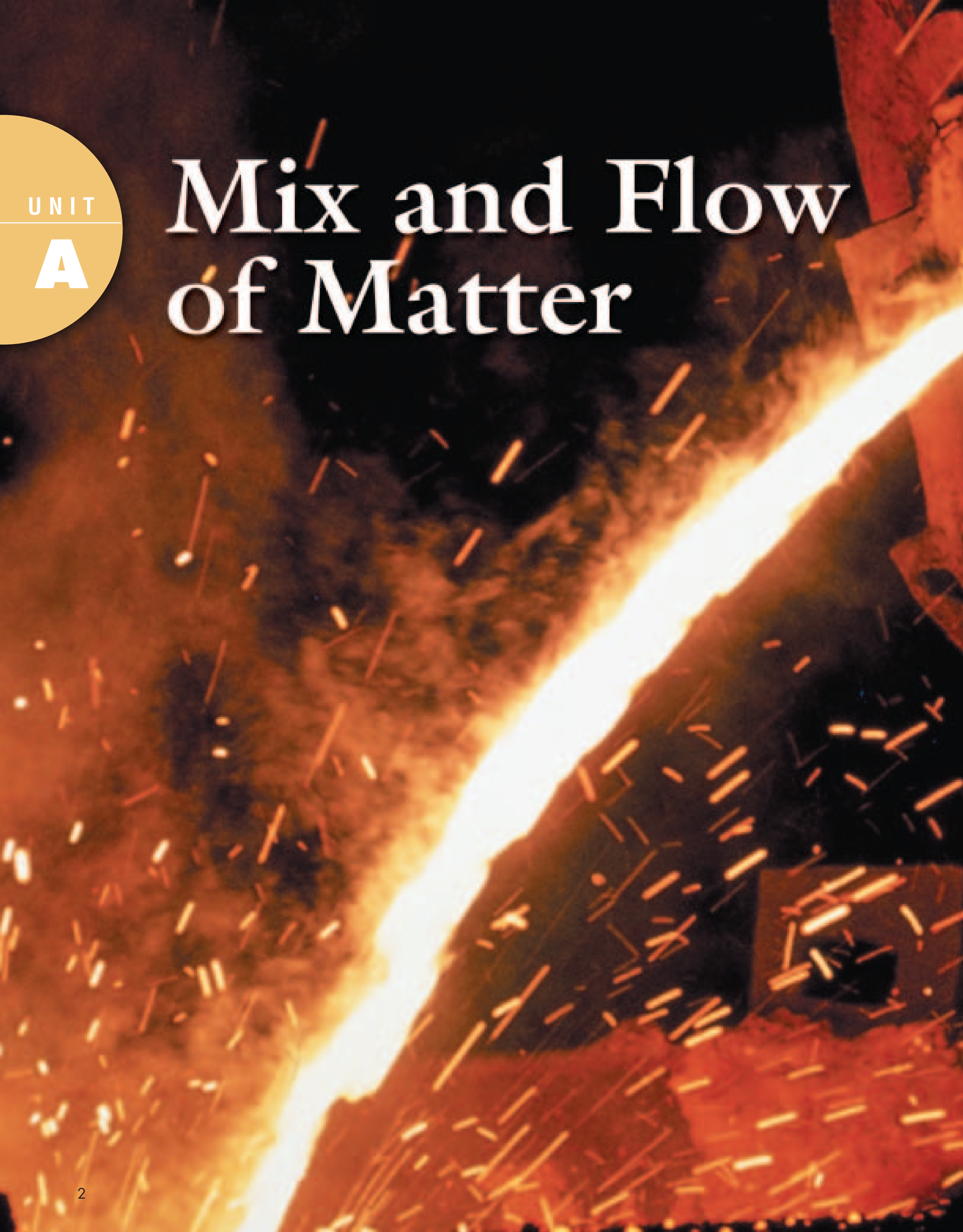
UNIT A

Mix and Flow of Matter



In this unit, you will cover the following sections:

1.0

Fluids are used in technological devices and everyday materials.

1.1 WHMIS Symbols and Safety Procedures

1.2 The Many Uses of Fluids

2.0

The properties of mixtures and fluids can be explained by the particle model of matter.

2.1 Pure Substances and Mixtures

2.2 Concentration and Solubility

2.3 Factors Affecting Solubility

2.4 The Particle Model of Matter and the Behaviour of Mixtures

3.0

The properties of gases and liquids can be explained by the particle model of matter.

3.1 Viscosity and the Effects of Temperature

3.2 Density of Fluids

3.3 Density, Temperature, and Buoyancy

3.4 Compression of Fluids

3.5 Pressure in Fluids—Pascal's Law

4.0

Many technologies are based on the properties of fluids.

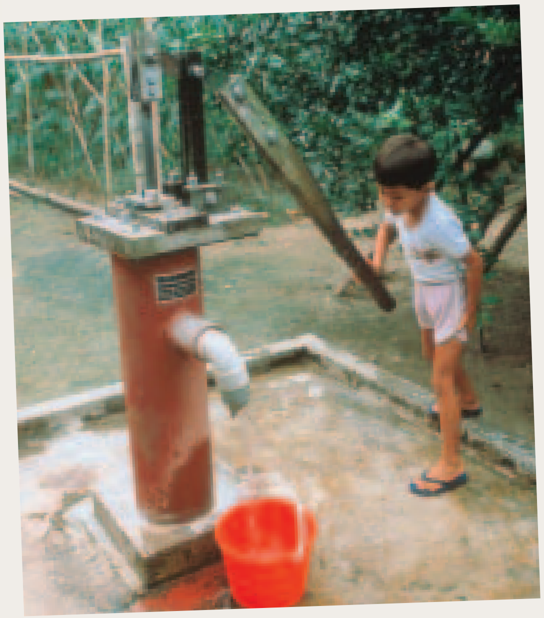
4.1 Technologies Based on Solubility

4.2 Technologies Based on Flow Rates and Moving Fluids

4.3 Designing a Working Model of a Fluid-Using Device

Exploring

Canadian Invention Brings Water to African Villages



RESEARCHERS AT THE University of Waterloo in southern Ontario have developed a low-cost, shallow-well pump that can easily be used in developing countries.

Since the early 1980s, many African and Southeast Asian communities have utilized the pump to bring clean drinking water to their villages.

Now, with the help of the International Development Research Centre in Ottawa, these inexpensive pumps are being made all over the developing world.

USING SCIENCE AND TECHNOLOGY TO SOLVE PROBLEMS

In 1978, two Canadian scientists, Alan Plumtree and Alfred Rudin, invented a reliable hand-operated water pump suitable for use in developing countries. The new pump had to meet the following criteria:

- It had to be durable enough to work continuously for 18 hours a day.

- It had to be cheap enough for people in poorer countries to afford.
- It had to be simple enough for villagers to maintain and repair themselves.
- It had to be designed so that it could be manufactured within developing countries. This would create jobs and ensure that spare parts would be available.

New Technology from Old

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

Adapting the Technology

Thanks to these Canadian inventors, villagers in developing countries are building and maintaining their own water pumps. Over 11 000 pumps are being used in 13 developing nations.

Of course, the basic pump design can be modified for local conditions. For example, in Sri Lanka, they decided to use a leather washer instead of a plastic one. The advantage of the leather one is that it can be made locally. In Malawi, the spigot on the pump has to be made out of black metal because hyenas ate the original white plastic ones. The hyenas thought the white spigots looked like bones and kept chewing them off the pumps!

