final reading on syringe B?
5. Try pushing the plunger of one syringe in, while preventing the plunger of the other one from moving. What do you notice? Record your observations.
6. Repeat steps 3 to 5, using a 50 cm length of tubing between the syringes. What do you notice? Record your observations.
7. Repeat steps 3 to 5, using water as your fluid instead of air. To set this up correctly, begin by pushing both plungers all the way in. Then connect the tubing to one of the plungers, put the end in water, and pull the plunger back to the required volume. This will keep the tubing filled with water. Record your observations.
8. Empty and dry the syringes. Connect a 30 mL syringe (plunger all the way in) to a 10 mL syringe (plunger all the way out) with a 5 cm piece of plastic tubing (Figure 1). Move both plungers back and forth, with and without adding resistance (trying to prevent one of the plungers from moving). Observe the distance moved by the plungers. Observe the ease of moving the plungers. Record your observations.

Figure 1

9. Repeat step 8 using water in the system. Record your observations.

Analyze and Evaluate

SKILLS HANDBOOK 2.B.7.

(a) Which syringe systems were pneumatic systems? Which were hydraulic systems?

(b) Compare your observations using the two 30 mL syringes with air and water. What differences did you notice

(i) when you added no resistance?

(ii) when you added resistance?

(c) What did you notice when you used tubing of different lengths between the syringes?

(d) What did you notice when you used syringes of different sizes?

(e) When you used the 10 mL and 30 mL syringe systems, which plunger was easier to move against the resistance you provided?

(f) Did your results support your hypothesis? Explain.

(g) Answer the Testable Question.

Apply and Extend

(h) With your pneumatic system above, how do you think your results would have been affected if there had been a leak in the tubing?

(i) Given your observations for this investigation, would you rather have a hydraulic braking system or a pneumatic braking system in your car? Explain.

Unit Task Do you think you could use one of the systems designed here in the toy you create for the Unit Task?

LINKING TO LITERACY

Summarize Your Learning: The Quick Write

Do a *quick write* to increase your learning. Take 5 minutes to write about what you have just learned from this experiment. Retell the process you followed to complete the investigation. Reflect on your findings. Relate what you learned about fluids to other systems that use the same principles.

Putting Fluids to Work

Pressurized fluids in both hydraulic and pneumatic systems are used to do work. In this activity, you will compare work done by these two types of systems.

SKILLS MENU

- ☐ Questioning
- ☒ Hypothesizing
- ☐ Predicting
- ☐ Planning
- ☐ Controlling Variables
- ☒ Performing
- ☒ Observing
- ☒ Analyzing
- ☒ Evaluating
- ☒ Communicating

Purpose

To compare the effect of using hydraulic and pneumatic systems to move a load.

Equipment and Materials

- eye protection
- 2 syringes (30 mL)
- syringe (10 mL)
- 10 cm of vinyl tubing
- 50 cm of vinyl tubing
- force meter
- 1 kg standard mass, brick, or small pile of textbooks to act as a load
- syringe (60 mL)
- wax crayon or masking tape
- water


eye protection


two syringes (30 mL)


syringe (10 mL)


10 cm of vinyl tubing


50 cm of vinyl tubing


force meter


a load


syringe (60 mL)


wax crayon or masking tape


water

Procedure

Part A: Pneumatics

1. Read the rest of the procedure (Part A and Part B). Decide how you will record your observations and design a table in which to record them.
2. Put on your eye protection. Begin with two 30 mL syringes. Use a wax pencil or masking tape to label one of the syringes "A" and the other "B."
3. Pull the plunger of syringe A to the 30 mL mark, and push the plunger of syringe B all the way in. Connect them with the 10 cm length of tubing.
4. Place both syringes flat on your desk. For the next steps, hold them firmly so that they do not move. Optional: You can easily make a simple device for holding the syringes in place using a spare board and a few nails (Figure 1).

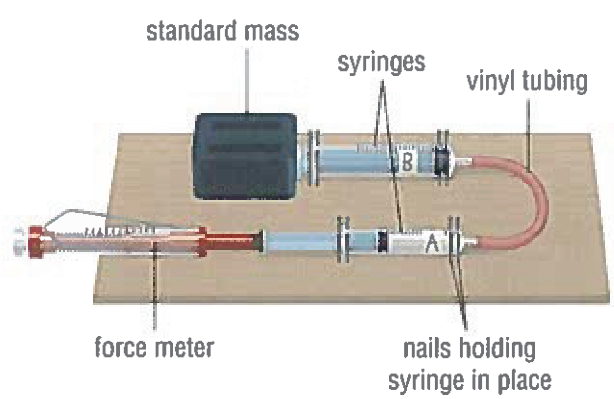


Figure 1 Setup for step 4

5. Place the standard mass (or other load) on the desk so that it is touching the plunger of syringe B.
6. Place the force meter against the plunger of syringe A. Then, as you slowly push in plunger A, measure the force needed to cause plunger B to move the load (Figure 2). Record this measurement.

Stop applying pressure when a plunger is moving close to the end of the syringe.

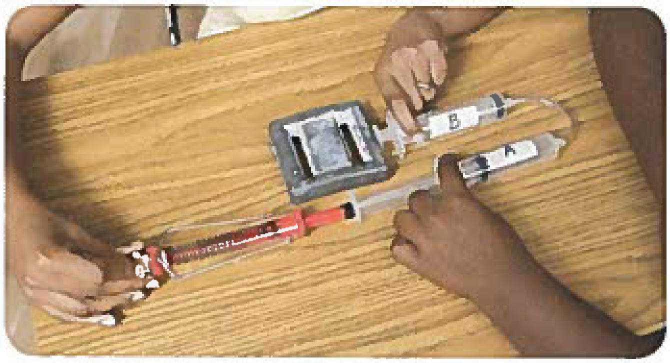


Figure 2 Slowly push on the force meter while taking the measurement.

7. Measure the distance moved by plunger A and the distance moved by the load pushed by plunger B. Record your observations.
8. Repeat steps 3 to 7 using
   - a 30 mL syringe (A) to push the plunger of a 10 mL syringe (B)
   - a 10 mL syringe (A) to push the plunger of a 30 mL syringe (B)
   - a 10 mL syringe (A) to push the plunger of a 60 mL syringe (B)
9. Repeat steps 2 to 7 using the 50 cm of tubing. Record your observations.

Part B: Hydraulics

10. Repeat steps 2 to 8 using the 10 cm length of tubing and water as the fluid. Make certain that there is no air trapped in your syringes or tubing. Record your observations.

Analyze and Evaluate

(a) Make a general statement about the force needed to move a load and the distance the load moves when

(i) a small plunger pushes a larger plunger

(ii) a large plunger pushes a smaller plunger

(b) Use evidence from your activity to answer the following questions:

(i) What effect did changing the length of the tube have? Why might this happen?

(ii) What effect did using water instead of air have? Give some reasons why this might happen.

Apply and Extend

(c) Why are hydraulic systems used in machinery such as bulldozers (Figure 3) and backhoes, while pneumatic systems are used for such things as opening and closing bus doors?

Figure 3 Hydraulics are a major component of heavy equipment.

Unit Task How might this activity inform you about the length of tubing to use in your toy?

