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.

**CHAPTER 7** Fluids on the Move

**CHAPTER 8** Density and Buoyancy

**CHAPTER 9** Fluids Under Pressure
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…
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?

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!
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

<table>
<thead>
<tr>
<th>FLUIDS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>What?</td>
<td>Where?</td>
</tr>
<tr>
<td>How used?</td>
<td>Environmental/Societal Impact?</td>
</tr>
</tbody>
</table>

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](image-url)
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
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 tornados from books, articles, or the news? How does this information match or not match what you read in the second story?
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 1](image1.png) All homes contain many different fluids.

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

---

**TRY THIS:** Counting Fluids

**SKILLS MENU:** performing, observing, analyzing, communicating

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.

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.

---

**Table 1**

<table>
<thead>
<tr>
<th>Room</th>
<th>Fluid found</th>
<th>Category of fluid</th>
<th>Safety warnings</th>
</tr>
</thead>
</table>

---

![Figure 2](image2.png) Two fluids essential for life—water and air—cover and surround our planet.

![Figure 3](image3.png) Human activity has an impact on the health of fluids.
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.

Table 2 Some Fluids in the Human Body

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

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.

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?
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.

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

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

**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?
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.

**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.

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!

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).

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

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).

![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.)

**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.
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 buildup 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.

**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.

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?

**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

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)

![Figure 1](image)

**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

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?
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.

Cohesion

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.

Surface Tension

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.

**Viscosity:** a measure of how easily a fluid’s particles are able to slide past one another

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

**Surface Tension:** the strong attraction among the particles that form the surface of a liquid
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).

**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.

**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.

**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)

**Procedure**

**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.

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>
<thead>
<tr>
<th>Fluid used</th>
<th>Volume of fluid</th>
<th>Flow rate</th>
<th>Amount of fluid stuck to the funnel</th>
</tr>
</thead>
<tbody>
<tr>
<td>water</td>
<td>30 mL</td>
<td>1 mL/s</td>
<td>++++</td>
</tr>
<tr>
<td>syrup</td>
<td>30 mL</td>
<td>0.5 mL/s</td>
<td>++++</td>
</tr>
</tbody>
</table>

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
(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).
(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.

**Testable Question**

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

**Hypothesis/Prediction**

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

**Figure 1** Molasses is a thick, brown syrup left over when sugar is refined.
7.5 Conduct an Investigation

**Procedure**

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**

(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?

(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**

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.

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

**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.
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.

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).
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.

![Figure 6](image)

_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.
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.

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

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.

**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)

**Procedure**
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).

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.

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

(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

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.

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
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?

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

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
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]

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]

12. Describe one way that streamlining plays a role in your daily activities. [K/U]

13. Should the practice of lining waterways with concrete continue? Justify your answer using concepts from this chapter. [K/U]

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]

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]

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]

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]
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.

![Graph showing fluid flow times at different temperatures.]

(a) Which fluid is most viscous? Justify your answer.
(b) Which fluid is most affected by changing temperature? Justify your answer.

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?

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?

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

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.

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?

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.

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

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.