Mennonites in southern Ontario have used hand pumps like this one for generations.

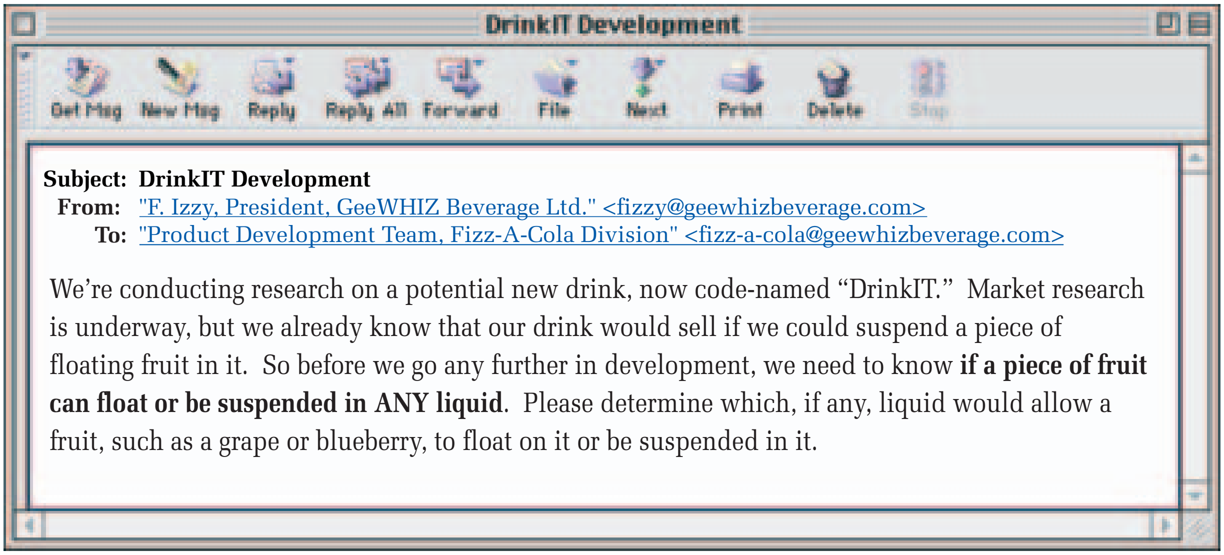
The PVC water pump is a good example of the importance of understanding a concept so that you can apply that understanding to different situations. In this case, the inventors knew about the properties of fluids and how a water pump operates. They applied this knowledge to develop a better pump that would work reliably for long hours and be easy to fix. In this unit, you will learn about the properties of fluids and see how they can be used to solve a variety of practical problems.

These villagers in Thailand are being trained to maintain and repair a Canadian-invented hand pump.

Give it a **TRY** — ACTIVITY

THE NEW DRINK

Now you have an opportunity to use what you already know about fluids and develop your problem-solving skills. You and your product development team have to find a solution to the following problem.



DrinkIT Development

Get Msg New Msg Reply Reply All Forward File Next Print Delete Stop

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

We're conducting research on a potential new drink, now code-named "DrinkIT." Market research is underway, but we already know that our drink would sell if we could suspend a piece of floating fruit in it. So before we go any further in development, we need to know **if a piece of fruit can float or be suspended in ANY liquid**. Please determine which, if any, liquid would allow a fruit, such as a grape or blueberry, to float on it or be suspended in it.

Test a variety of liquids to determine if a piece of fruit floats, sinks, or can be suspended in any of them.

A variety of liquids will be available for you to test. You may use any one of these liquids or a combination of them. Design a procedure that will allow you to collect the necessary data. Have your teacher approve your design before you start.

Prepare a reply to the president of the company that summarizes your results.

Focus On SCIENCE AND TECHNOLOGY

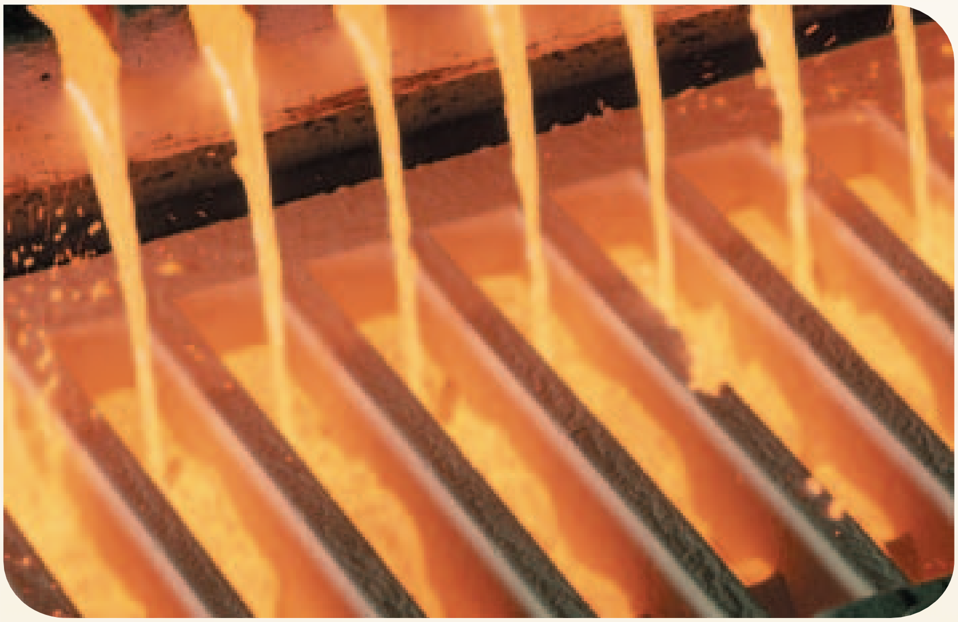
As you work through this unit, you will be reading about mixtures and fluids and doing activities that focus on science and technology. Science attempts to explain the phenomena in our world. The goal of technology is to provide solutions to practical problems.

In this unit, one of your main tasks is to practise your problem-solving skills. The scientific knowledge you gain throughout this unit will help you develop these skills. Remember that many technological problems have many different solutions. There may be no one right way to solve the problem. These three steps can help you in your problem solving:

- clearly define your need
- develop appropriate plans and designs
- test and evaluate these designs

You will be learning about the role of the properties of mixtures and fluids in both scientific research and technological developments. Use the following questions to guide your reading.

1. **What are the properties of fluids?**
2. **Why are these properties and their interactions important?**
3. **What technologies have been designed to use the interactions between fluids and other materials?**



1.0 Fluids are used in technological devices and everyday materials.

Key Concepts

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

- WHMIS symbols
- properties of fluids

Learning Outcomes

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

- explain WHMIS and other safety symbols
- describe safety precautions for using substances
- identify examples of fluids in products and devices
- describe examples of fluids used to transport, process, or use materials
- identify important properties of fluids

The ladder on this truck helps firefighters save lives in tall buildings. But without fluids, firefighters wouldn't be able to use it. It would take many people working together to put up a huge, heavy ladder like this one. But with the push of a button, a hydraulic system can raise and lower it easily. A **hydraulic system** uses fluids under pressure to move loads. It is just one of many technologies that use fluids to make our lives easier and safer. Fluids are substances that flow. Both liquids and gases are fluids.