9.4 Effects of External Pressure on Fluids

pressure (scientific definition): the force per unit area

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

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

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

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

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

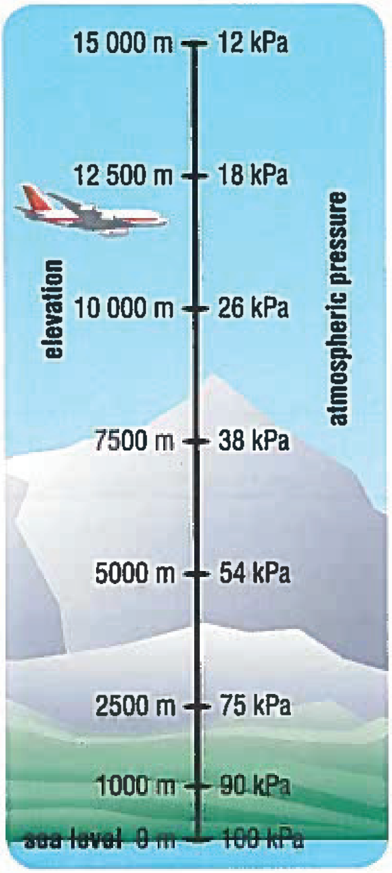


Figure 1 Atmospheric pressure on Earth

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

Air and Water Pressure

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

TRY THIS: Observing Atmospheric Pressure

SKILLS MENU: performing, observing, analyzing

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

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

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

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

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

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

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

Pressure and Pascal's Law

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

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

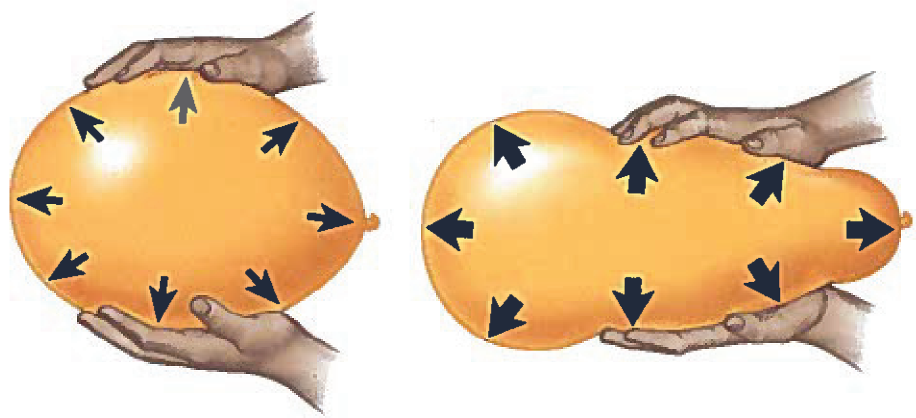


Figure 3 The inward force of the hands is transferred equally in all directions.

Applying Pascal's Law

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

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

LINKING TO LITERACY

Taking Notes: Main Ideas

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

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

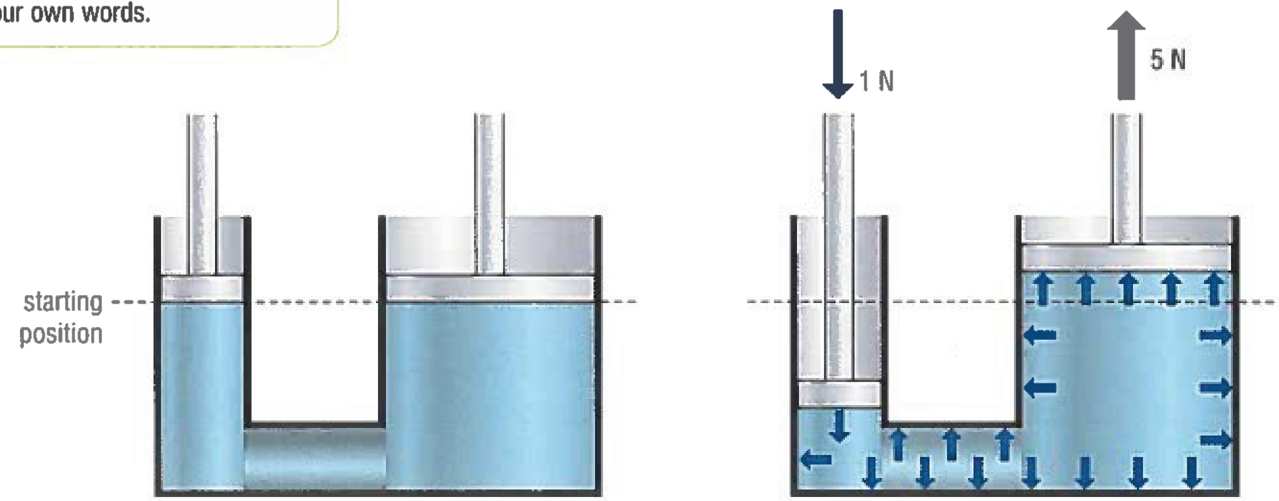


Figure 4 The distance moved by the large piston is always less than the distance moved by the small one. However, since the large piston has an area five times larger than the small piston, the force from the small piston is multiplied five times.

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

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

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

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

CHECK YOUR LEARNING

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

Tech CONNECT

Hydraulic Marvel—The Falkirk Wheel

In Scotland, on May 24, 2002, Queen Elizabeth II opened the Falkirk Wheel—the world's only rotating boat lift (Figure 1).

Figure 1 This amazing structure stands more than eight stories tall with a huge tank at the end of each of its two giant arms.

The Falkirk Wheel is used to pass barges and other boats from one canal to another (Figure 2). It replaces eleven traditional boat locks that were once needed to connect two canals whose water levels differ by 35 m.

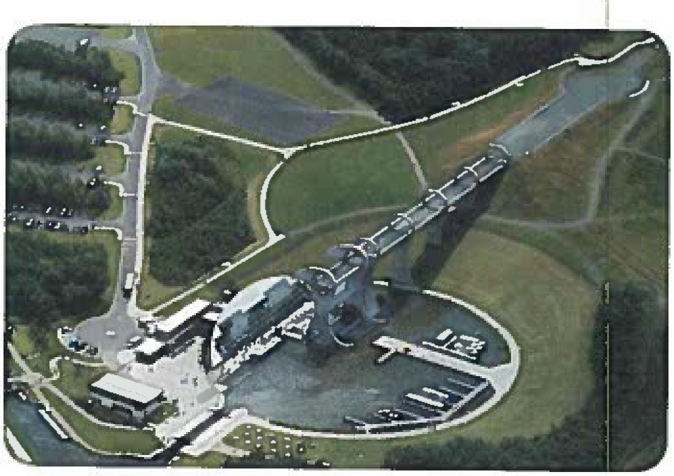


Figure 2 The Falkirk Wheel connects the Union Canal with the Forth and Clyde Canal 35 m below.

Each of the Falkirk Wheel's two giant tanks can hold 360 000 L, or 600 tonnes, of combined boat and water. The tanks are designed to always weigh the same since, according to Archimedes' principle, any boat entering one tank will always displace its own weight in water. The weight of the water and boats in the upper tank can then be used to help lift the water and boats in the lower tank. As the arms rotate, specially designed gear trains cause the tanks to rotate in the opposite direction so that the water always stays level (Figure 3).

Figure 3 The small gear between the two large ones causes the large gears to turn in opposite directions.

Ten hydraulic motors are used to turn the massive central wheel and axle. This truly amazing lift can raise and lower its 600-tonne load in just 5.5 minutes and it does so using about the same amount of energy as that needed to boil eight kettles of water!

For more information on the Falkirk Wheel,
Go to Nelson Science

9.5 Relationships: Pressure, Volume, and Temperature

LINKING TO LITERACY

Reading Diagrams

Use the following strategies to gain the best understanding of a diagram.

- Read the caption. It will give details about the diagram.
- Scan the diagram. Make sure you notice all details.
- Follow the arrows that point to parts of the illustration.
- Make connections between the words in the caption and the information in the diagram.

When you push a plunger in a sealed container, it compresses the air in the cylinder into a smaller volume. When a gas is under pressure in a closed system, its volume is decreased significantly (Figure 1). When liquids are under pressure, their volumes decrease as well; however, the decrease in volume is so small that it is barely noticeable. This is because particles of a liquid are much closer together than particles of a gas.

