9.0 Many technologies are based on the properties of fluids.

Fluids are used to clean vehicles at an automatic car wash.

What You Will Learn

In this chapter, you will:

- explain how forces are transferred in all directions in fluids (Pascal's law)
- compare how fluids are controlled and used in living things and manufactured devices
- assess the social, economic, and environmental impacts of several fluid technologies
- assess the impact of fluid spills on society and the environment

Skills You Will Use

In this chapter, you will:

- investigate applications of the principles of fluid mechanics
- use technological problem-solving skills
- design, build, and test devices that use pneumatic or hydraulic systems

Why This Is Important

Our understanding of the properties of fluids allows us to design fluid systems that are safe and effective. We need to take care to prevent fluid spills.

Before Reading

Thinking Literacy

Compare and Contrast Writing

Often science is best understood when you look at related topics in terms of their similarities and differences. Scan this chapter to find related topics that could be written as a comparison and contrast.

Key Terms

- fluid system
- Pascal's law
- hydraulic system
- pneumatic system
- hoist
- piston
- pump
- valve

Many technologies are based on the properties of fluids.

9.0 Getting Started

Figure 9.1 People have been making and eating popcorn for thousands of years.

Figure 9.2 The steam escapes as the popcorn kernel pops.

Water, the most common liquid fluid on Earth, is the secret to making good popcorn. Each kernel of popcorn contains a small amount of water, stored in the soft, white starch. A hard casing surrounds the whole kernel. When the kernel of popcorn is heated, the water turns to steam. Since steam is a gas, it occupies more space than the liquid water. The result is that pressure is created inside the hard outer shell of the kernel of popcorn. Finally, when the pressure created inside by the steam is too great to contain, the kernel explodes. The steam escapes, and the kernel is turned inside out.

Have you noticed that some kernels do not pop? If the hard casing of the kernel has a small crack or hole, the steam is released while it is heated, so the pressure is not allowed to increase. Also, if the kernel is allowed to "dry out" before it is popped, there will not be enough water inside to make the steam to create the needed pressure. Popcorn kernels pop well only if their moisture content is between 11 and 14 percent. You should keep popcorn kernels in a sealed container so that they retain their water content.

C28 *Quick Lab*

Soap Foam

Foam is any substance that is produced when fluid, in the form of gas, becomes trapped in a liquid or a solid. Some materials can become foam when they are heated. This is often due to the expansion of water or air trapped in the material.

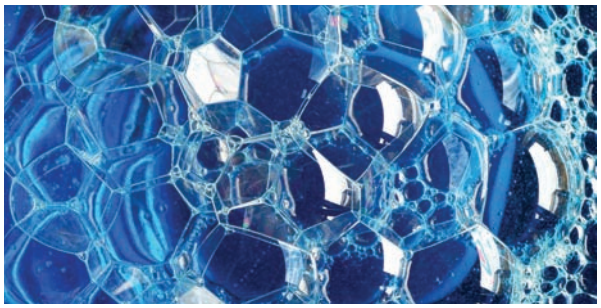


Figure 9.3 Examples of foam include whipped cream, shaving cream, and the suds created by a detergent (above).

Purpose

To observe what happens when a fluid expands within another material

Materials & Equipment

- bar of Ivory soap
- paper towel or microwave-safe dish
- microwave oven
- bar of another brand of soap

Procedure

1. Cut off a sample of the Ivory soap of approximately one-quarter of the whole bar. Place this sample on a paper towel or microwave-safe dish in a microwave oven.
2. With the power set to "high," turn on the microwave oven and observe the soap. Depending on the power of your microwave, the soap will reach its maximum volume within 30 to 60 s.
3. Allow the soap to cool for 1 min before touching it.
4. Repeat steps 1 to 3 for a different brand of bar soap.

Questions

5. Did both brands of soap behave the same way when heated in the microwave? Describe the differences in their behaviour.
6. Why did the Ivory soap become a foam when heated in the microwave? **Hint:** Refer to the information about popcorn, above.
7. What would you conclude is different between the two types of soap you tested?

9.1 Fluid Systems

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

- Pascal's law states that when force is applied to an enclosed fluid, the increase in pressure is transmitted equally to all parts of the fluid.
- There are both natural fluid systems and manufactured fluid systems.
- Hydraulic systems are fluid systems that use liquid, such as water or oil, as the enclosed fluid.
- Pneumatic systems are fluid systems that use gas (usually air) as the enclosed fluid.
- Fluids can be transported within a fluid system by pumps and valves.

A **fluid system** is a group of parts, including at least one fluid, that interact with each other and function together as a whole. Natural fluid systems include our body's circulatory system and respiratory system, the movement of sap in trees, and the movement of sea stars (Figure 9.4). Sea stars have several rows of tube feet with suckers at the ends. Each tube foot contains fluid. The pressure in the fluid changes when a sea star contracts its muscles. These pressure changes allow the sea star to move and gather food by pushing down and pulling up its suckers.

Figure 9.4 A sea star moves by changing the pressure of the fluid in its feet.

C29 *Starting Point*

Skills P C

Pressure Push

You can observe how pressure is transferred through a liquid.

1. Fill an empty 2-L plastic bottle to the top with water so that no air is allowed in. Screw the cap on tightly.
2. Lay the bottle on its side on a table in front of you. Hold each end of the bottle.
3. Push in with your left thumb at one end of the bottle. Hold your thumb in, and push in with your right thumb at the other end. What do you notice?
4. Repeat step 3 using two different positions on the bottle.
5. Each time you push in with your right thumb, what happens to the water pressure? How do you know?

Pascal's Law

An important breakthrough in our understanding of fluids occurred in the mid-1600s. The French mathematician, philosopher, and physicist Blaise Pascal (Figure 9.5) investigated what happens when a force is applied to a fluid in a closed system. After many experiments, a law was developed to describe his and others' observations. **Pascal's law** states that when force is applied to an enclosed fluid, the increase in pressure is transmitted equally to all parts of the fluid (Figure 9.6).

Figure 9.5 Blaise Pascal, 1623–1662

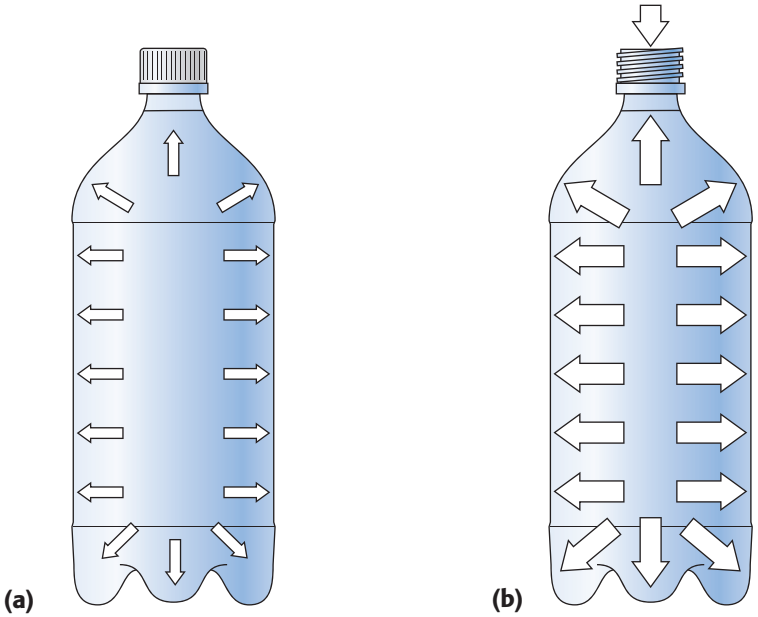


Figure 9.6 The fluid in the bottle exerts pressure in all directions (a). When the stopper is pushed farther into the bottle, the pressure increases everywhere in the fluid (b).

You have observed Pascal's law in effect if you have squeezed the end of a toothpaste tube and watched the fluid pushed out of the opening. If you have pressed on one end of an air mattress to push the air out of the opening at the other end, you have again seen the effect that Pascal's law describes.