In this section, you'll begin to learn about fluids and how and why they are used in technological devices and everyday materials. The first step in investigating fluids is learning how to work with them safely in the lab.

 For Web links relating to 1.0, visit **www.pearsoned.ca/scienceinaction**

1.1 WHMIS Symbols and Safety Procedures

Before you begin your study of mixtures and fluids, you need to review some safety rules and basic lab skills. Figure 1.1 shows a science class performing a science activity. Unfortunately, some of the students are not following proper safety procedures. Work with a partner to identify and list the problem actions. Then suggest a better, safer way to perform each action. After you have finished, share your observations with the class.

Figure 1.1 What are these students doing wrong? What are they doing right?

WHMIS and Other Hazard Symbols

You will be doing many activities in this unit. Before you do an activity, read through it and watch for "Caution!" notes that will tell you if you need to take extra care. There are two areas of special consideration when working in the lab—understanding warning labels and following safety procedures.

Some of the materials you will use in the lab are hazardous. Always pay attention to the warning labels described on the next page, and follow your teacher's instructions for storing and disposing of these materials. If you are using cleaning fluids, paint, or other hazardous materials at home, look on the labels for special storage and disposal advice.

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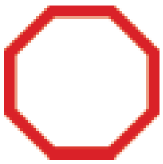
Symbol Shapes

caution

warning



danger

These shapes and their colours indicate how dangerous the substances are.

All hazardous materials have a label showing a hazard symbol. The **hazard symbol** has a safety warning and a shape to indicate how hazardous the material is. You may have already seen these labels on fluids you find at home, such as bleach or oven cleaner. There are two separate pieces of information for each symbol. The first is the shape of the symbol, shown in the *info*BIT. A yellow triangle means "caution," an orange diamond means "warning," and a red octagon means "danger."

The second piece of information is a picture inside the shape that indicates the type of hazard. There are seven pictures of common hazards shown in Figure 1.2.

Figure 1.2 These pictures tell you what type of hazard to watch out for.

Figure 1.3 shows some of the WHMIS symbols. **WHMIS** stands for Workplace Hazardous Materials Information System. This is another system of easy-to-see special symbols on hazardous materials. These symbols were designed to help protect people who use potentially harmful materials at work.

Figure 1.3 WHMIS symbols

Understanding the Rules

When performing a science investigation, it is very important that you follow the lab safety rules.

Lab Safety Rules

TOOLBOX

1. Read all written instructions before doing an activity.
2. Listen to all instructions and follow them carefully.
3. Wash your hands carefully after each activity and after handling chemicals.
4. Wear safety goggles, gloves, or an apron as required.
5. Think before you touch. Equipment may be hot and substances may be dangerous.
6. Smell a substance by fanning the smell toward you with your hand. Do not put your nose close to the substance.
7. Do not taste anything in the lab.
8. Tie back loose hair and roll up loose sleeves.
9. Never pour liquids into containers held in your hand. Place a test tube in a rack before pouring substances in it.
10. Clean up any spilled substances immediately as instructed by your teacher.
11. Never look into test tubes or containers from the top. Always look through the sides.
12. Never use cracked or broken glassware. Make sure you follow your teacher's instructions when getting rid of any broken glass.
13. Label any container you put chemicals in.
14. Report all accidents and spills immediately to your teacher.
15. If there are WHMIS (Workplace Hazardous Materials Information System) safety symbols on any chemical you will be using, make sure that you understand all the symbols. See Toolbox 1 at the back of this book.

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WHMIS Symbols at School

Check around your school for WHMIS symbols. Try the art room or a cleaning room. Make a map showing where the different hazardous materials are located in your school.

Safety Begins with You

Not following one or more of the lab safety rules could result in injury to you or your classmates. Follow the list of 15 safety rules to ensure that you work in a safe manner. Your teacher will also discuss any specific rules that apply to your classroom. After you have read the rules here, you can read more about safety in Toolbox 1 at the end of the book.

Remember that safety in a science class begins with you. Before you start any activity, you should be prepared to

- follow the safety instructions outlined by your teacher and this text
- keep an eye open for possible hazards, and report them immediately
- show respect and concern for your own safety and the safety of your classmates and teachers

Check and Reflect

1. What does each hazard warning label mean on the fluids shown in Figure 1.4?

Figure 1.4 Warning labels on hazardous products

2. Choose five of the lab safety rules given on page 11. For each one, explain briefly why it's important to follow it. Give an example of what could happen to a student who didn't follow that rule.
3. Make your own chart of hazard warning symbols. When you go home, check for each symbol on materials where you live or at your local grocery store. List two or three substances or items to which the symbol applies.

1.2 The Many Uses of Fluids

A **fluid** is anything that has no fixed shape and can flow. Usually it is a liquid or a gas. Look at Figure 1.5. How many different examples of fluids being used can you observe? Make a list of the fluids you see there and how they are being used. Include one additional use for each fluid. Remember to note uses by other living things besides humans. After you have made your list, group the examples into four different categories. Label each category with a title that makes sense to you.

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Agrifoam Cold Crop Protector

Frost damage is a big risk for farmers who grow fruit. To help farmers protect their crops, Canadians Dr. D. Siminovitch and J.W. Butler invented Agrifoam Cold Crop Protector. Agrifoam is a shaving-cream-like material that can be sprayed onto plants to protect them from freezing.

Figure 1.5 How are fluids being used?

Fluids Make It Easier to Use Materials

It's easy to think of many fluids you use every day, such as water, soft drinks, and detergents. One of the reasons that fluids are so useful is that they make it easier to transport, process, and use different kinds of materials, even if these materials are solids.

Figure 1.6 Because it's a fluid, the water can carry the sand and other solids away.

Slurries

Think about washing off a sidewalk or driveway with a hose. If you had a coating of mud or sand on your driveway, you could turn your hose on it. The water would wash or carry the mud or sand off the driveway. This mixture of water and solids is called a *slurry*. Slurry technology—the transport of solids in water—is important in many applications. One of these is in mining oil sands. Syncrude in Alberta is the world's largest producer of oil from oil sands. Syncrude started out by using conveyor belts to move the oil sands from the mine to the processing plant. But this technology proved to be very expensive. Now Syncrude creates an oil-sand slurry at the mine site and pumps this slurry through pipelines to the processing plant.

Fluids Become Solids

Fluids are easy to move, and they take the shape of containers. Because of these properties, many of the things we see and use as solids were originally prepared as fluids. Glass, for example, is manufactured by heating a mixture of substances that includes sand, limestone, and other carbonates. Other materials can be added to give the glass colour or special qualities. The mixture is heated in a furnace at 1000°C until it becomes a fluid. This allows it to be shaped into the form needed for particular uses, such as bottles, windows, or fibre-optic strands.

Figure 1.7 Glass bottles being formed

Steel is another example of the use of fluids as a stage in processing materials. Steel consists of a mixture of iron, carbon, and small quantities of other substances. This mixture is heated to 1650°C to melt everything together, and to add more materials. The fluid steel is then shaped into the desired forms and allowed to cool.

Fluids Can Hold Other Materials

The ability of fluids to spread or flow and to carry other materials makes them useful in many applications. Toothpaste is an example that you may not have thought of. Most toothpaste contains powdered materials, such as bauxite, to polish your teeth. It also contains a detergent to clean your teeth, and fluoride to keep your teeth strong. Substances called binders, made from wood pulp, keep the paste mixed. Colouring and flavouring are added to make the mixture more agreeable.