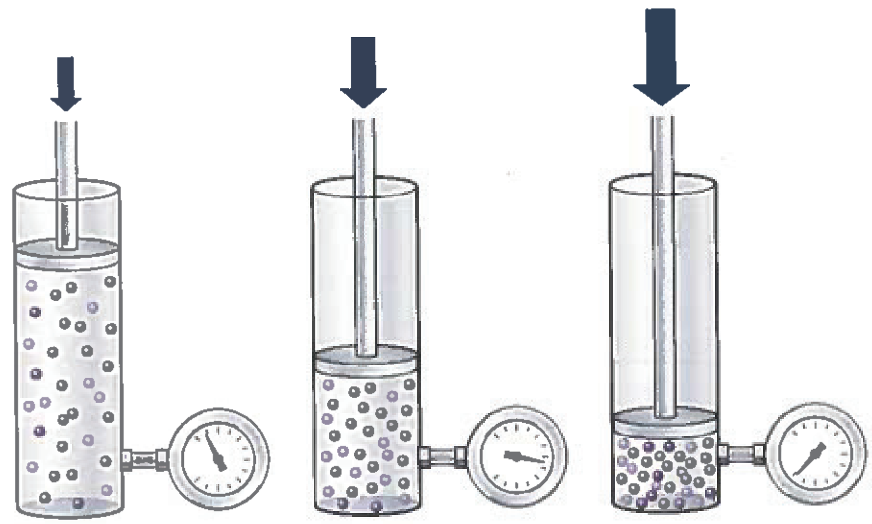


Figure 1 Increasing the pressure on a gas in a closed system reduces its volume significantly.

Figure 2 Pressure has been used to force a large amount of gas into a small volume in these welders' tanks.

For more information on the uses and process of compressing gases,
Go to Nelson Science

We use this property of fluids when we compress gases into scuba tanks and other rigid containers (Figure 2). All of these containers have a large amount of gas compressed into a small volume. As more gas particles are forced into the rigid container, the number of collisions between particles and the sides of the container increases. This increases the pressure that the gas particles exert on the interior walls of the container. The container is made of strong material (usually metal), so it does not burst. Why are most containers that hold gases under pressure curved?

If you have ever used a hand pump to fill a bicycle tire, you may have noticed that the barrel of the pump warms up. Some warming is due to friction between the piston and the cylinder walls. Rapidly pushing in the plunger of the pump also forces the air into a smaller volume. This compression causes more collisions among the particles of air and between the particles and the cylinder walls. This increase in collisions not only causes the pressure to increase, it also causes the temperature to rise. Conversely, increasing the volume causes the temperature to drop.

TRY THIS: Observing the Effects of Temperature Change on a Fluid

SKILLS HANDBOOK 2.B.1., 2.B.3.

SKILLS MENU: questioning, hypothesizing, performing, observing, analyzing, communicating

In this activity, you will change the temperature of the air in a bottle and observe the effects on the volume of air in the bottle.

Equipment and Materials: plastic pop or water bottle; balloon; 2 containers; hot water; ice water

1. Read over the entire activity. In your notebook, write a testable question you will attempt to answer. Once you have written the question, write a hypothesis based on your question. Your hypothesis should include a prediction and the reasons for your prediction.
2. Stretch the opening of a deflated balloon over the mouth of an empty pop or water bottle.
3. Immerse the upright bottle up to its neck in a container of hot water. Record what happens.
4. Remove the bottle and immerse it up to its neck in a container of ice water. Record your observations.

A. What happened to the volume of air as you heated and then cooled the bottle?

B. Did your observations support your hypothesis? Explain.

C. If your observations did not support your hypothesis, try to explain your observations using the particle theory.

D. Answer your testable question.

As temperature increases, the particles of a fluid move faster and farther apart. This causes the fluid to expand. As the temperature of a fluid drops, its volume decreases (contracts). This is generally true for all forms of matter. (As you saw in Chapter 8, water between 0 °C and 4 °C is a special case that does not follow this pattern.) Thermometers use this principle of thermal expansion during heating and thermal contraction during cooling to give us accurate temperature readings (Figure 3).

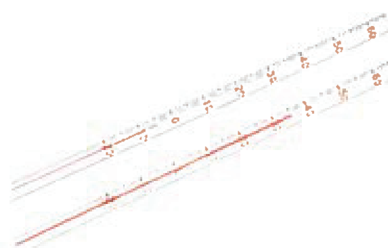


Figure 3 The principle of expansion and contraction of fluids has been used in thermometers for centuries.

Figure 4 shows a familiar warning sign. Why is heating aerosol containers so dangerous? As the temperature inside the pressurized can increases, so does the speed of the particles. As the particles move faster, they hit the inside walls of the can with increased force, causing the pressure on the walls to build up. Eventually, the pressure could become so great that the walls of the container explode.

In the opposite way, decreasing the temperature causes particles to slow down and move closer together. There will be fewer collisions with the sides of the container, and the pressure inside the container will drop.

Figure 4 Aerosol cans and other containers of compressed gas are extremely dangerous when heated, due to the danger of explosion.

Unit Task Will you need to consider relationships between temperature, pressure, and volume when designing your toy? Why or why not?

CHECK YOUR LEARNING

1. What happens to the volume of a gas in a cylinder when you try to compress it? Use a diagram in your explanation.
2. How is the property of compressibility of gases used in everyday life? Give an example.
3. Explain why the barrel of a bicycle pump heats up when you use it to pump a tire.
4. Why is heating an aerosol can so dangerous?

Solving Problems with Hydraulics and Pneumatics

We use pressurized fluids to make our lives more manageable, to make work easier to do, and to increase human productivity. In this activity, you will create a working model of a hydraulic or pneumatic system.

SKILLS MENU
- Identify a Problem/Need
- Planning
- Selecting Materials and Equipment
- Designing
- Testing
- Modifying
- Communicating

Scenario

You and your class are part of an innovative design team. Each year, members of your team identify a challenge to solve, then pool your learning to form a community of learners. In this way, you share the knowledge and skills learned during the challenge in order to apply them to future challenges. This year's challenge is to construct a working model of a hydraulic or pneumatic system, as described below.

Design Brief

You have learned how air and water inside syringes can transfer forces and do work. You will now use this knowledge to build a working model that uses a closed hydraulic or pneumatic system to perform a task. Choose one of the following devices:

- a dentist's chair that can move up and down, and has an adjustable back
- a car hoist that can raise and lower a model car in a controlled way
- a device that can raise and lower a stage set in a controlled way
- a hydraulic brake that can stop a spinning wheel or disk
- a backhoe that can move its digging arm in two directions

Equipment and Materials

SKILLS HANDBOOK 5.C.

- eye protection

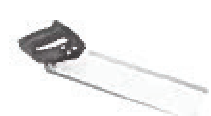
You may choose from the following materials:

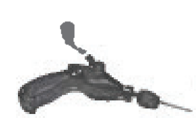
- variety of syringes
- vinyl tubing
- hand saw
- hand drill
- mitre box
- 1 cm × 1 cm basswood
- popsicle sticks, tongue depressors, or wood scraps
- low-temperature glue guns with glue sticks
- dowels
- paper gussets
- scrap materials (for example, cloth, cardboard)

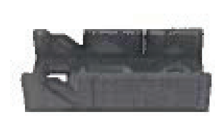

eye protection


variety of syringes


vinyl tubing


hand saw


hand drill


mitre box

1 cm × 1 cm basswood


popsicle sticks, tongue depressors, and wood scraps


low-temperature glue gun with glue sticks


dowels


paper gussets


scrap materials

Wear eye protection when using hand tools. Use glue guns in a low-traffic area with good air flow. Do not touch hot glue. Ensure the wood you are cutting or drilling is held securely to your work surface. When finished with your tools, put them away in a safe place.

Research and Consider

Research the items you might wish to build. On the Internet, see if you can find some models of what other students have built, but do not let this limit your imagination. Brainstorm a few possible solutions, making thumbnail sketches to guide you.

Go to Nelson Science

Plan and Construct

SKILLS HANDBOOK 4.B., 4.C.

1. Choose the sketch or sketches you will use from your brainstorming sessions and make a working drawing of your prototype (roughly to scale). If you make changes to your plans along the way, include these changes on your working drawing as you make them.
2. Create a step-by-step plan for constructing your prototype. Include a list of materials you will use and equipment you will need.
3. Finalize the plan for your prototype and check it with your teacher.
4. Construct your prototype.

Test and Modify

Test your prototype to see if it works the way you want it to. Does it meet the criteria you or the class set for the device? Make modifications and then test your revised prototype. Keep a written record of the modifications you make and the results of those modifications. Continue to improve your design as time permits.