Keeping in the Pressure

What would happen if a hole was cut into the side of the bottle in Figure 9.6(b), above? When you pushed down on the cork, the increased pressure would force the water out through the hole. For a fluid system to function properly, the entire system must be completely sealed. Even the smallest hole or leak can cause the system to fail.

Hydraulic Systems

Hydraulic systems are systems that use a liquid under pressure to transmit a force and do work. Some examples of hydraulic systems are shown in Figure 9.7.

Figure 9.7(a) Hydraulic systems are used to move materials, such as rock, soil, and scrap metal.

Figure 9.7(b) Rescue workers use hydraulic systems in the Jaws of Life® to free people trapped in vehicles.

Liquids Cannot Be Compressed

One of the useful properties of hydraulic systems is that liquids cannot be compressed by ordinary means. This means that when pressure is applied to a liquid in a pipe or tube, the force can be transmitted over a distance. For example, you could have a long hose connected to a water tap at the side of the building. When you turn on the water, the pressure is transmitted along the hose and forces water out at the other end of the hose. This property is useful for moving fluids over long distances, such as transporting water or oil in pipelines.

Multiplying the Force

Another benefit of hydraulic systems is that they can multiply the force exerted by a liquid. Figure 9.8, on the next page, shows a fluid system called a hoist. A **hoist** uses two pistons of different sizes to create pressure to lift a vehicle. A **piston** is a disk that moves inside a cylinder. The small piston is the input piston, which pushes down on the liquid to create pressure. This pressure is then transmitted through the liquid, where it pushes up on the large piston. The large piston is the output piston.

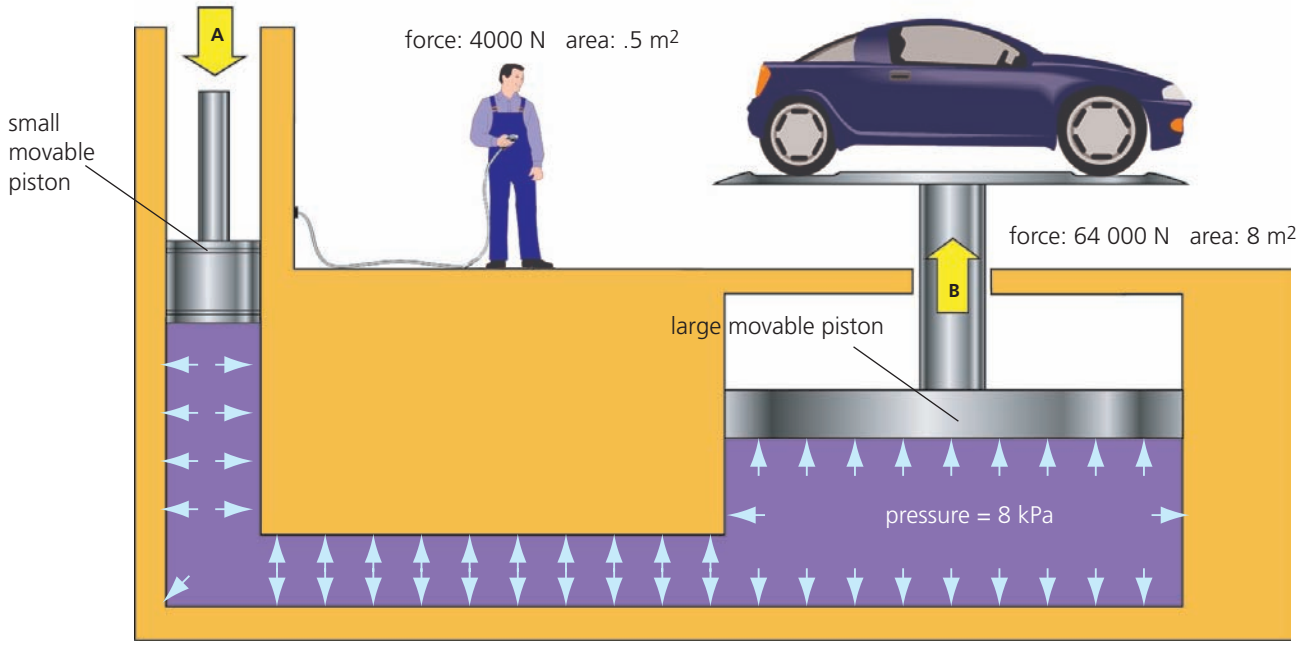


Figure 9.8 Hoists are used in repair garages so that mechanics can work under cars more easily.

The arrows in the liquid in Figure 9.8, indicate the pressure transmitted throughout the system. The pressure is the same everywhere in the system.

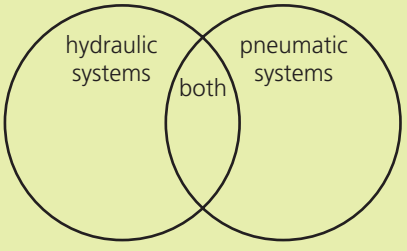
You can see in Figure 9.8 that the output piston has a much larger area than the input piston does. The area of the output piston in this example is 16 times larger than the area of the input piston. The result is an output force 16 times greater than the input force — a force large enough to lift a car. In order to move the large piston, the small piston must move much farther than the large piston does.

C30 *During Writing*

Thinking Literacy

Using a Venn Diagram to Compare and Contrast

As writers research their topics, they often record information in a graphic organizer. You have just been reading about hydraulic systems and will read next about pneumatic systems. Use a Venn diagram to show the similarities and differences between these two systems. You will use this research later to write a compare and contrast paragraph.



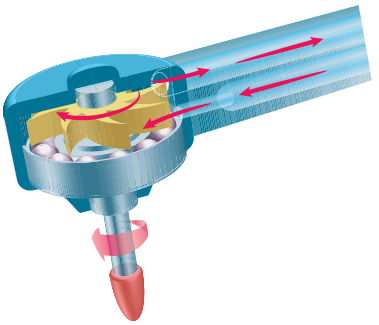


Figure 9.9 Compressed air drives the mechanism that makes the dentist's drill spin.

Pneumatic Systems

Imagine a visit to your dentist's office. You sink back into the chair, and your dentist presses a pedal to turn on the drill. Do you picture that the drill is electric? Actually, it uses something much safer as its fuel: air (Figure 9.9). A **pneumatic system** is a system that uses a gas, usually air, under pressure to transmit a force.

In order for a gas to be put to work in a fluid system, it must first be compressed. For example, natural gas is compressed and transported through a system of pipes to reach the furnace or stove in a home. Two advantages of pneumatic systems are safety and reasonable cost. Compressed air is safe to use, as the devices do not create sparks within the system. You can see some examples of pneumatic systems at work in Figure 9.10.

Another advantage of pneumatic systems is that they are more reliable over a larger temperature range than are hydraulic systems. This is an important consideration in designing bus doors and ramps for use in Canadian winters.

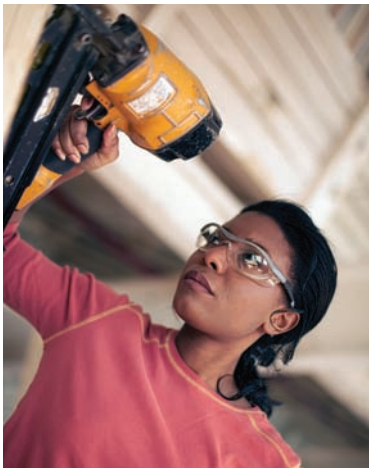


Figure 9.10(a) A pneumatic nail gun uses compressed air to drive nails into wood.

Figure 9.10(b) A mechanic uses a pneumatic wrench to change a tire.

Figure 9.10(c) Bus ramps and bus doors operate using changes of pressure in pneumatic systems.

Air under Pressure

People are able to dive deep below the surface of oceans and lakes because of the invention of a familiar pneumatic system — scuba. Scuba gear includes an air tank filled with compressed air and a regulator to maintain the flow of air.

Another fluid-based technology helps a scuba diver deal with the stress of making a deep dive. At greater water pressures, nitrogen gas dissolves in the blood and tissues at a much higher concentration than normal. When a scuba diver ascends slowly to the surface, the extra gas leaves the body gradually as the water pressure decreases.