Useful Properties of Fluids

From the information you have learned so far in this section, you can begin to appreciate the importance of fluids in our world. You've seen some examples of the different ways that fluids are involved in transporting, processing, and using materials. Fluids can be used in all these ways because of their properties.

By understanding the properties of fluids, people can design technological devices that use these properties. Later in this unit, you will be exploring these properties: viscosity, density, buoyancy, and compressibility. Figures 1.8 to 1.12 on the next page show how these properties can be important in choosing and using fluids in different applications.

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Froth Flotation

A common method of processing mineral ore is called froth flotation. How are fluids used in this process?

Give it a TRY — ACTIVITY

Another Property of Fluids

In this activity, you will observe a situation that uses two liquids—detergent and water. You have a pan of water with some pepper floating on it. Add a couple of drops of liquid detergent. What happens?

Suggest a situation where what you observed could be used in a practical way. Present your ideas to the class either orally or as a short written description.

Figure 1.8 Your bicycle starts to make grinding noises as you pedal. What do you do? You use oil on your bicycle or in a car to make sure that the parts operate smoothly together. The viscosity of the oil that you use is important. Viscosity describes how easily a fluid flows. You will learn more about viscosity in section 3.0.

Figure 1.9 In making maple syrup, you have to determine when the mixture reaches the right concentration of sugar. A device called a **hydrometer** is used to measure the density of the syrup to find out if there is enough sugar in it. You will learn more about density in section 3.0.

Figure 1.10 This ship floats because of the buoyant force of the water acting on it. You will learn more about buoyancy in section 3.0.

Figure 1.11 This jackhammer is pneumatic. Systems that use compressed air are called **pneumatic systems**. **Hydraulic systems** use liquids to lift or move things. You will learn more about pneumatic and hydraulic systems when you learn about the compression of fluids in sections 3.0 and 4.0.

Figure 1.12 The hovercraft operates by directing air downward so it floats on a fluid cushion over the waves.

Check and Reflect

1. Review the list of fluids and their uses that you made at the beginning of this subsection when you looked at Figure 1.5. Are there any changes you would make based on what you have learned? Add at least three other examples, and make one new category for your list.
2. Describe an example where materials are prepared as fluids so they can be moved more easily.
3. Explain why it is important for steel to go through a fluid phase as it is being produced.

Assess Your Learning

1. What labels would you expect to find on containers of the following materials?
   a) oven cleaner in a spray can
   b) bleach
   c) paint thinner
   d) unknown bacteria
2. Describe the process for getting rid of broken glass in your class.
3. What protective measures must you take when you work around an open flame?
4. Describe an example where materials are prepared as fluids to make it easier to use them.
5. Describe two technologies that require a specific property of a fluid to function properly.

Focus On SCIENCE AND TECHNOLOGY

The goal of technology is to provide solutions to practical problems. For example, toothpaste is a technology to solve the problem of tooth decay. It was invented to keep teeth clean and strong. It also freshens your breath. Think back to what you learned in this section.

1. What were some practical problems that you read about?
2. What technologies were used to solve these problems?
3. Did it seem to you there would be more than one way to solve some of these problems?

2.0 The properties of mixtures and fluids can be explained by the particle model of matter.

Key Concepts

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

- pure substances, mixtures, and solutions
- solute and solvent
- concentration
- solubility and saturation points
- particle model of matter

Learning Outcomes

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

- distinguish between pure substances and mixtures
- define concentration and solubility
- identify factors that affect solubility and rate of dissolving
- relate the behaviour of mixtures to the particle model of matter

All the objects in the pictures on this page have at least one thing in common. They are all examples of matter. Matter may be hard, soft, rough, smooth, round, square, hot, or cold. It may be smaller than a cell or larger than the sun. Matter may have colour or it may be colourless. Matter is what makes up everything in our universe.

Matter can be organized in different ways. You already know one way: matter can be classified as solid, liquid, or gas. In this section, you will look at another classification system. This system classifies matter as pure substances or mixtures. You will also learn about a model that you can use to describe the nature of matter. This model will help you understand fluids and their properties.

2.1 Pure Substances and Mixtures

All matter is either a pure substance or a mixture. A **pure substance**, such as sugar, is made up of only one kind of matter. A **mixture**, such as soil, is made up of a combination of different substances.

Give it a **TRY** ACTIVITY

CLASSIFYING PURE SUBSTANCES AND MIXTURES

You can find examples of pure substances and mixtures all around you. Work with a partner to make a list of 20 different things you have used in the last day or two. Try to include at least two solids, two liquids, and two gases.

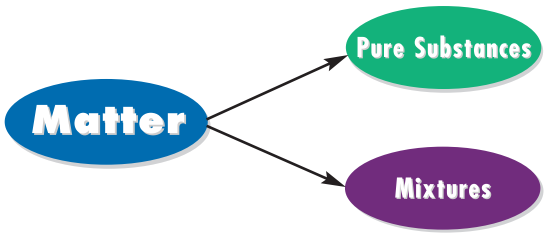
Classify the items in your list as either pure substances or mixtures. If you are not sure into which grouping an item fits, make a third grouping.

Review your groupings and answer the following questions in your notebook or in a class discussion:

- Could you tell pure substances and mixtures apart?
- Which were the hardest items to classify?
- Did some items seem to be neither a pure substance nor a mixture?

PURE SUBSTANCES

A pure substance is made up of one type of matter and has a unique set of characteristics or properties. For example, aluminum foil, baking soda, and distilled water are all pure substances. You cannot separate them into different substances.



MIXTURES

Mixtures are two or more substances combined together. In a mixture, each substance keeps its properties, but it may be difficult to identify these properties. For example, you may not see the sugar in a drink of soda pop, but you can certainly taste it. Sometimes it is easy to identify the different substances in the mixtures. For example, you can see the different vegetables in a package of mixed vegetables.

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What Are Pennies Made Of?

Until 1997, pennies were made of a pure substance—copper. Since then, other substances have been added so pennies are now a mixture of metals. Mixtures of metals are called *alloys*.

Mechanical Mixtures and Solutions

If you think about pure substances, you might list common examples such as sugar, water, salt, and oxygen gas. Some other examples you might think of may seem to be pure substances, but aren't. For example, how would you classify vinegar—is it a pure substance or a mixture? To be able to classify matter, you need to know more about mixtures.

In a **mechanical mixture**, you can see the different substances that make up the mixture. Soil and mixed vegetables are both mechanical mixtures. This type of mixture is sometimes called a **heterogeneous mixture**. In other mixtures, you can't see the different substances that make them up. These mixtures may be solutions, suspensions, or colloids. A **solution** looks as if it is all one substance. It is called a **homogeneous mixture**. Sometimes it is difficult to tell the difference between a pure substance and a solution without performing some tests. You can learn more about suspensions and colloids on the next page. The chart in Figure 2.1 summarizes the classification of matter as pure substance, mechanical mixture, solution, suspension, or colloid.