Evaluate

Compare the performance of your device with the criteria in the Design Brief. When you test the device, make careful observations. Note any problems and think about how you might modify the design further. Consider the following questions:

1. How well did your product meet the criteria?
2. What difficulties did you encounter with your design? If you had more time, how might you overcome these difficulties?
3. (a) What skills do you need to work on to improve your ability to solve technological problems?
   (b) How can you develop these skills?
   (c) Discuss your plans with your teacher.

Communicate

SKILLS HANDBOOK 8.

(a) Oral presentation: Show how your device works and briefly describe the main things you learned during the process, as well as what you would change and why.

(b) Written communication: Create a permanent record of your design and the design process so that it can be displayed and added to the group's combined knowledge. You may wish to use a graphic organizer, electronic presentation media, or written format to share your learning.

(c) Include a labelled diagram or technical drawing of your final product.

Unit Task Be sure to keep a list of everything you learned from your work and the work shared by others. You can use what you learn in this activity to complete the Unit Task.

9.7 The Value of Valves

The circulatory system pumps blood (a fluid) throughout the body. It is a closed hydraulic system. It is a hydraulic system because it is fluid-filled, and it is closed because the heart and blood vessels form a long, convoluted, sealed compartment inside the body.

The circulatory system has special features that help it do its job. The heart is a pump that pushes blood through arteries and veins. The walls of arteries—the vessels that carry blood away from the heart—are thick and muscular to withstand the pressure created by the pumping heart.

Since the pressure in veins—the vessels that collect blood from the body and return it to the heart—is much lower, vein walls are not as thick. In fact, veins have very thin walls compared to those of arteries. However, veins are equipped with valves. Valves are devices that control the movement of a fluid through a hollow tube or pipe. Valves in veins (Figure 1) are like one-way gates that prevent blood from backing up or pooling.

valve: a mechanism that controls the flow of fluid in a pipe or tube

Some people have valves that do not close completely, so blood backs up and pools in certain veins. The veins become large and swollen. These are called varicose veins (Figure 2).

The heart also has valves that force blood to move through it in one direction. As the heart muscle contracts and relaxes, four heart valves keep blood flowing in the right direction (Figure 3).

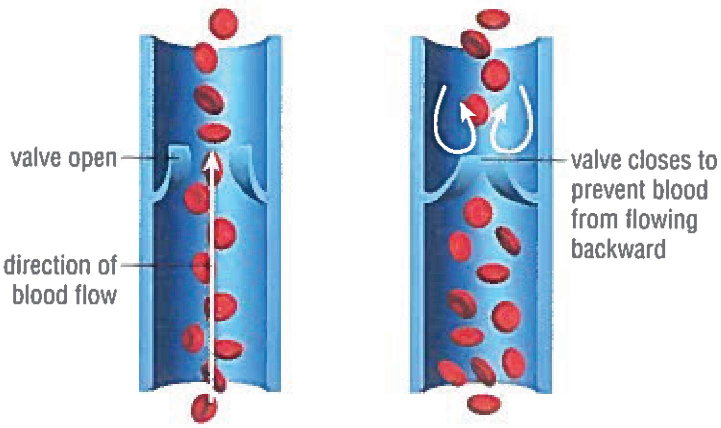


Figure 1 As the heart relaxes, blood pressure in the veins is lowered, but backflow is prevented by closure of the valves.

Figure 2 Incomplete closing of the valve allows blood to flow backwards and pool, causing varicose veins.

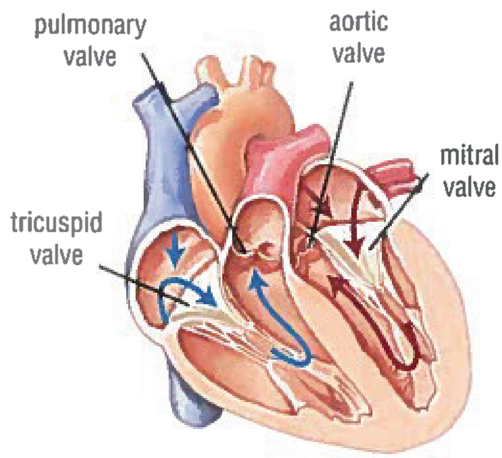


Figure 3 The heart's four valves prevent blood from flowing in the wrong direction.

NEL

TRY THIS: Exploring Valves

SKILLS MENU: performing, observing, analyzing

SKILLS HANDBOOK 4.C.

In this activity, you will compare the way fluids flow between syringes, with and without the use of a valve.

Equipment and Materials: two 10 mL syringes; 20 mL syringe; three 5 cm pieces of vinyl tubing; T-connector; T-valve

1. Connect the three syringes to the T-connector, using the 5 cm pieces of tubing as shown in Figure 4.

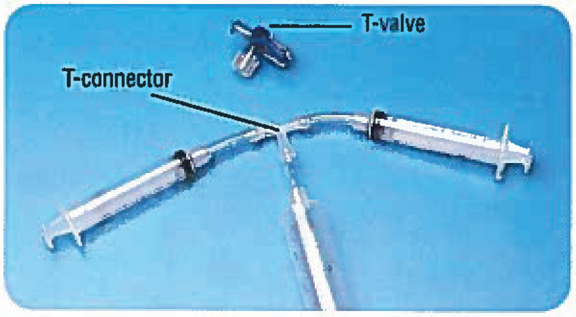


Figure 4

2. Sketch this system.
3. Depress each of the plungers in turn and record your observations.
4. Switch the position of the 20 mL syringe with one of the 10 mL syringes and repeat step 3. Record your observations.
5. Replace the T-connector with the T-valve and repeat steps 3 and 4 as you turn the valve. Record your observations.

A. Describe the movement of the plungers in the two smaller syringes when you used the T-connector with the 20 mL syringe in the centre. How did this compare to the movement that resulted when a 10 mL syringe was in the middle?

B. Compare the results when using the T-valve versus using the T-connector.

Many human-built systems also use valves. A car engine is called an **internal combustion engine** because it burns (combusts) fuel in chambers inside the engine. The engine relies on valves to allow fuel to enter the chambers and exhaust gases to escape at the correct time and in the correct direction (Figure 5).

internal combustion engine: a device that provides power by burning fuel within its cylinders