However, a problem arises when a diver ascends too quickly. The sudden change in pressure causes the nitrogen gas to bubble out of the blood and tissues, a condition known as "the bends" or decompression sickness. These bubbles can collect in other body parts and cause considerable pain or even death.

One treatment for decompression sickness is to place the affected diver in a hyperbaric chamber (Figure 9.11). This chamber increases the pressure surrounding the diver's body. The greater pressure forces the gas bubbles to redissolve into the blood and tissues. When the pressure in the chamber is slowly decreased back to normal, the gas slowly leaves the body.

WORDS MATTER

Scuba stands for self-contained underwater breathing apparatus.

Figure 9.11 A hyperbaric chamber.

Suggested Activities

C32 Decision-Making Analysis on page 248
C33 Problem-Solving Activity on page 249

Pumps

Suppose you want to add air to a basketball or filter the water in your aquarium (Figure 9.12). What would you use to move the fluid in each case? For both examples, you may have thought that a pump would be the solution.

Most fluid systems include the movement of fluids from one location to another. A **pump** is a device that moves a fluid through or into something. For example, your heart pumps blood to your lungs for oxygen and then pumps the blood through your body.

Figure 9.12 A pump moves air into the ball.

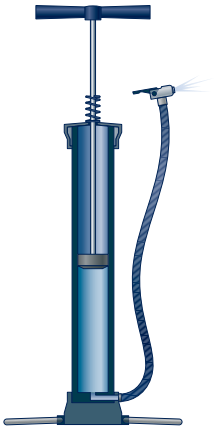


Figure 9.13 When force is applied to the air in the cylinder, the pressure increases.

The Bicycle Pump

A bicycle pump has a piston that moves up and down in a cylinder (Figure 9.13). When you pull up the piston, air fills the cylinder. By pushing down on the piston, you apply a force to the air in the cylinder. This compresses the air. The pressure of the air in the pump therefore increases. If the opening at the bottom of the cylinder is connected to an area of lower pressure, the air will move to that area. For example, the area of lower pressure could be a flat bicycle tire or an uninflated soccer ball.

The Archimedes Screw Pump

Some pumps can raise water from a lower elevation to a higher elevation (Figure 9.14). Other pumps can force air into a bicycle tire or oil through a car's engine. Although there are many different types of pumps, they work in a similar way, by creating areas of high and low pressure.

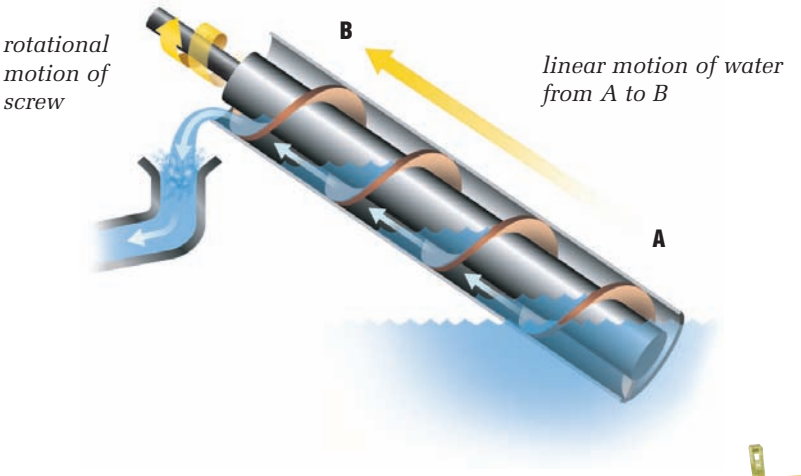


Figure 9.14 One of the earliest uses for the Archimedes screw pump was to remove water from the hold of a ship.

C31 *During Writing*

Thinking Literacy

Talk Time — A Rehearsal for Writing

Share your Venn diagram on hydraulic and pneumatic systems with a partner. Take turns explaining one feature that is common to both systems. Make note of the "linking" words your partner uses to relate the two systems to each other. Record these in a T-chart as "Comparison Signal Words." Now explain a difference between both systems. What "linking" words did you use? Record these in your chart as "Contrast Signal Words."

You can now use the information in your Venn diagram and the T-chart above to help you write a paragraph comparing and contrasting hydraulic systems and pneumatic systems.

Valves

Valves are devices that control the flow of fluids. For example, valves also control the amount of water flowing through a faucet. Turning a tap one way allows water to flow out. Turning a tap the other way closes off the flow of water. There are also valves in your body, such as in your heart and blood vessels. Many veins in your body contain one-way valves that ensure that your blood flows in the correct direction (Figure 9.15).

Valves can also be used to control the water level in the toilet tank (Figure 9.16). The float in the toilet tank is connected to a valve that closes off the flow of water when the water reaches the right level. That is why your toilet tank does not overflow when you flush the toilet. Two other valves are shown in Figures 9.17 and 9.18.

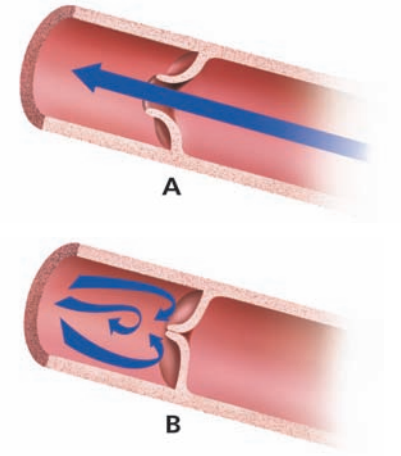


Figure 9.15 The flaps of the valve stay open when the blood flows in the correct direction (A). The flaps close if the blood flows backward (B).

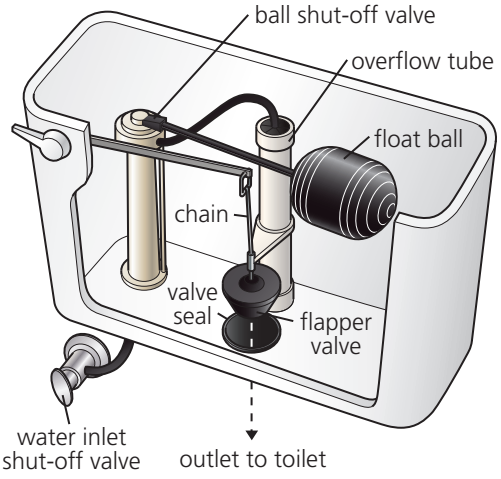


Figure 9.16 When a toilet tank refills with water, the float eventually rises high enough to turn the valve off.

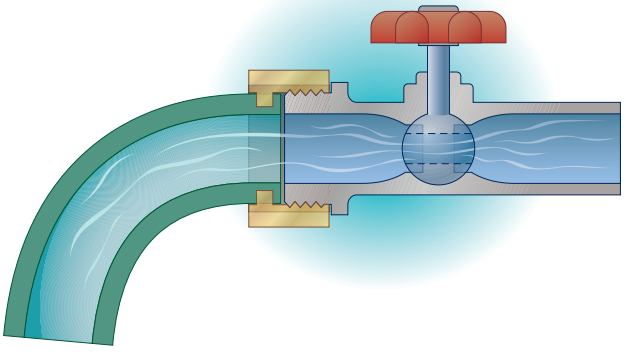


Figure 9.17 A ball valve works by turning. Turned on, it allows water to flow through. Turned off, it stops the flow. This ball valve is in the faucet.

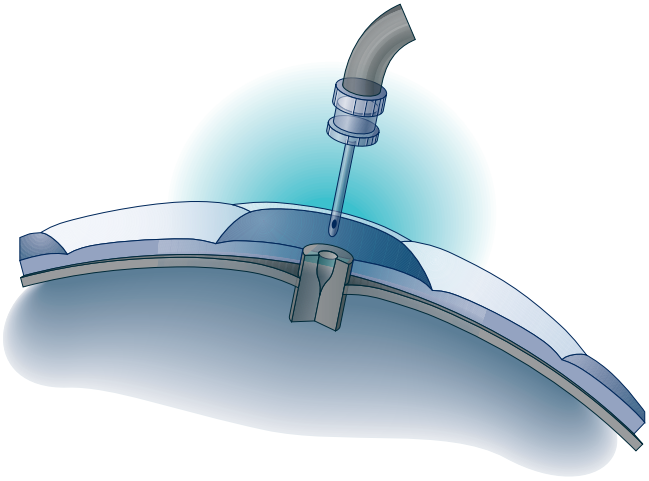


Figure 9.18 This type of valve allows you to inflate a ball, but it also keeps air from leaking out. To open the valve, you insert a hollow pin. You inflate the ball by pumping air through the pin. You deflate the ball by allowing air to escape through the pin.