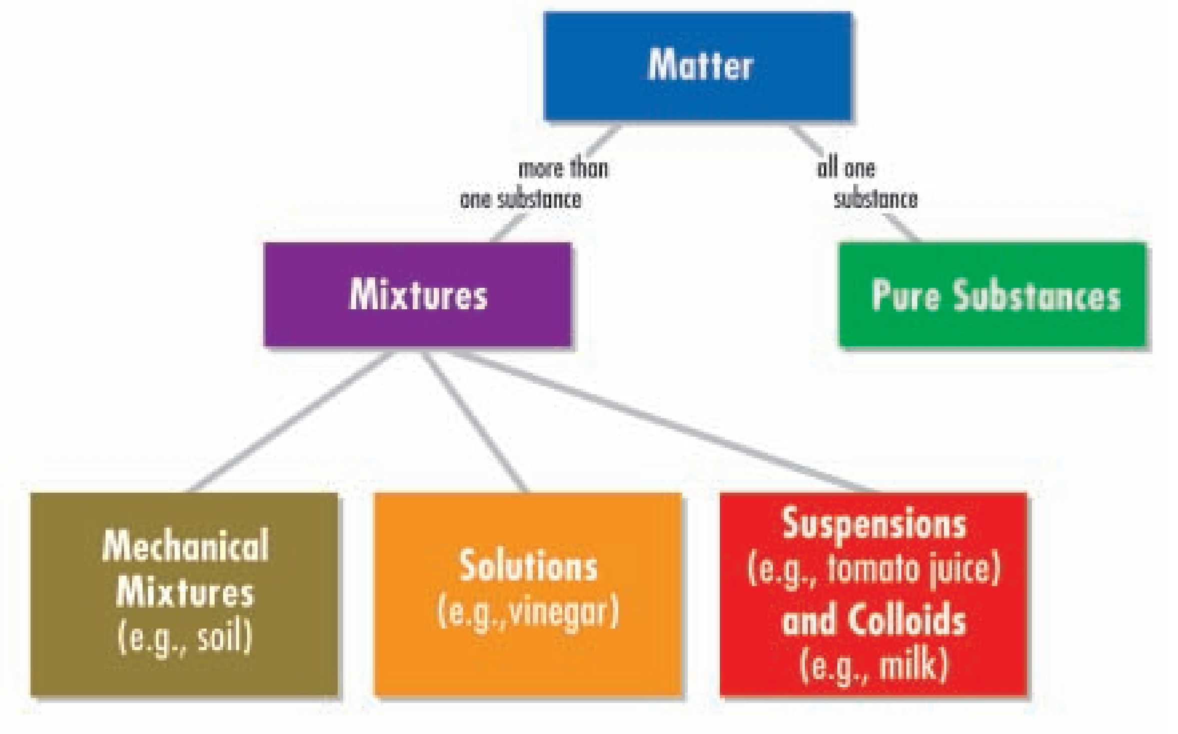

Figure 2.1 Matter classification chart

Suspensions and Colloids

A **suspension** is a cloudy mixture in which droplets or tiny pieces of one substance are held within another substance. If you leave a suspension undisturbed, its parts will usually separate out. Muddy water is an example of a suspension. A **colloid** is also a cloudy mixture but the droplets or tiny pieces are so small that they do not separate out easily. Homogenized milk is a colloid of tiny cream droplets in whey.

Figure 2.2 A *foam* is a colloid of a gas in a liquid. The foam in this photo is used for insulation. It comes out of the can as a fluid, and then hardens in place to seal cracks.

Pure Substance or Solution?

Look at the list of different fluids in this table. Answer the following questions.

- Are these fluids pure substances or solutions?
- How would you determine if your classification is correct?

Copy the table into your notebook. In your table, mark ✔ in the column to which each fluid belongs.

Fluid	Pure Substance	Solution
soda pop		
hot chocolate		
water		
apple juice		
windshield washer fluid		

Paper Chromatography

For some fluids, the *paper chromatography* test can be used to determine if they are pure substances or solutions. A piece of filter paper is placed partly in a solution. If the fluid is a pure substance, it will move up a strip of filter paper to one level. If the fluid is a solution, the different substances in it will move up the paper to different levels. This is a powerful technique for separating several substances mixed together.

Inquiry Activity

Paper Chromatography

The Question

Is the black ink in a marker pen a pure substance or a solution?

The Hypothesis

Write a hypothesis stating whether the marker pen's ink is a pure substance or a solution. (See Toolbox 2 if you need help with this.)

Materials & Equipment

- filter paper or coffee filters
- pencil
- 250-mL beaker
- black, water-soluble marker pen
- paper towels
- water

Figure 2.3 Step 1. Cut a piece of filter paper slightly larger than the width and height of the beaker.

Figure 2.4 Step 6. Curve the paper so it will stand up by itself in the beaker.

Procedure

1. Cut a piece of filter paper so that it is slightly larger than the width and height of the beaker. This will become your chromatogram.
2. Using a pencil, draw a horizontal line 1 cm from one end of the paper.
3. Put 2 large dots of black ink on the filter paper along the horizontal line. Make sure that the dots aren't too close to each other.
4. Pour water into the beaker to a depth of 0.5 cm.
5. Predict what will happen to the ink dots when you put the paper in the water.
6. Curve the paper so that it can stand up by itself in the beaker. Be sure the bottom edge is touching the bottom of the beaker. The line of dots should be just above the water. Do NOT allow the water to touch the line of dots.
7. The water will move up as it soaks into the paper. When the water almost reaches the top of the paper, take the paper out and place it on a paper towel. Allow it to dry.

Collecting Data

8. Record your observations. Be sure to include or draw your strip of paper.

Analyzing and Interpreting

9. What happened to the original colour of the black dots?

Forming Conclusions

10. Is the ink in a marker a pure substance or a solution? Support your answer with your data.

Applying and Connecting

Chromatography has many uses, including identifying forged cheques. In one recent case, a greedy man changed the dollar amount on a will from $1000 to $10 000 simply by adding an extra 0. Using chromatography and comparing the ink from the different digits, investigators determined that the ink from one of the zeros came from a different pen. The man was convicted of forgery.

Extending

What would happen if you tested coloured markers? Try it and find out.

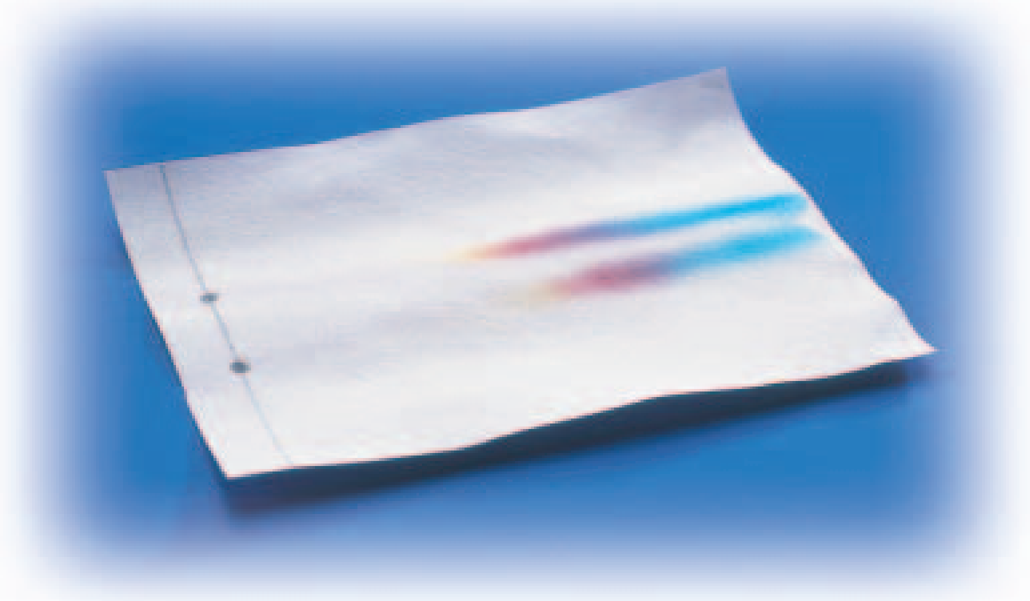

Figure 2.5 You can see from this chromatogram that the ink is not a pure substance. How many substances are mixed together in this kind of ink?