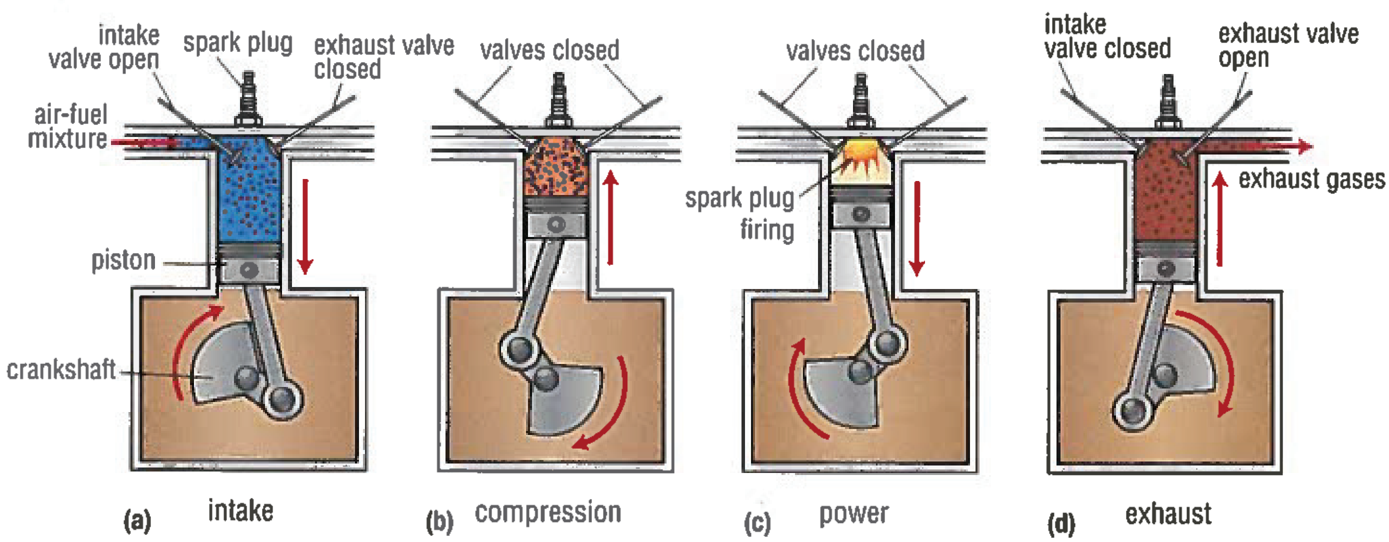


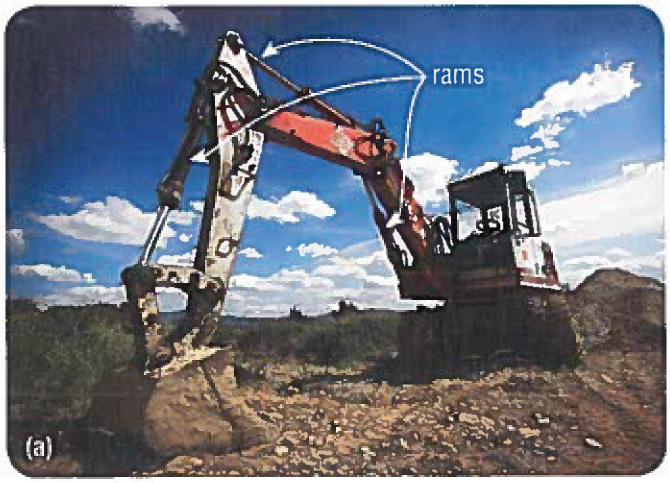
Figure 5 (a) Air and fuel enter in past the open intake valve. (b) Valves are closed to allow compression of the air-fuel mixture. (c) Valves remain closed during combustion so no fuel or gases escape. The explosion pushes the piston down. (d) Exhaust valve opens to allow gases to escape.

CHECK YOUR LEARNING

1. What kind of system—hydraulic or pneumatic—is the human circulatory system?
2. What is the role of valves in the human circulatory system?
3. In the human circulatory system, what is one result from a valve that does not work properly?
4. What is the function of valves in the internal combustion system of a car engine?

9.8 The Power of Fluids

We use fluids every day to help us do work. Machines such as excavators, backhoes, and front-end loaders use hydraulic rams to do work (Figure 1(a)). Rams are similar to syringes: they are composed of a piston (plunger) inside a cylinder. The cylinder is connected by pipes to a reservoir of hydraulic fluid. A pump provides the pressure, and fluid is directed into the cylinder on either side of the piston, depending on the movement desired (Figure 1(b)). This lets the piston move in or out with tremendous force and great precision.



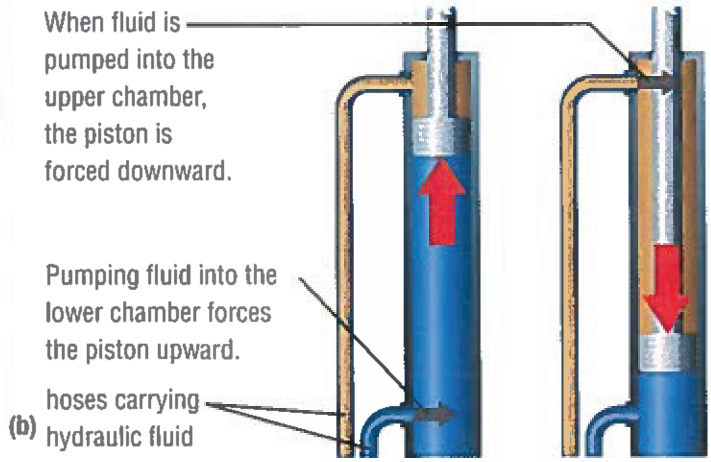


Figure 1 (a) Hydraulic rams allow this single worker to do the work of many people. (b) The rams work by forcing fluid into either side of the piston, allowing powerful and precise movement in both directions.

Fire pumps and hoses are hydraulic systems designed to cause fluids (either water or foam) to leave the system with great force. Water coming from a fire hydrant is already under some pressure. The pumping unit and nozzle design significantly increase this pressure to project the water a considerable distance away (Figure 2(a)).

Human-made devices are not the only users of hydraulic power. Animals use it as well (Figure 2(b)).

To learn more about the archer fish,
Go to Nelson Science

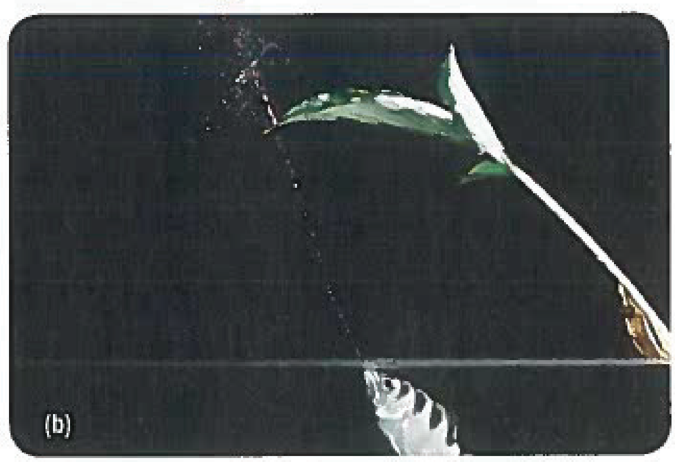


Figure 2 Like water shooting from a fire hose (a), the archer fish uses hydraulic power to shoot insects off low-hanging vegetation (b).

While fire pumps take in water and eject it under pressure, hovercraft use the power of air in a similar way (Figure 3). Large motors draw in air from the atmosphere and drive it out under intense pressure below the craft, allowing the craft to ride on this cushion of air over land or water. Often, the craft uses rear propellers to move the machine forward.

Figure 3 A hovercraft is a pneumatic system.

Pneumatic power can also be used to move heavy loads. Kneeling buses (Figure 4) use forced air to raise and lower the bus, making it easier for people to enter or exit. One advantage of using pneumatics instead of hydraulics is that the viscosity of air, unlike many liquids, is not significantly affected by changes in temperature.

Figure 4 Kneeling buses make it easier for many people to access public transportation.

Some systems use a combination of hydraulic and pneumatic power. Some automobile hoists, for example, pump compressed air into a master cylinder filled with hydraulic fluid (usually oil). This oil is then forced into a closed chamber that drives a piston upward. The piston is attached to a platform on which the car sits (Figure 5).

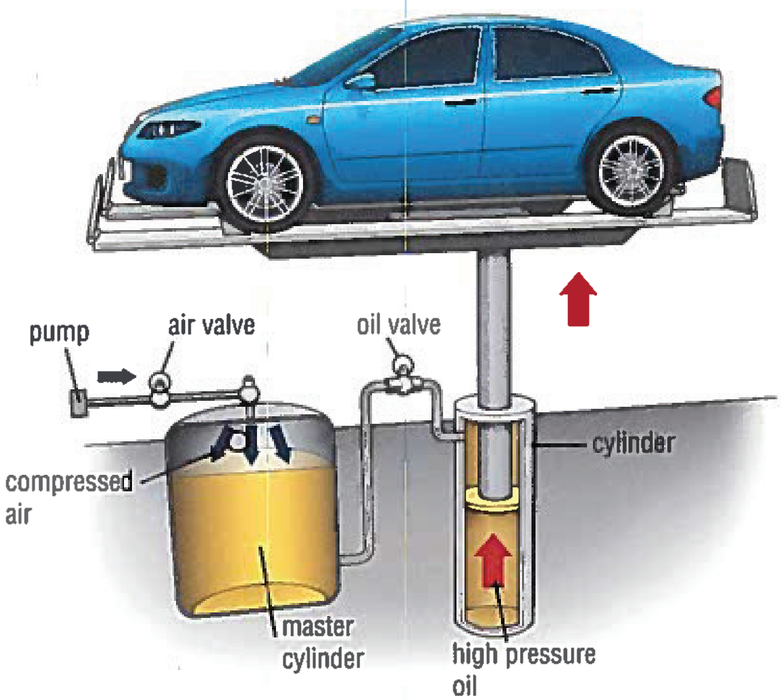


Figure 5 An automobile hoist uses a combination of gases and liquids under pressure.