Take It Further

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

SKILLS YOU WILL USE
- Gathering information
- Summarizing information

The "Cost" of Extracting Oil

Issue

Our understanding of fluid technology allows us to extract oil from Earth's crust. We use this oil to heat our homes, run our factories, and fuel our cars. However, burning this oil has caused air pollution and possible climate change.

Background Information

Most of the crude oil that is extracted from Earth is located more than 1.5 km below the surface. Our scientific understanding of the properties of fluids combined with the technology of building pumps allows us to bring this oil to the surface (Figure 9.19). Without the use of science and technology, this oil would not be accessible to human needs.

Currently, Canada uses approximately 2 million barrels of oil each day. The world consumption is 76 million barrels per day. The oil industry provides employment to millions of people world wide. In 2007, Canada's largest growth in employment was in the oil industry.

The consumption of fossil fuels also has a negative impact on our planet. Burning fossil fuels produces huge carbon emissions. These carbon emissions have been linked to the greenhouse effect and global warming. Even when the fuel is not burned, the impact of an oil spill can be devastating.

When you consider the social, economic, and environmental effects of burning oil for a fuel, is it a good choice or a poor choice to pump oil from deep inside Earth's crust?

Your task is to choose the "pro" or "con" side of the following resolution:

Be it resolved that Canada should drastically reduce crude oil exploration, mining, transportation, use, and export.

Figure 9.19 Oil pump

Research the issue, considering the social, economic, and environmental effects of burning oil for fuel. You will present your findings as a debate or in a class presentation. Your teacher will provide more details about how to present your information.

Analyze and Evaluate

1. Go to ScienceSource to begin your search for information.
2. Look in print materials such as magazines, newspapers, and books for information.
3. Summarize the information you find in a short report for presentation to your class or for use in a debate. Be sure to include only information that supports your viewpoint or refutes the opposite view.

SKILLS YOU WILL USE
- Designing, building, and testing
- Making technical drawings

Golf Ball Loader

Recognize a Need

A hydraulic device or a pneumatic device is often used to lift heavy objects. Some systems involve the use of more than one hydraulic system or pneumatic system. For example, when an excavator moves dirt into a dump truck, one set of hydraulics lifts the soil into the bucket and another set of hydraulics is used to dump the soil.

Problem

Design and build a hydraulic arm or pneumatic arm that will lift a golf ball vertically a minimum of 15 cm and dump the ball into an empty coffee can.

Materials & Equipment

- syringes
- rubber tubing
- water
- golf ball
- empty coffee can
- wood, nails, glue, etc., as needed

Criteria for Success

- Motion should be produced by hydraulic pressure or pneumatic pressure created by the syringes.
- The golf ball should be lifted a minimum of 15 cm.
- The golf ball should be released into the empty coffee can.

Brainstorm Ideas

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

Build a Prototype

2. Create a plan for how you will build your device. Your plan must include a detailed sketch of your device and a list of the equipment you will need.
3. Show your plan to your teacher for approval.

Test and Evaluate

4. Build and test your device.
5. If you make changes to your original plan, make a note of these changes. Explain why you made these changes.
6. Continue to refine your device until it successfully meets the criteria.

Communicate

7. Make a technological drawing of your final design. Be sure to label the parts. Your drawing may be done using media such as poster paper or computer drawing.
8. Present your device to the class. Your presentation should include:
   - an explanation of the function of each part of your device (use your technological drawing to aid in your presentation)
   - any modification you made to your original design (as recorded in your journal)
   - a demonstration of your device accomplishing the task

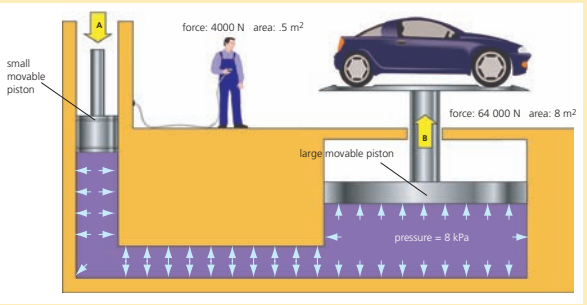
9.1 CHECK and REFLECT

Key Concept Review

1. What does Pascal's law state?
2. How is a hydraulic system different from a pneumatic system?
3. Explain why liquids are more difficult to compress than gases.
4. How is a force multiplied in a hydraulic system?
5. If the output piston in a car hoist was replaced by a piston of twice the area, what would happen to the output force of this system?
6. What is the purpose of a valve?

Connect Your Understanding

7. Suppose you used a needle to poke two holes in a sealed tube of toothpaste. One hole is near the cap and one hole is near the middle of the tube. You then squeeze the tube at the base. Compare how the toothpaste will leave each needle hole. Explain.
8. Why might a pump be needed in a hydraulic system?
9. Suppose that the oil in a hydraulic hoist is replaced by air. Would the hoist still operate as well? Explain.



Hoists are used in repair garages so that mechanics can work under cars more easily.

Practise Your Skills

10. Look at the hand bicycle pump shown in Figure 9.13 on page 246 and the valve shown in Figure 9.15 on page 247. How does the particle theory help to explain how a hand bicycle pump and tire valve operate? Draw a labelled diagram to help explain your answer.

For more questions, go to ScienceSource.

C34 *Thinking about Science and Technology*

Transporting Fluid

Our knowledge of fluids has allowed us to transport fluids in a variety of ways. A common way to transport fluid is through a pipeline.

1. With a partner, identify three types of fluids that might travel through pipelines near a larger town or city.
2. Suppose a pipeline did not exist for each of these fluids. Suggest an alternative way in which each of these fluids could be transported.
3. Compare the environmental impact of transporting fluids by pipeline with environmental impact of your alternative methods.

9.2 The Impact of Fluid Spills

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

- Fluid spills on water are generally more environmentally damaging than fluid spills on land.
- The majority of fluid spills occur on land and these spills are carried to rivers and oceans by run-off.
- Methods of cleaning up oil spills include booms, skimmers, sorbents, dispersants, burning, and bioremediation.
- Everyone can help to prevent fluid spills.

On March 24, 1989, a tanker called the *Exxon Valdez* struck a reef 20 km off the coast of Alaska and dumped more than 50 million litres of crude oil into the ocean (Figure 9.20). This oil spill is considered to be one of the worst ecological disasters of all time, affecting 1700 km of Alaska's shoreline. Estimates of damage include the deaths of more than 250 000 sea birds, 3000 sea otters, hundreds of seals and bald eagles, and several whales.

The cost of cleaning up the oil spill was more than $2.5 billion. Now, 20 years after the spill, it is estimated that 100 000 L of oil still remains embedded in the sandy shoreline.

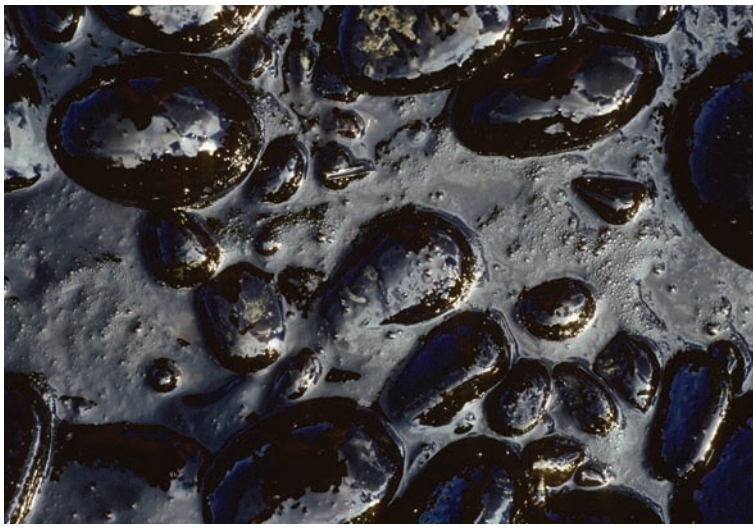


Figure 9.20 Oil from the tanker *Exxon Valdez* coated rocks, plants, birds, and mammals.