Reading Chromatograms

The filter paper used to test the substance is called a *chromatogram*. Figure 2.5 shows a filter paper with two spots of ink from a black marker on it after it was placed in water. The water soaked into the paper and eventually dissolved the ink spots. Notice how the different substances making up the ink separated at different levels on the chromatogram. The distance a substance moves depends on its attraction to the paper. Some substances are more strongly attracted to the paper. Those with the strongest attraction to the paper don't move very far. Those with the weakest attraction move farthest.

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Separating Mixtures

Methods of separating mixtures can be classified as either destructive or non-destructive. Use print or electronic resources to find examples of methods and what they are used for. Try to find examples other than chromatography.

Check and Reflect

1. What is the difference between a mixture and a pure substance?
2. Below is a list of some examples of matter. Classify each example as a heterogeneous mixture, a homogeneous mixture, or a pure substance. Explain your classification in each case.
   a) chocolate chip cookies
   b) coffee with cream
   c) aluminum foil
   d) potting soil
   e) gold medal
3. Create a flowchart that would help you classify matter into heterogeneous mixtures, homogeneous mixtures, or pure substances. Hint: Review the flowchart on page 20. Test your flowchart using the examples in question 2.
4. What practical uses can you think of for chromatography?

2.2 Concentration and Solubility

Dissolving one substance into another makes a solution. The substance that dissolves is called the **solute**. The substance that does the dissolving is called the **solvent**.

In a concentrated solution, there are large amounts of solute in the solvent. For example, you may have made orange juice from frozen juice concentrate. The concentrate has a large amount of orange solids (solute) in a small amount of water (solvent). You add water to make a diluted solution. A diluted solution has small amounts of solute in the solvent. So the orange juice you drink is actually a diluted solution.

Measuring Concentration

Concentrated and *diluted* are not exact terms. They don't tell you the actual amount of solute in the solvent. The **concentration** of a solution tells you the amount of solute dissolved in a specific amount of solvent. For example, a solution with 50 g of solute dissolved in 100 mL of water has a concentration of 50 g/100 mL of water. This is read as "fifty grams per one hundred millilitres."

Another common way of describing concentration is to state the number of grams of solute per 100 mL of *solution*. A concentration of 50 g/100 mL of solution means that 100 mL of the *solution* has 50 g of solute dissolved in it. Sometimes you will see concentrations stated in other ways. For example, the label on a juice box may say "5% real juice." Very low concentrations may be stated in parts per million (ppm).

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The Smell of Chlorine

A concentration of one part per million of chlorine in a swimming pool can be detected by the human nose.

Give it a **TRY** — ACTIVITY

Comparing Solutions

You have three drinks in front of you. You know how they were made, but are unsure which one has the highest concentration of juice crystals. The first drink has 10 g of juice crystals dissolved in 50 mL of water. The second drink has 15 g of juice crystals dissolved in 100 mL of water. The third drink has 6 g of juice crystals dissolved in 25 mL of water.

Work with a partner to make a plan to figure out the concentration of each drink.

What was the most concentrated drink? How did you determine this since all three drinks had different amounts of solvent?

Comparing Concentrations

To compare the concentrations of two solutions, you need to know the amount of solute in the same volume of solvent for each solution. For example, you have two solutions. One has 10 g of salt in 50 mL of water (10 g/50 mL). The other has 25 g in 100 mL (25 g/100 mL). Which one is more concentrated?

For a comparison, the volume of solvent must be the same for both solutions. In our example, this means doubling the 10 g/50 mL to 20 g/100 mL. So now you are comparing the amount of salt per 100 mL of water in both solutions. The solution with the most solute in the same amount of water is the most concentrated: the solution with 25 g/100 mL is more concentrated than the one with 20 g/100 mL.

math Link

A cleaning solution is made of 5.25 g of a chemical called sodium hypochlorite in 100 mL of water. If you had a solution of 21 g of sodium hypochlorite in 100 mL of water, how would you make the cleaning solution?

Saturated and Unsaturated Solutions

You have just learned how to state the concentration of a solute in a solvent. You know that you can make a very diluted solution by adding a small amount of juice crystals to water. If you add more juice crystals, the solution becomes more concentrated. As long as the juice crystals keep dissolving, you have an **unsaturated solution**. An unsaturated solution is one in which more solute can dissolve.

What would happen if you kept adding juice crystals until no more would dissolve? You would now have a **saturated solution**. A saturated solution is a solution in which no more solute can dissolve at a given temperature. **Solubility** is the maximum amount of solute you can add to a fixed volume of solvent at a given temperature. In our example, the solubility of the juice crystals would be the maximum amount of juice crystals that you could dissolve in water at that temperature. Every solution has a **saturation point** at a given temperature. This occurs when no more solute can be dissolved in a fixed volume of solvent at that temperature.

Figure 2.6 When you drink juice made from concentrate, you have mixed water with the concentrate to make a diluted solution. The water is the solvent and the part of the concentrate that dissolves is the solute.

Inquiry Activity

Saturated and Unsaturated Solutions

The Question

How can you make saturated solutions?

Materials & Equipment

- graduated cylinder
- beaker
- balance
- paper to hold solutes
- spoon or scoopula
- water at room temperature
- powdered drink crystals
- sugar
- salt
- stir sticks

Figure 2.7 Step 2. Accurately measure 5 g of a substance.

Procedure

1. Use the graduated cylinder to measure 50 mL of water into a beaker.
2. Measure 5 g of one substance. Add this to the water.
3. Stir the mixture until the substance has dissolved. Record your observations in the table.
4. Keep adding more of the same substance to the water, 5 g at a time, until no more will dissolve.
5. Repeat steps 1 to 4 for each substance.

Collecting Data

6 Make a table like the one below in your notebook:

Substance	Mass Added	Volume of Water	Concentration in g/100 mL Water	Observations

7 Fill in the table for each substance you use.

Analyzing and Interpreting

8 Calculate the concentration of each solution in grams per 100 mL. Don't forget you used only 50 mL of water, so you will need to correct the differences in mass and volume.

9 How did you know when a solution was saturated?

Forming Conclusions

10 Describe how you made saturated solutions and calculated the concentration of each of your solutes.

Applying and Connecting

Many industrial processes depend on producing solutions of various concentrations. In some situations, the more concentrated the solution, the more useful the solution can be. An example of this is red dye for food colouring. In the 1970s, synthetic red dye was banned because of its potential carcinogenic effects. Industry needed a safe replacement. Scientists found it in an insect called the cochineal [kotch-e-neel] that lives in cacti in the Andes Mountains of South America. This bright red natural dye has been approved for use in cosmetics, drugs, and foods. Recently, two chemists from Simon Fraser University, Dr. Cam Oehlschlager and Dr. Eva Czyzewska, developed a method of improving the production process to make a more concentrated dye. The process is being used on the condition that the dye production remain close to the source of the insects. This is important because rural people are employed in collecting the insect.