Unit Task How might you use some of these examples of hydraulics and pneumatics to help you with the Unit Task?

CHECK YOUR LEARNING

1. What is a hydraulic ram?
2. What benefits have you enjoyed personally from using the power of hydraulics and pneumatics?
3. What is one advantage of using pneumatic power over hydraulic power?

SKILLS MENU

- Defining the Issue
- Researching
- Identifying Alternatives
- Analyzing the Issue
- Defending a Decision
- Communicating
- Evaluating

Fluid Power: Costs and Benefits

We benefit greatly from our knowledge of fluids and how they behave, and we have put this knowledge to work for us. However, costs accompany these benefits. For example, dialysis machines, artificial hearts, and lung transplants enable us to replace or repair human fluid systems. However, the cost of health care is always increasing.

Heavy hydraulic equipment allows a small number of people to do the work of many. This reduces the cost of construction, but also eliminates jobs. What are the costs and benefits of being able to change the environment so easily?

Pipelines allow us to move water, oil, and natural gas over vast distances. Sometimes these lines run through environmentally sensitive areas (Figure 1) or places where people are living. People may be affected during the construction of pipelines or later by leaking pipes, which may also damage the environment.

The benefits of fluid technology always have costs—economic, social, and environmental. Responsible action requires that we try to reduce the negative impact of our choices while we enjoy the benefits of the technology.

Figure 1 Who benefits most from pipelines?

The Issue

Select one example of fluid technology and use it to support or refute the statement below:

The benefits of using this form of fluid technology outweigh the costs.

Also, identify individual actions that could help alleviate some of the costs, or enhance the benefits, of the technology you have chosen.

Goal

Select an example of fluid technology that is of interest and importance to you. Briefly explain the technology and state whether or not you support the issue statement. Justify your stance by describing the benefits and costs related to the technology. Finally, offer suggestions as to how Grade 8 students might help reduce those costs or increase the benefits.

Gather Information

Review some of the uses of fluids described in this unit, plus others that may be of interest to you. Research how the technology works, as well as the benefits and costs. You can begin by asking these questions:

- Who benefits from this technology?
- What are the costs?
- Who pays the costs?
- Whose voices are not being heard but should be?

Go to Nelson Science

Identify Solutions

Whether or not you feel the benefits outweigh the costs, you need to identify some actions that Grade 8 students in your school could take to help reduce the negative impact of the technology. These do not have to be huge actions; specific, targeted actions by individuals can have considerable impact. For example, if more of us committed to walk or bike to get places, reduced fuel consumption and less air pollution would be the result.

Make a Decision

SKILLS HANDBOOK 3.J.6.

Use your research to decide whether or not to support the issue statement and to provide justification. Also suggest some actions for reducing the negative impact of our choices or increasing the benefits.

Communicate

SKILLS HANDBOOK 3.J.7., 8.

The results of your research and your decisions must be communicated effectively and concisely in an interesting manner to your classmates and others in your school. You may choose to create a poster, brochure, or computer presentation. Depending on the issue you have chosen, a letter to the student council seeking some action on their part might also be appropriate. Check with your teacher if you would like to use a different way to communicate your work.

LINKING TO LITERACY

Text Forms: Persuasive Text

This activity requires you to write persuasive text. Begin by selecting a topic and then gathering information about that topic.

When you write your text

- State your position on the topic.
- List evidence that supports your beliefs.
- End with a conclusion that confirms your position.

CHAPTER 9

SUMMARY

Fluids Under Pressure

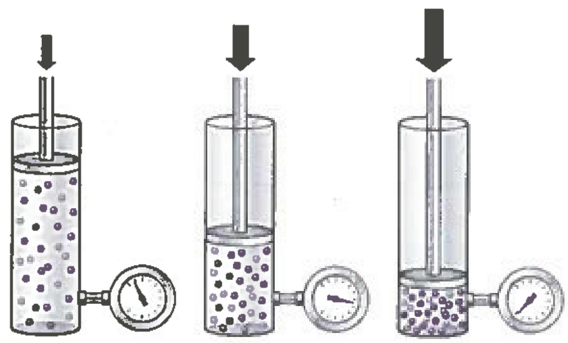
BIG Ideas

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

Looking Back

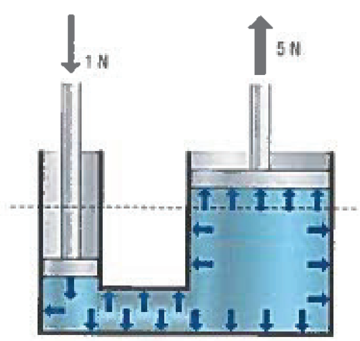
Under pressure, some fluids behave differently than others.

- Pressure is a measure of the force per unit area.
- Gases are more compressible than liquids.
- The particle theory explains the different behaviour of gases and liquids under pressure.
- There are strong relationships between the temperature, pressure, and volume of a fluid.



Systems use fluids to accomplish tasks.

- Hydraulic systems use pressurized liquids to perform tasks.
- Pneumatic systems use pressurized gases to perform tasks.
- Valves allow us to use hydraulic and pneumatic systems in controlled ways.

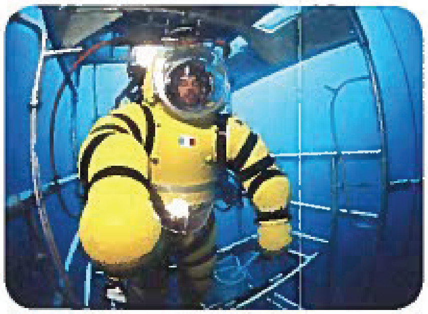


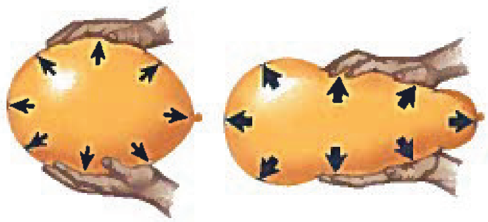
The skills of scientific inquiry can be used to study how fluids are used in hydraulic systems and pneumatic systems.

- Hydraulic and pneumatic systems can be created using syringes, tubing, water, and air.
- Applications of Pascal's Law can be modelled using syringes, tubing, water, and air.
- The ability of hydraulic and pneumatic systems to move a load can be observed using syringes, tubing, water, and air.

Pressurized fluid systems occur in nature as well as in human-made devices.

- Atmospheric pressure is exerted by the weight of the atmosphere.
- Water pressure increases with depth due to the weight of the water.
- Pressure applied to a fluid is distributed evenly throughout all parts of the fluid.





Technological problem-solving skills can be used to create a working model of a hydraulic or pneumatic device.

- Everyday materials and a knowledge of Pascal's Law can be used to design, build, and test a working model of an everyday object that operates using hydraulics or pneumatics.

Human use of fluids technology has social and environmental costs and benefits.

- We use pressurized fluids daily to make our lives more manageable and to increase the amount of work that humans can do.
- We use pressurized fluids at home, at work, and at play.
- Our use of hydraulic and pneumatic systems allows us to make major changes to society and the environment.
- Our ability to make such changes must be accompanied by a commitment to make these choices responsibly.

VOCABULARY

compress, p. 228
compressibility, p. 228
pneumatic system, p. 229
hydraulic system, p. 229
pressure, p. 234
atmospheric pressure, p. 234
Pascal's Law, p. 235
valve, p. 242
internal combustion engine, p. 243

CHAPTER 9

REVIEW

The following icons indicate the Achievement Chart categories: K/U Knowledge/Understanding, T/I Thinking/Investigation, C Communication, A Application

What Do You Remember?