C35 ***Starting Point*** Skills I C

Not Every Oil Spill Is the Same

Four months before the *Exxon Valdez* disaster, an oil tanker split in half and caught fire before sinking in the Atlantic Ocean, 1400 km off the coast of Newfoundland. Even though the *Odyssey* spilled more than three times as much oil as the *Exxon Valdez*, the environmental impact of the *Odyssey* spill was much less.

1. Brainstorm factors that might determine the severity of an oil spill.
2. Compare your list with that of another student.
3. Choose what you believe are the three most significant factors.
4. Share the factors in a class discussion.

Oil Spills on Water

Oil is the most common pollutant of water. More than three million tonnes of oil pollute Earth's water systems each year. Oil spills, such as from tankers, account for less than 10% of the total oil pollution. Much of the oil that pollutes water comes from the run-off and wastes from large cities and industries (Figure 9.21).

When oil is added to water, it floats on top, as shown in Figures 9.22 and 9.23. Oil floats because it is less dense than water. Oil has a density of 0.88 g/cm^3, whereas fresh water has a density of 1.0 g/cm^3. Salt water has a density of 1.02 g/cm^3.

The fact that oil floats on water makes the clean-up easier. Could you imagine trying to clean the oil from the bottom of an ocean or lake? Even though the oil floats, if the surface of the water is moving quickly, the oil can "mix" with the water. This is similar to how you need to shake salad dressing in order for the oil and vinegar to mix. On a large body of water, such as an ocean or lake, waves can cause the oil to mix temporarily with the water.

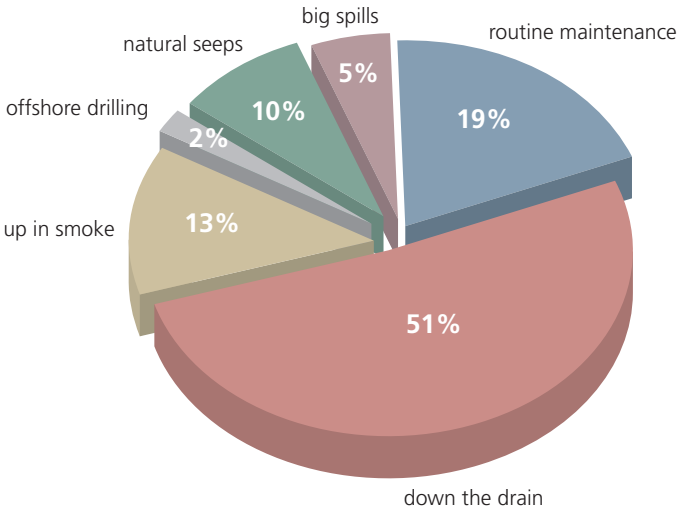


Figure 9.21 Sources of oil pollution

Figure 9.22 Oil is less dense than water so it floats.

Figure 9.23 You may have seen evidence of an oil spill in water.

The Impact on the Environment

The extent of damage caused by an oil spill depends on many factors, such as the type of oil, the location of the spill, and the size of the spill (Figures 9.24 and 9.25). Waves and wind also have an effect on the amount of environmental damage. Oil spills affect the marine environment as shown in Table 9.1.

Table 9.1 Results of Oil Spills

Cause	Effect
Oil coats the plants living on nearby shorelines.	• The oil blocks the sunlight and prevents gas exchange, causing the plants to die.
Oil breaks into smaller particles and is ingested by zooplankton and small fish.	• The ingested oil becomes part of the marine food chain.
Oil coats the feathers and fur of birds and mammals.	• The oil reduces the insulating ability of the feathers or fur. The animals die of hypothermia. • The animal is much less buoyant in the water. • Oiled feathers make it difficult for birds to fly, find food, or avoid predators. • When the animals try to clean themselves they ingest the oil, which causes kidney damage and digestion problems.

Figure 9.24 A sea bird covered in oil after the *Sea Empress* ran aground near Wales, in February, 1996. This oil spill was one of the largest and most environmentally damaging in European history.

Figure 9.25 Soldiers remove crude oil spilled from the oil tanker *Hebei Spirit* on a beach near Seoul, in South Korea, December 15, 2007.

Clean-up Methods

Suggested Activity
C38 Inquiry Activity on page 258

There are different methods that can be used to clean up oil spills on water (Table 9.2). The choice of which methods to use on a spill depends on factors such as cost, time, and environmental impacts.

Table 9.2 Common Clean-up Methods for Oil Spills on Water

Method	Description	Example
Booms	Oil is easier to clean up if it is contained in one area. Booms are large, floating barriers that act like a fence to contain the oil.	
Skimmers	Skimmers are machines like vacuum cleaners that pull up the oil from the surface of the water. The water must be calm in order for skimmers to be effective.	
Sorbents	Sorbents are large, sponge-like materials that absorb the oil. A problem arises when the oil-soaked sorbents become denser than the water and sink.	
Dispersants	Dispersants are chemicals that act like detergents and break the layer of oil into smaller pieces. The oil remains in the water, where it may continue to be harmful to marine life.	
Burning	Burning the oil can remove over 90 percent of the spill. The spill must be more than 3 mm thick and have happened recently in order for this method to work. Burning is not successful if the winds are strong.	
Bioremediation	Bioremediation involves using bacteria and fungi to break down oil. Nitrates or fertilizers are added to the spill to provide nutrients for quicker growth of the bacteria and fungi.	

C36 Learning Checkpoint

Classifying Clean-up Methods

You can classify the methods used to clean up oil spills into three categories: mechanical, chemical, and biological. A mechanical method means that the oil is being physically moved. A chemical method means that the oil is changed into a new substance. In a biological method living organisms are used. Identify the category that each of the six methods belongs to.

Oil Spills on Land

Much of marine oil pollution comes from oil spills that originally occurred on land. In Canada, an average of 12 spills of more than 4000 L are reported every day. An average of 11 of these spills occur on the land (Figure 9.26). Run-off brings this oil into the water system.

The environmental impact of a spill on land is much more localized than that of a spill in water since the spill does not spread as quickly. The methods used to clean up an oil spill on land are similar to those used for an oil spill on water. Barriers are placed around the spill to contain the oil. Sorbents are used to soak up as much oil as possible. As well, the top layer of contaminated soil may be excavated and removed.

Figure 9.26 A major spill of crude oil occurred in Burnaby, British Columbia, on July 24, 2007. An excavator accidentally broke a crude oil pipeline, causing 240 000 L of oil to be released. The spilled oil coated the ground, vehicles, and homes.

Figure 9.27 Even small fluid spills can damage the environment.

Oil Is Not the Only Problem

An oil slick floating on the surface is an obvious clue that the water is contaminated. Many other fluids do not provide such visible clues when they are spilled into the water. In August of 1985, 11 000 L of dry-cleaning fluid (perchloroethylene) spilled into the St. Clair River near Sarnia, Ontario. This chemical has a density greater than water and sank to the bottom of the riverbed. Materials that sink in water are more difficult to clean up than those that float and also pose a greater threat to the marine environment.

Since most of the pollution in our waters is the result of run-off, we must be aware of what we dump on our land. Antifreeze or brake fluid dripping from a car or liquid fertilizer seeping into the farmer's ditch could end up in our water system (Figure 9.27).

Fluid spills have both an economic and an environmental impact. The average cost of cleaning up a fluid spill is between $20 and $200 for every litre spilled. Accidental spills and natural sources account for approximately 30 percent of the pollution entering our water. More than half of the pollution is a result of our day-to-day use of fluids. If we improve our behaviour as citizens, we can improve the health of our environment (Figure 9.28).