Figure 2.8 Cochineal insects live on cacti. They are the source for a bright red dye.

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Insoluble Substances

Sometimes a substance won't dissolve in a solvent. That substance is insoluble in that solvent. Find out why some substances are insoluble.

Comparing Solubility of Common Substances

The solubility of a solute is the maximum amount of that solute that you can dissolve in a given amount of solvent at a given temperature. If you did the last Inquiry Activity, you noticed that different solutes have different solubilities. Solubility is a unique property for each substance. The table below shows the solubilities of some common substances in water at 0°C. You can see that 35.7 g of salt will dissolve in 100 mL of water at 0°C, and 180 g of sugar will dissolve in 100 mL of water at 0°C.

Solubility in g/100 mL of Water at 0°C

Compound	Solubility (g)
salt	35.7
baking soda	6.9
carbon dioxide	0.35
sugar	180
hydrogen	0.00019
oxygen	0.007
ammonia	92

Check and Reflect

1. What is the difference between a diluted solution and a concentrated solution?
2. If a solution has a concentration of 75 g per 100 mL, what does this mean?
3. Calculate the concentrations in grams per 100 mL for the following solutions:
   a) 10 g of chocolate in 50 mL of water
   b) 3 g of sugar in 300 mL of water
   c) 5 g of maple syrup in 25 mL of water
4. What is the difference between a saturated solution and an unsaturated solution?
5. What is the solute in a fruit punch drink?

2.3 Factors Affecting Solubility

In the last section, you learned about solubility. It is the maximum amount of solute you can dissolve in a given amount of solvent at a given temperature. Solubility depends on at least three factors: the type of solute, the type of solvent, and the temperature. First, let's consider the type of solute and the type of solvent.

Give it a TRY — ACTIVITY

DISSOLVING SOLUTES IN DIFFERENT SOLVENTS

Your teacher will give you these solutes: juice drink crystals, petroleum jelly, sugar, and salt. You will have two solvents: water and vegetable oil.

Which solutes will dissolve in water and which solutes will dissolve in vegetable oil?

Create a procedure that will allow you to collect data that will answer the above question. You will have to design a fair test to determine the answer to this question. (See Toolbox 2 for more information on how to design a fair test.)

TYPES OF SOLUTES AND SOLVENTS

The most common solvent is water. Water is sometimes referred to as the *universal solvent* because it can dissolve so many different substances. If you see the term **aqueous solution**, that means the solvent is water. (*Aqua* is the Latin word for water.)

It is important to remember that solutions do not have to be made up of only liquids. The table below contains examples of solutes and solvents in other states.

Examples of Common Solutions

Solute	Solvent	Solution
gas	gas	air (oxygen and other gases in nitrogen)
gas	liquid	soda water (carbon dioxide in water)
liquid	liquid	antifreeze (ethylene glycol in water)
liquid	solid	rubber cement (benzene in rubber)
solid	liquid	seawater (salt and other substances in water)
solid	solid	brass (zinc and copper)

Inquiry Activity

Temperature and Solubility

The Question

What effect does temperature have on the solubility of a substance? Hint: Recall that solubility is the maximum amount of solute (solid) that you can dissolve in a fixed volume of solvent (liquid) at a given temperature.

The Hypothesis

Write a hypothesis about how the temperature of the solvent affects the amount of solute that can dissolve in it.

Materials & Equipment

- 2 beakers
- water
- thermometer
- hot plate or access to hot water
- solute and solvent
- spoon or scoopula
- graduated cylinder
- triple beam or electronic balance

Procedure

1. Decide which materials you will need to test the hypothesis.
2. Plan your investigation.
   a) What variable(s) will change?
   b) What variable(s) will stay the same?
3. Write a procedure and show it to your teacher. Do not proceed any further until it is approved.
4. Carry out your investigation.

Caution!
If you spill liquid on your hands, wash it off with water right away. Wash your hands when you have completed the activity.

Collecting Data

5. Make sure you have recorded at least the following information: the hypothesis, your procedure, the temperature of the liquids used, and the mass of solute added.

Caution!
Always heat solvents in a water bath.

Figure 2.9 Carefully measure the mass of solute that you use.

Analyzing and Interpreting

6. Share and compare your results with your classmates. What variables did each group have to keep the same so that you could compare results?

Forming Conclusions

7. In a short paragraph, describe your results and how they compared with the hypothesis.

Extending

A *supersaturated* solution is one that contains more solute than it normally would be able to dissolve at a certain temperature. How do you think you could make a supersaturated solution with the solute and solvent combination you tested here? Find out how to do this and try it.

Solubility Changes with Temperature

For most common solid or liquid substances, solubility increases as the temperature of the solvent increases. For example, at 25°C, you can dissolve 36.2 g of salt in 100 mL of water, but at 100°C, you can dissolve 39.2 g. The reverse is true for a gas. As the temperature increases, the solubility of a gas in a liquid solvent decreases.

Thermal Pollution

This decrease in the solubility of gases can have a serious effect on the environment. Many industrial plants use water as a coolant in their processes. Usually this water is drawn from a lake or a river. Once the water is used, it is warmer than when it was taken into the plant. Before it can be returned to the lake or river, it must be stored in a cooling pond. What would happen if the warm water were poured directly back into the river or lake? This is commonly called *thermal pollution*.

All water contains various amounts of different gases, including oxygen. The oxygen is important for supporting life that lives in the water. If the temperature of the water increases, the concentration of oxygen decreases. This occurs because the solubility of a gas in a liquid solvent decreases as the temperature increases. So the solubility of the oxygen is less in the warmer water. What do you think will happen to the living organisms in the lake or river if the amount of oxygen in the water decreases greatly?

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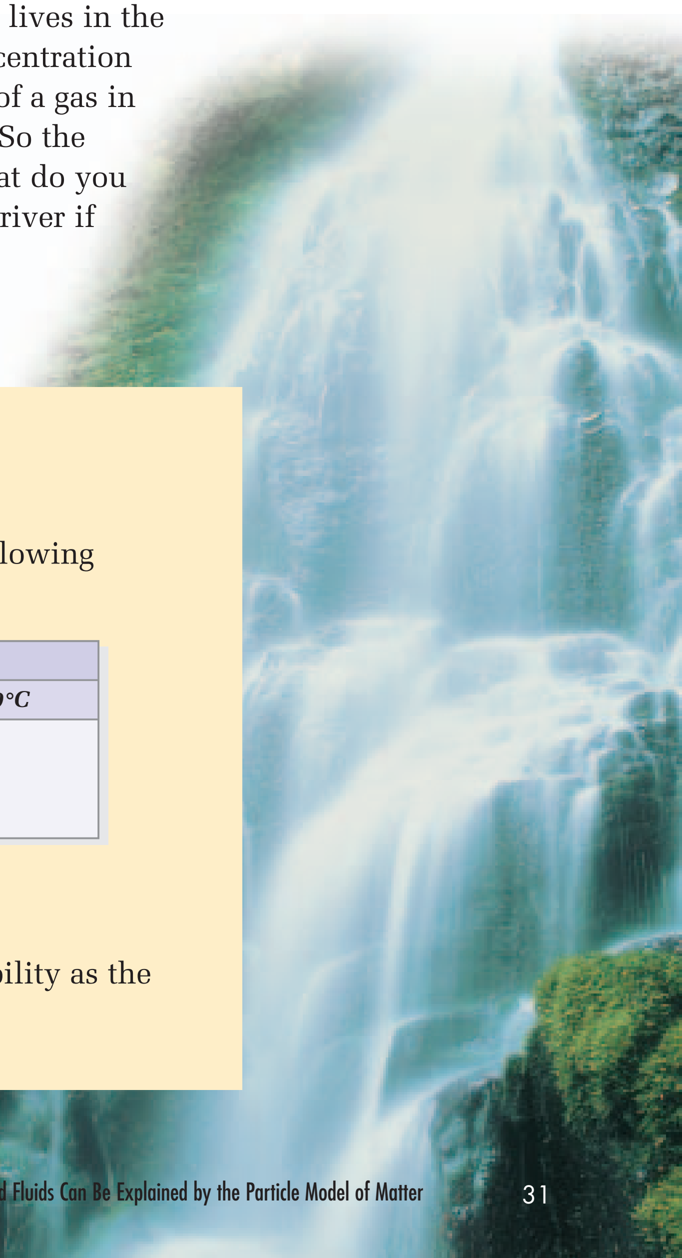
The Colour of Money