1. Use the particle theory to compare the compressibility of liquids and gases. K/U
2. Give two examples each of hydraulic systems and pneumatic systems. K/U
3. (a) What components make up a typical fluid system?
   (b) Make a simple sketch of a fluid system and label the parts. K/U C
4. In your notebook, complete Table 1 using the terms "increases" or "decreases" to replace the blanks. K/U

Table 1

Change to a fluid	Results in
increase in pressure	volume: ________ temperature: ________
increase in temperature	volume: ________ pressure: ________
increase in volume of the container	pressure: ________ temperature: ________

5. (a) Define "pressure" in your own words.
   (b) What units are used for measuring pressure? K/U
6. In which direction does air pressure push on your body? K/U
7. What does Pascal's Law state? Use a graphic in your explanation. K/U C
8. Describe one way in which modern machinery uses Pascal's Law. K/U
9. Explain the importance of valves in the human circulatory system. K/U
10. How are hydraulic and pneumatic systems similar? How are they different? K/U
11. How are atmospheric pressure and water pressure similar? How are they different? K/U
12. What are valves and what is their purpose in hydraulic and pneumatic systems? K/U
13. Where have you seen or used valves in your daily life? K/U

What Do You Understand?

14. List three benefits of fluid-powered systems. List three costs. K/U
15. You have created a lift system using syringes. You would like the system to respond in such a way that when you push one plunger, the plungers in other syringes move immediately. Should this be a hydraulic system or a pneumatic system? Explain. T/I A
16. Use the concept of pressure to explain how people can lie on a bed of sharp nails without individual nails piercing their skin. K/U A
17. Figure 1 shows a simple pneumatic system.
   (a) If you wanted to use this system to increase force, should the effort be applied to piston A or piston B? Explain.
   (b) What advantage would you gain if you applied the force to the other piston? Explain why this is so. K/U T/I

Figure 1

18. When travelling in an airplane, as you descend to land, your ears sometimes "pop." Use the Internet to find out why this occurs. K/U T/I

Go to Nelson Science

19. Use the Internet to find out how hydraulics are used in roller coasters. K/U T/I

Go to Nelson Science

20. Figure 2 shows someone using a snorkel to breathe while swimming along the water's surface. He thinks it might be interesting to try extending the length of the snorkel to 1 m. However, when he tries it, he finds he cannot breathe. Explain why. T/I A

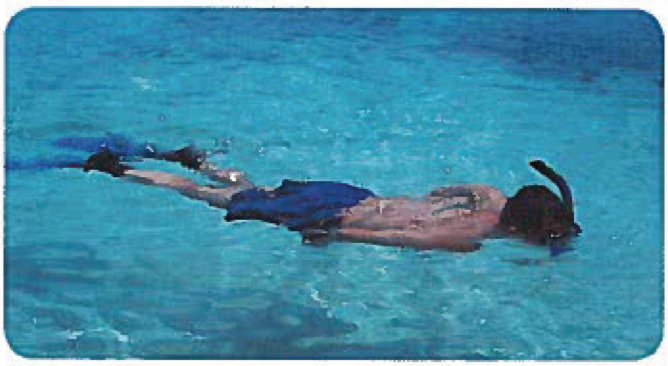


Figure 2

21. Describe how the air pressure inside a tennis ball changes when you hit it. T/I A

22. A scuba diver stays underwater for about 30 minutes. How is this possible when the air tank on her back is so small? K/U A

23. Give two examples of hydraulic systems that you have seen used. Do the same for pneumatic systems. K/U A

Solve a Problem!

24. Design an experiment to investigate whether changing the temperature of different liquids (water and rubbing alcohol) will affect their volume equally.
    (a) Describe how you will do this investigation.
    (b) What is the variable that you are changing? What variables will you control?
    (c) What steps will you take to ensure safety? T/I

Create and Evaluate!

25. Research a type of valve. Make a labelled drawing explaining how that valve works. Have a classmate ask you questions about your chosen valve to check how well you understand it. T/I C

Go to Nelson Science

26. We use pipelines to move oil and natural gas great distances. Investigate the environmental costs and benefits of pipelines. Which are greater, the costs or the benefits? K/U C

Go to Nelson Science

27. Continue to build your concept map from the Let's Get Started activity, using ideas and key terms from this chapter. Again, have a classmate evaluate your work. K/U C

Reflect on Your Learning

28. (a) Which of the ideas in the chapter relates the most to your everyday life?
    (b) Describe how this idea relates to your life outside of school.

29. Think back to the Key Question on the first page of this chapter.
    (a) In a brief paragraph, answer the Key Question. You may use diagrams.
    (b) Write one or two more questions about the topic of this unit that you would like to explore.

UNIT C

Unit Task

Playing with Fluids

Scenario

Your local public school is holding a toy fair. Your class has been asked to create toys for a display called "Playing with Fluids." The Grade 5 classes have just finished the unit called "Forces Acting on Structures and Mechanisms." These students are interested in examining the forces acting on your creations.

You will create a toy that moves by using some of the properties of fluids. As with many toys, controlled movement is preferable to uncontrolled movement. Your three options are described below. You will also develop a brochure that uses at least one drawing and correct use of scientific and technological terminology. Your brochure will help the Grade 5 students understand how your toy works. The brochure should also explain how your toy is environmentally friendly.

1. **Land Roamer** Toys move across the ground or floor in many different ways. Design and build a toy that uses the properties of fluids to move on land (Figure 1).

Figure 1 Which property of fluids is used to propel this toy?

2. **Water Wonder** Boats, submarines, and diving machines all move using the properties of fluids—either the fluids inside them or the fluids that flow around them. Design and build a toy that uses these properties to move over or through water.
3. **Air Rider** People who design toys and other devices that move through the air must understand and use the properties of gases (Figure 2). Use these properties to design and build a toy that can move through the air.

Figure 2 Think about how the properties of gases help this toy stay aloft.

Design Brief

- Begin by describing which type of toy you are designing.
- List the properties of fluids that you will use to make your toy move.
- Describe how you will construct your toy. You may wish to use diagrams and sketches to help you explain the system you will be building.

Equipment and Materials

Make a list of the items you intend to use. You may be using a number of materials found around the home or classroom. You might use construction materials (for example, wood, plastic, and glue) to build your toy. If so, they should be listed. Do not use pieces from toy-making kits unless you use them in new ways. You will be able to use some school equipment, such as syringes and tubing. Check with your teacher to see if these need to be returned to the school after your toy has been assessed.

Research and Consider

SKILLS HANDBOOK 4.B.4.

- Investigate other devices that perform tasks similar to your toy.
- Visit toy stores to gather ideas.
- Look on the Internet and in the library.

If you find ideas that you would like to use, change them to make them your own. Modifying the designs of others is an acceptable form of innovation in technological problem solving. Use your notebook to brainstorm ideas with thumbnail sketches, then choose the one you would like to develop.

Go to Nelson Science

Plan and Construct

Review the steps you took when designing your hydraulic and pneumatic devices in Section 9.5. Look back over the Try This activities. You may want to use these as a guide in planning and performing your task. Your toy should be environmentally friendly. Try to design your toy using the three R's—reduce, reuse, and recycle.

Test and Modify

SKILLS HANDBOOK 4.B.5., 4.B.6.

Allow enough time to test your device and make changes to your work, if needed.

Evaluate

Compare the performance of your device with the need you chose to address. Are you meeting all of the criteria? Use the Assessment box to help you.

Communicate

Create a brochure to help explain to younger students how your toy works. You must also explain the properties of fluids on which your toy is based. Your brochure must include at least one diagram. Your brochure should also describe how your toy is environmentally friendly. In addition to the brochure, submit your working notes. These should include early thoughts, drawings, plans, and any changes you made to your toy.

Assessment

You will be assessed on how well you

- state the design problem or challenge
- identify several possible solutions
- develop a plan for solving the problem based on one of your possible solutions
- complete the plan you develop
- test your device and record observations about which parts work efficiently and which do not
- make or identify modifications that could improve the effectiveness and efficiency of the system and its components
- use your brochure to explain the principles behind how your toy works (or should work)

UNIT C

Unit Review

Fluids

Make a Summary

At the start of this unit, you created a table with some classmates to activate your knowledge of fluids (what they are, where they are found, how they are used, and some harmful effects of and to fluids). You have also developed a concept map as you worked through the material in the chapters. You will now use that table and initial concept map to finish examining and summarizing what you have learned since then.