Suggested Activity
C37 Decision-Making Analysis
on page 257

Figure 9.28 Leftover household fluids can be taken to special disposal sites instead of being poured down the drain.

Take It Further

On June 9, 2005, the Ontario government passed Bill 133, "the spills bill." Find out how Bill 133 helps reduce the amount of spills in Ontario. Begin your search at ScienceSource.

SKILLS YOU WILL USE
- Gathering information
- Summarizing information

Disposing of Household Fluids

Issue

Every day, households across Ontario pour consumer products down the drain and into the ground. These products have the potential to cause serious damage to the environment. However, these products can be disposed of safely, and some can be recycled. In this activity, you will find out what facilities are available in your community to ensure these products are disposed of or recycled in a manner that does not harm the environment.

Background Information

If you put batteries into the garbage, they eventually end up in a landfill. Over time, the chemicals inside the battery slowly leak out into the environment. This may not seem like a big problem for your three or four batteries, but consider the potential problem. In 2007, Canadians bought 550 million non-rechargeable batteries. Up to 90 percent of these batteries ended up in a landfill.

The improper disposal of various household products such as paints and stains, paint thinners, fertilizers, pesticides, oil filters, antifreeze, non-rechargeable batteries, engine coolant, and propane tanks pose a serious problem for our environment.

Recently, governments have addressed this problem by creating plans to make recycling depots for a variety of consumer products that have a negative impact on the environment. It is expected that with these new depots over 23 000 tonnes of waste material will be recycled rather than placed into the landfill.

An interesting part of this program is that most of the cost for these programs is coming from companies that produce consumer products. You may recall from previous science classes the idea of "cradle to grave" for a product. The recycling of these consumer products is another example of the cradle-to-grave lifespan of a product.

Your task is to find out what your community is doing to recycle consumer wastes that otherwise could potentially harm the environment. After finishing your research, decide on how you will tell people about your findings. This may be a poster, computer-generated presentation or video. Once you have completed the task, be prepared to present your findings to your class and then out to your community.

Analyze and Evaluate

1. Go to ScienceSource to begin your search for information.
2. Look in print materials such as magazines, newspapers, and books for information.
3. Summarize the information you find and create a poster or use another form of media that will educate your classmates and people in your community about what materials can be recycled. Be sure to include only information that can be supported by your research.

Figure 9.29 All of these fluids can be disposed of safely instead of being poured down the drain.

C38 *Inquiry Activity* Toolkit 2

SKILLS YOU WILL USE
- Recording and organizing data
- Evaluating procedures

Oil Spill Clean-up

There are various methods for cleaning up oil spills. Some methods allow oil to be recovered, whereas others do not. Some methods are more expensive than others, some are more efficient than others, and some have more of an environmental impact than others (Figure 9.30). Regardless of the method used, cleaning up oil spilled on water is a very time-consuming and difficult task.

In this activity, you will model various methods used for cleaning up an oil spill on water.

Figure 9.30 The toxins in the detergents used to clean up an oil spill can be more harmful to the environment than the oil.

Question

Which method is most efficient in cleaning up an oil spill on water?

Materials & Equipment

- 3 containers for the oil-and-water mixture (such as soup bowls)
- graduated cylinder or measuring cup
- water
- vegetable oil
- medicine dropper
- plastic cup
- shredded paper towel
- spoon
- powdered and/or liquid detergent

Hypothesis

Write a hypothesis about which method is the most efficient and why it is the most efficient.

Procedure

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

Table 9.3

Method	Equipment	Observations	Rank
Skimmer	Medicine dropper		
Sorbents	Shredded paper and spoon		
Dispersant	Detergent and spoon		

2. Using the graduated cylinder, add 150 mL of water to each of the three containers.
3. Using the graduated cylinder, measure 20 mL of vegetable oil. Slowly pour the oil into the first container so that the surface of the water is covered. Repeat this process for the other two containers. Clean up any oil or water that you spill.

4. Your task is to clean up the "oil spill" using a skimmer, sorbents, and a dispersant. Try to remove as much oil from the surface of the water as possible. Try to not allow the oil to mix with the water. Observe which method works most quickly and recovers the most oil.
   (a) Skimmer – Using the medicine dropper as a vacuum skimmer, collect the oil from the surface of one of your containers. Place the oil you collect in the cup. Continue until you have removed as much oil as possible. Record your observations in the table.
   (b) Sorbents – Tear your paper towel into small pieces. Scatter the shredded paper towel onto the surface of the water in your second container. Once the pieces of paper towel have absorbed the oil, use the spoon to remove the paper towel. Place the oil-soaked paper towel in the cup. Continue adding and removing shredded paper towel until you have removed as much oil as possible. Record your observations in the table.
   (c) Dispersants – Add a spoonful of detergent to the third container. Then use the spoon to collect the oil. Continue adding detergent and collecting the oil until you have removed as much oil as possible. Record your observations in the table.
5. In your table, rank each method to show which method you think was the most efficient.

Analyzing and Interpreting

6. When you slowly poured the oil onto the water, did it float or sink? Explain your observation in terms of density.
7. Which of the three methods do you think would have the least impact on the environment? Explain.
8. If a strong wind was blowing and the surface of the water was rough, which method do you think would work the best? Explain.
9. Was cleaning up your oil spill more difficult or easier than you thought it would be? Explain.

Skill Builder

10. In science, it is often useful to use numbers or measurements when comparing different methods. Suppose you wanted to take a measurement so that you could compare the three methods. Explain what measurement you would take and how you would change the procedure to collect the measurement.

Forming Conclusions

11. Two factors that determine the efficiency of the clean-up method are how quickly the oil was cleaned up and the amount of oil that was cleaned up. Using these two factors, explain which method you believed was the most efficient.

9.2 CHECK and REFLECT

Key Concept Review

1. Most of the oil that enters our water comes from what source?

2. What scientific concept explains why oil floats on water?

3. Match each of the following clean-up methods to the correct description.

1. ___ boom
2. ___ skimmer
3. ___ sorbents
4. ___ dispersants
5. ___ burning
6. ___ bioremediation

(a) sponge-like materials that absorb the oil

(b) using fire to remove the oil

(c) floating barriers that act like a fence

(d) chemicals such as detergents

(e) living organisms that break down the oil

(f) device that pulls the oil from the surface

4. Choose the method in question 3 that has the least impact on the environment. Explain your answer.

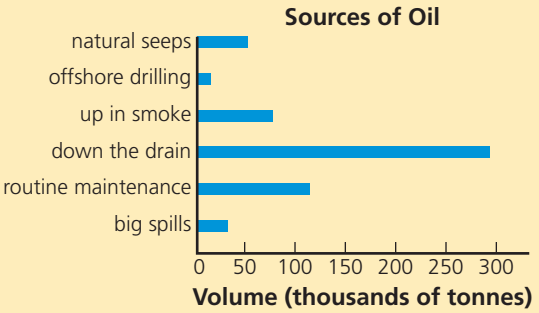
Connect Your Understanding

5. Give three reasons why fluid spills in water are more damaging than fluid spills on land.

6. Explain why a spill of a fluid with a density greater than water might cause more damage than the spill of a fluid that is less dense than water.

Practise Your Skills

7. Oil poured down drains and leaked during routine maintenance accounts for a large proportion of the total oil pollution. Use the graph below to estimate the total volume of oil added to our environment by these two sources.



For more questions, go to ScienceSource.

C39 *Thinking about Science and Technology*

Searching for the Source of Spills

When an oil tanker spills crude oil, the source of the spill is obvious. However, some spills are more difficult to trace. For example, fluids that leak from cars on highways can eventually wash down sewers and appear in streams and ponds many kilometres from where the spills occurred.

What steps would you recommend that a community take if it was affected by fluid spills that were difficult to trace?

DAILY PLANET

Making Connections

Jay Ingram

Jay Ingram is an experienced science journalist and is the host of *Daily Planet* on Discovery Channel Canada.

Quicksand

Of all the horrible ways to die, surely falling into quicksand and being pulled under would be one of the worst. Well, cheer up! It cannot happen.

Quicksand is sand all right, but it is mixed with water, clay, and salt. Sand makes up about 40 percent of the total. That means it is hazardous stuff. Think of a stack of oranges in a supermarket: the oranges make up about two-thirds of the space of the stack. Imagine trying to remove nearly half of the oranges and still maintain the stack.

It is the clay in quicksand that holds it all together by forming a jelly-like framework – about the consistency of yogurt – around the sand grains. If you were to put just your foot lightly on the quicksand you might be fine, but as soon as you move, the clay liquefies (like stirring the yogurt) and the whole thing collapses. You start to sink because nothing is really holding you up.

The change is pretty dramatic because the viscosity — how much the quicksand resists flowing — practically disappears, and rather than sinking a few millimetres per hour, you drop by a metre per second!

Worse still, you cannot just step back out. The salt ensures that the mix of sand, clay, and salt that holds you in is so finely packed that it would take the same amount of force to pull you out as it would to pull a car out.

So you are really stuck. But the good news is you will not drown, because this mix is twice as buoyant as water. You might sink a little, but you will not sink forever. You will just float there, half in, half out. If you move your legs very, very slowly in circles, water will flow in around your legs and you will gradually rise to the top – and be able to escape.

Figure 9.31 It is much easier to step into quicksand than it is to get back out.

9.0 Chapter Review

Assess Your Learning

Key Concept Review

1. According to Pascal's law, what happens to the pressure at the top of a container if the pressure at the bottom is increased? (k)

2. State the type of fluid used in:
   (a) a hydraulic system (k)
   (b) a pneumatic system (k)

3. A hydraulic system has a greater output force than input force. How does the area of the output piston compare to the area of the input piston? (k)

4. Give two examples of hydraulic systems that occur in nature. (k)

5. Give two examples of pneumatic systems. (k)

6. State two reasons why a person might choose a pneumatic system rather than a hydraulic system. (a)

7. (a) What are three different pumps you have used?
   (b) What fluid was moved in each case?

8. Valves are used to control both the direction of the flow of fluid and the amount of flow. (k)
   (a) Give an example where a valve controls the direction of flow. (k)
   (b) Give an example of where a valve controls the amount of flow. Use a different example from the one you used in (a). (k)

9. Which fluid pollutes our water the most often? (k)

10. List six methods used to clean up an oil spill on water. (k)

11. What is the average cost of cleaning up an oil spill? (k)

After Writing — Thinking Literacy

Reflect and Evaluate

Reflect with a partner on the process involved when writing with the Compare and Contrast organizational pattern. What elements are necessary when a writer uses this pattern? Did both you and your partner organize the information in the same way? How does the ability to recognize Compare and Contrast writing help you as a reader? Share your observations with the class.

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

Connect Your Understanding

12. When you are vacuuming under your bed, a piece of paper gets stuck on the end of the hose. Explain why it takes a large amount of force to remove this piece of paper if the vacuum cleaner is still turned on. (a)

13. Suppose an oil spill has occured 50 km off the shore of Lake Ontario. Suggest several reasons why it is important to clean up the oil spill as quickly as possible. (t)

14. Suppose you wanted to increase the force that a hoist produces, but you were not able to increase the force that you applied to the small piston. What else could you do? Explain.

15. Identify pumps and fluid control valves and their function in all of the following locations: (a)

(a) your body

(b) your home or school

(c) an automobile

Unit Task Link

Pascal's Law states that the pressure applied to any point in a confined fluid is transmitted equally to all parts of the fluid. How does Pascal's Law apply to the pipeline you are testing? Be sure to consider the environmental effect caused by a leak in a "real" pipeline.

Practise Your Skills

16. Draw a diagram of a hydraulic system that could be used to lift a person sitting in a hairdresser's chair. (a)

17. Make a sketch of a bicycle pump. Indicate the areas of high and low pressure. Use an arrow to show the direction in which the air flows. (a)

C40 Thinking about Science and Technology

Taking Care of Fluids

The photograph at the beginning of this chapter showed a vehicle being cleaned in an automatic car wash. What fluids do you know that are used in cleaning? Create a chart like the one shown below.

Table 9.4 Fluids for Cleaning

Type of Fluid	Function of Fluid	How Can We Prevent Spills?

1. Make a list of all of the types of fluids used in cleaning.
2. Identify the function each fluid performs.
3. Suggest ways to prevent spills so these fluids do not have a negative impact on the environment.

UNIT C Summary

7.0 Fluids are used in technological devices and everyday materials.

KEY CONCEPTS

- Fluids are an important part of many systems.
- The particle theory of matter explains the differences between solids, liquids, and gases.

CHAPTER SUMMARY

- Fluids are substances that can flow. Fluids include liquids and gases.
- Fluids can transport solids, hold other materials, and become solids if they are cooled.
- Matter is made of tiny particles that are always moving, may be attracted to each other, and have spaces between them.

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

KEY CONCEPTS

- Different fluids have different viscosities.
- Density $= \frac{\text{mass}}{\text{volume}}$
- Gases are much more compressible than liquids.

CHAPTER SUMMARY

- Viscosity is the resistance of a fluid to flow. Viscosity can change with temperature changes.
- Density is the amount of mass contained in a given volume. In most substances, density decreases when heat is added.
- Archimedes' principle states that the buoyant force on an object is equal to the weight of the fluid displaced by the object.
- Pressure increases with depth in a fluid.

9.0 Many technologies are based on the properties of fluids.

KEY CONCEPTS

- There are both natural fluid systems and manufactured fluid systems.
- Fluid spills have negative impacts on the environment and the animals that live there.

CHAPTER SUMMARY

- Hydraulic systems use a liquid as the enclosed fluid.
- Pneumatic systems use a gas as the enclosed fluid.
- Pumps and valves are used to control the flow of fluid through a system.
- It can be difficult and expensive to clean up fluid spills. Ontario is developing prevention programs to help avoid the damage caused by spills.

Planning a Pipeline

Getting Started

Modern pipelines move enormous volumes of hydrocarbon fluids, such as oil and natural gas, over vast distances. Much of the land that pipelines pass through is remote, ecologically sensitive, and subjected to severe weather conditions. Pipelines are also built close to homes, schools, and businesses. Designers must plan pipelines carefully to avoid the possibility of fluid spills.

Your Goal

To answer the question: how does the variable you identify affect the movement of fluids in a pipeline?

What You Need

- plastic tubing
- 1 or more syringes
- water and/or other liquids as approved by your teacher
- optional: stopwatch, thermometer, hot plate, ice water, etc.

CAUTION: Be careful handling hot liquids.

Steps to Success

1. As a group, decide which variable you will test: distance, temperature of fluid, resistance (number of bends in pipeline), or type (density) of fluid.
2. Make a hypothesis about how your variable will affect the flow of a fluid through your pipeline.
3. Brainstorm design possibilities for building your pipeline, which will be a closed hydraulic system made of plastic tubing and a syringe or syringes.
4. Decide what materials you will need to test your hypothesis.
5. Plan and record your procedure. Think about these questions.
   (a) What evidence are you looking for to support your hypothesis?
   (b) What steps will you follow to collect the data you need?
   (c) How will you make sure the test you are planning is fair?
   (d) How will you record your results?
   (e) How many trials will you make?
   (f) What safety precautions will you need to follow?
   (g) How will you ensure that there are no leaks in your system?
6. Have your teacher approve your plan.
7. Carry out your experiment.

How Did It Go?

8. Compare your results with your hypothesis. Did your results support your hypothesis? If not, what reasons might explain the difference?
9. Share and compare your experimental plan and findings with your classmates' plans and findings. Did anyone plan an experiment exactly like yours? Similar to yours? Completely different from yours? How do your results compare with theirs?
10. Present your findings to the class or in another form suggested by your teacher.