Concept Mapping

1. With your group, review the table you made at the start of the unit. Discuss any changes you would make to the paper now that you have completed this unit.
2. Record the changes either on the paper or in your notes.
3. Use your revised table to continue developing your concept map. Include what you have learned about
   - the properties of fluids
   - how fluids are used by humans and other living things
   - how our use of fluids affects society and the environment
4. Extend the concept map by creating a special code or symbol to indicate skills you feel you gained during the unit.

Unit C Review Questions

The following icons indicate the Achievement Chart categories: K/U Knowledge/Understanding, T/I Thinking/Investigation, C Communication, A Application

What Do You Remember?

1. Identify each of the following statements as either true or false. If false, explain why. K/U
   (a) Viscosity is a measure of how easily a fluid flows.
   (b) Although important, fluids are not essential to many living things.
   (c) A meniscus forms when water particles adhere to the sides of their container.
   (d) Buoyancy, like water pressure, acts in all directions.
2. Describe the relationship between mass, volume, and density of matter. K/U
3. Use the particle theory to explain the differences between solids, liquids, and gases. K/U
4. Comment on the accuracy of the statement below. Describe some exceptions to the statement if there are any. K/U

   In general, solids are more dense than liquids, and liquids are more dense than gases.
5. Use the particle theory to explain why changing the temperature of a fluid can also change its density. K/U
6. The density of a fluid usually decreases as the temperature rises. Explain how the behaviour of water differs from this pattern. K/U
7. What is a hydrometer and what is it used for? Describe how to use a hydrometer. K/U
8. Do hydrometers float higher in liquids that are more dense or less dense? K/U

9. Using the particle theory, describe the relationship between temperature and the viscosity of a fluid. Explain any exceptions to the rule. K/U

10. (a) What is the purpose of a valve?

    (b) Choose a type of valve and draw at least two sketches to show how that valve works. K/U C

11. Describe the location of valves in the heart and explain their role. Use a diagram, if you find it helpful. K/U C

12. List six devices or machines that use fluid power. State whether each is a hydraulic system, a pneumatic system, or a combination of both. If any are a combination, describe which parts are hydraulic and which are pneumatic. K/U A

13. Describe how water striders and other small insects are able to walk across the surface of water. K/U

14. Why are wind tunnels useful in studying fluid flow? K/U A

15. In your notebook, complete Table 1 to show how each property changes when the temperature changes. An upward arrow ↑ means "increasing," and a downward arrow ↓ means "decreasing." K/U

Table 1

	Volume	Density	Viscosity
Temperature ↑	?	↓	?
Temperature ↓	?	?	?

What Do You Understand?

16. When the mustard container in Figure 1 is squeezed, on which part of the container does the mustard exert the greatest force? K/U A

Figure 1

17. In what ways does human use of fluids have a positive effect on society and the environment? In what ways does it have a negative effect? T/I A

18. Describe, or show using a graphic organizer (for example, a Venn diagram), the relationship between fluid mechanics, fluid dynamics, aerodynamics, and hydrodynamics. K/U C

19. People who have poor circulation should not sit with their legs crossed. Consider what you have learned about fluid flow and explain why this is so. T/I A

20. Would you prefer turbulent flow or laminar flow in your blood vessels? Explain. K/U A

21. Explain how the difference in compressibility between liquids and gases affects their use in fluid systems. K/U

22. Explain why scuba divers use weight belts when diving. Would they require more or less weight when diving in colder waters? Explain your answer. T/I A

23. Cars use a hydraulic braking system. If the system used air instead of hydraulic brake fluid, how different might pushing on the brake pedal feel? Explain. K/U A

24. During the production of a batch of maple syrup, a hydrometer is placed in four test samples taken at different times throughout the evaporation process (Figure 2).
    (a) Rank the liquids from least dense to most dense.
    (b) Which sample was collected earliest in the evaporating process? How do you know?
    (c) Which sample would taste the sweetest? Explain. T/I A

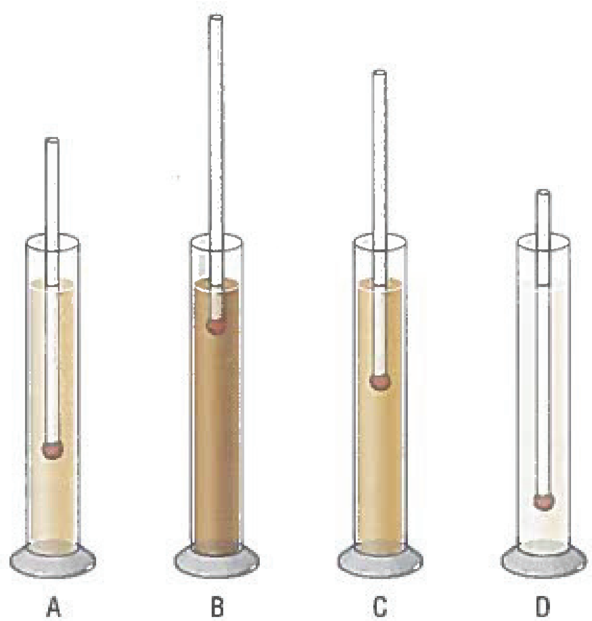


Figure 2

25. Research an object that uses valves to control fluid flow. Make a simple drawing to show how the valve works. T/I C

Go to Nelson Science

26. Figure 3 shows water coming from a bottle with three punctures. Describe why the water is flowing the way it does. K/U

Figure 3

27. When a person donates blood, doctors can use the various components of that blood for different purposes. Research and describe how blood is separated into its components. T/I A

Go to Nelson Science

Solve a Problem!

28. You have seen that ice cubes float on water. How do you explain what is happening in Figure 4? T/I A

Figure 4

29. The mass of four different liquids was measured and then recorded in Table 2.

Table 2

Liquid	Mass (g)	Volume (mL)
A	50	20
B	50	50
C	30	40
D	10	40

(a) Determine the mass-to-volume ratio of each fluid.

(b) Show this information in a line graph.

(c) Make a sketch of what you would expect to see if equal volumes of these fluids were poured into a single tall, narrow cylinder. T/I A C

30. In Figure 5, plunger A has an area of 5 cm^2 and plunger B has an area of 15 cm^2. How much more force can be exerted by plunger B? T/I A

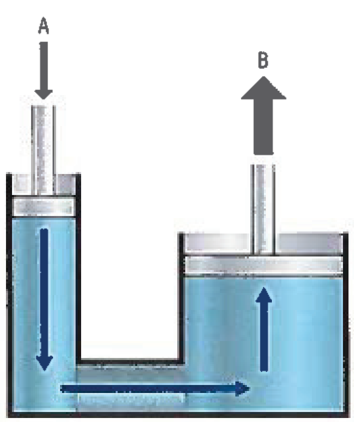


Figure 5

31. Design an experiment to determine how the flow rate of a fluid is affected by changing the diameter of the tube through which it is poured. T/I A

Create and Evaluate!

32. Which is of greater importance, the benefits that dams bring or the damage that they do? Explain your reasoning. T/I A

33. Choose a living thing and a human-built object that both use fluids in a similar way. Create an interesting way of showing how these systems are similar and how they are different in the way they use fluids. Evaluate how well your method shows what you want it to show. T/I C

34. Choose an idea in the unit that interests you. Clearly identify the concept or idea, and then create a poem, short story, or cartoon that describes or explains the idea. How useful is this form of writing in describing the idea to others? T/I A C

35. Dialysis and blood separation techniques save lives, but come with substantial costs. Research one of these techniques and the costs associated with it. Report on (a) what the costs are; (b) whether, in your opinion, the benefits are worth the costs; and (c) who should be responsible for paying the costs. T/I A C

Go to Nelson Science

Reflect on Your Learning

36. Describe the idea about fluids that you found most challenging in this unit. What did you do to help you understand this idea better?

37. What was the most useful idea you learned in this unit? Why?