UNIT C Review

Key Terms Review

1. Create a mind map that illustrates your understanding of the following terms. (k)

- buoyancy
- compression
- density
- flow rate
- fluid
- fluid system
- friction
- hoist
- hydraulic system
- mass
- matter
- particle theory
- Pascal's law
- piston
- pneumatic system
- pressure
- pump
- thermal expansion of matter
- valve
- viscosity
- volume

Key Concept Review

7.0

2. What are three important properties of fluids? (k)

3. Give an example of a technology that uses each property in question 2. (k)

4. Use the particle theory to explain the difference between a liquid and a gas. (k)

5. Use the particle theory to explain an example of thermal expansion. (k)

8.0

6. What is the relationship between viscosity and flow rate? (k)

7. Use the particle theory of matter to describe what happens to the density of a substance when it cools. (k)

8. Draw and label a diagram to explain why a liquid compresses much less than a gas does. (k)

9. In order for water to travel up in a vertical pipe, how does the pressure at the bottom of the pipe compare to the pressure at the top of the pipe? (k)

10. Liquid A floats on top of liquid B. How does the density of liquid A compare to the density of liquid B? (k)

9.0

11. (a) Describe Pascal's law. (k)

(b) Give one example of its application. (k)

12. When a cut flower is placed in water, the water travels up the stem to the flower. Is this an example of a hydraulic or pneumatic system? Explain. (t)

13. Describe, using the concepts of high pressure and low pressure, how a pump is able to inflate a soccer ball. (k)

14. Explain what is meant by the statement "most water pollution originates on land." (k)

15. Describe three techniques used for cleaning up an oil spill on water. (k)

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

16. What is the average cost to clean up an oil spill, in dollars per litre? (k)

Connect Your Understanding

17. Aerosol cans contain a warning not to put them in a fire because they will explode. Describe why the can will explode when heated. Use the following words in your description: gas, particle, expansion, and pressure. (t)

18. An inflated balloon is taken from the pool deck to the bottom of the deep end of the pool. What happens to the volume of the balloon? Explain your answer. (t)

19. On the coast of British Columbia, a fishing boat loaded with fish sank when it left the ocean and entered the Fraser River. Why do you think this happened? (t)

20. How is it possible to lift a heavy car with a small force? (k)

21. Suggest reasons why some oil spills on water are more difficult and more costly to clean up than others. (t)

22. A woman with a mass of 50 kg who is wearing high-heeled shoes can exert about three times more pressure on a floor than an elephant of 5000 kg. Explain how this could be so. (t)

23. A penny will sink in water but float in mercury. Use your understanding of density to explain why this happens. (t)

24. Suppose the door of an airplane flying at a high altitude suddenly opened. Would air move into or out of the airplane? Explain. (a)

25. List three effects of an oil spill on a marine environment. (k)

26. Suggest two ways to help reduce fluid spills. (a)

27. Burning can remove over 90 percent of an oil spill. Suggest reasons why burning is not always used as the method to clean up an oil spill. (t)

28. What is the relationship between the buoyant force of a liquid and its density? (k)

29. Two blocks of wood have the same volume, but Block A is denser than Block B. Explain how this could be so. (t)

30. Suppose you filled three of the same-sized balloons with the same amount of water. You used the same amount of force to press on Balloon A with the bottom of a can, on Balloon B with your finger, and on Balloon C with a needle. (t)

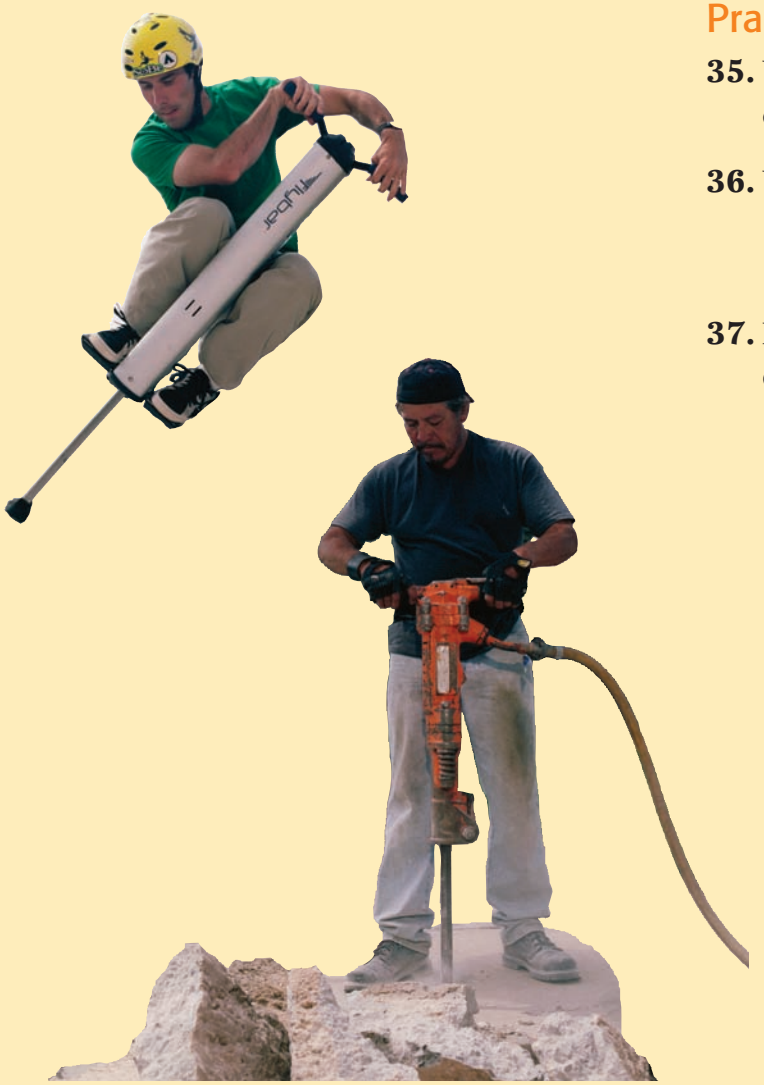
(a) Which item produced the greatest amount of pressure on a balloon?

(b) If only one of the balloons popped under the pressure, which balloon do you predict it was?

31. (a) Which has a greater flow rate, a milkshake with a temperature of 2°C or a milkshake with a temperature of 6°C? Explain using the particle theory. (k)

(b) Which milkshake has a greater density? Explain using the particle theory. (k)

32. What fluid technologies can you see being used in these photographs? Describe them in detail. (a)



33. A new pipeline is being built across northern Ontario to bring water to remote communities. Your job is to design a machine that can work year round to lift the heavy pipes and put them in place. Would you design a machine that used a hydraulic system or one that used a pneumatic system? Explain the reasons for your choice. (a)

34. What is one technology described in this unit that you would like to learn more about? Explain. (c)

Practise Your Skills

35. What is the density of olive oil if 20 mL of olive oil has a mass of 18 g? (a)

36. What is the density of the corn syrup if 10 cm^3 of corn syrup has a mass of 13 g? (a)

37. Plan an experiment that would test the compressibility of three different fluids. (a)

(a) What materials do you need?

(b) What procedure would you use?

(c) What variables would you need to control?

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

Revisit the Big Ideas

38. Many mechanical systems make use of hydraulics and pneumatics. Analyze two different mechanical systems, stating the purpose(s) of the hydraulic and pneumatic components to the system. a

39. (a) State two technological innovations that are based on the properties of fluids.

(b) Suggest a job or industry that uses each technology.

(c) Discuss the environmental impact of using each technology. a

40. Suppose you are asked to design a new piece of equipment that uses a fluid to transfer forces. The requirements are that the fluid should travel quickly through a hose but not compress when pressure is applied. Describe the fluid you would choose, using as many of the following terms as possible: "liquid versus gas," "viscosity," "flow rate," and "density." c

41. (a) Make of list of natural fluid systems that use water.

(b) Make a list of human-designed technologies that use water.

(c) Suppose that the density of all water on Earth doubled. What effect would the new density have on your list of natural fluid systems?

(d) What effect would the new density have on your list of human-designed technologies? t

C41 *Thinking about Science, Technology, Society, and the Environment*

Pipeline Problems

Pipelines cross our country bringing water and fuel to homes and communities. Usually, the fluids are transported without problems, but sometimes spills can occur.

1. Go to ScienceSource to find out the fluids that travel across Canada in pipelines.
2. For each fluid, identify what environmental problems could be caused by leaks.
3. For each fluid, identify any danger to people if a leak should occur.
4. Who should be responsible for cleaning up a pipeline fluid spill that occurs in a community? Who should have to pay the costs?