In 1857, Thomas Sterry Hunt, a professor at McGill University in Montreal, produced a green ink called chromium trioxide. This green ink is used to this day to print American money. Dr. Hunt's green ink cannot be dissolved or copied by photography.



Check and Reflect

1. Why is water called "the universal solvent"?
2. What factors affect the solubility of a solute?
3. For the substances in the chart below, answer the following questions.

Solubility in g/100 mL of Water		
Substance	**at 0°C**	**at 100°C**
sodium chloride	35	39
sodium nitrate	74	182
sodium carbonate decahydrate	21	421

a) Which substance is the most soluble at 100°C?
b) Which substance is the most soluble at 0°C?
c) Which substance shows the most change in solubility as the temperature increases?

2.4 The Particle Model of Matter and the Behaviour of Mixtures

As you study the properties of mixtures, you may observe events that seem difficult to explain. For example, how would you explain the following situations involving mixtures?

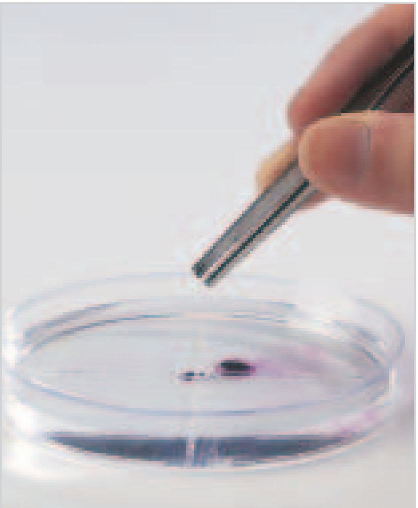


Figure 2.10a) The potassium permanganate has just been added to the water.

Figure 2.10b) What happened to the potassium permanganate after 5 min in the water?

Situation 1. Can something dissolve without stirring?

Figure 2.10a) shows a petri dish three-quarters full of water. A crystal of potassium permanganate was carefully added to the still water. The dish was left for 5 min without disturbing it. Figure 2.10b) shows the potassium permanganate after 5 min. What happened to it? Why do you think this happened?

Figure 2.11a) 20 mL of rubbing alcohol and 20 mL of water in separate 25-mL cylinders

Figure 2.11b) The two liquids combined in a 50-mL cylinder

Situation 2. Can you combine two liquids and have a volume less than the sum of the volumes when you started?

A lab technician carefully measured 20 mL of rubbing alcohol into one graduated cylinder and 20 mL of water into another. He then combined the two liquids. The combined liquid filled the graduated cylinder to a level of 39 mL. Did the technician make a mistake? Can you explain why this measurement resulted?

You may have developed explanations for these two situations, but you may not be completely sure of your answers. A model of matter would help explain these and other observations.

The Particle Model of Matter

Why did the potassium permanganate start to dissolve without being stirred? Why did the volumes not add up when the water and the rubbing alcohol were added together? The **particle model of matter** can help to explain these and other situations. The particle model has four main points that describe the structure of matter. Using this model, you will be better able to explain the properties of mechanical mixtures and solutions. As you look through the description of the particle model shown here, think about the situations described on the previous page.

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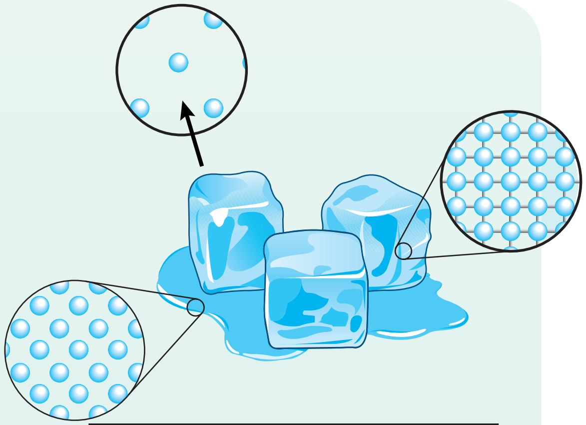
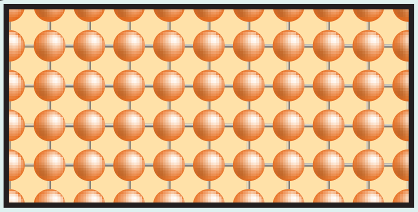
How Big Is a Particle?
There are about 10^{18} particles in a snowflake. That's the number 10 with 18 zeros after it.

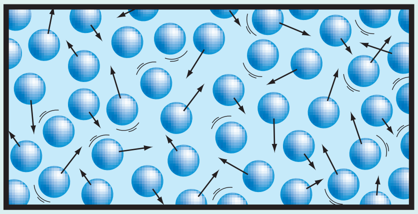
1 All matter is made up of tiny particles. Different substances are made up of different particles.
- This means every object in any state is made up of tiny particles too small to see.
- There are more particles in a given volume of solid than there are in the same volume of a liquid or a gas.



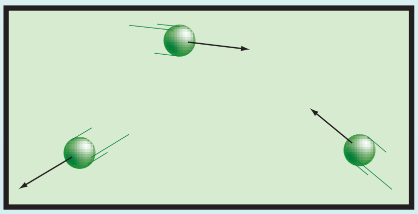
2 The tiny particles of matter are always moving and vibrating. For solids, this movement is like wiggling in one place. For liquids, the particles are sliding around and over each other. For gases, this movement means moving as far as the space they are in allows.



3 The particles in matter may be attracted to each other or bonded together.
- Some particles, such as water, have more attraction for other particles, such as salt, than for each other.



4 The particles have spaces between them.
- Notice the difference in the amount of space between particles of a solid and a gas.



Give it a **TRY** ACTIVITY

USING THE PARTICLE MODEL OF MATTER

You have 50 mL of sand in one container and 250 mL of marbles in another container. When you mix the contents of the two containers, you will be modelling what happens when alcohol and water are mixed together.

What will be the total volume of the sand and marbles when they are mixed together?

Slowly pour the 50 mL of sand into the container of marbles. Record your observations.

Use the particle model to explain what happened when you mixed the sand and marbles together. Now use it to explain what happened when the technician mixed the alcohol and water earlier in this subsection.

Figure 2.12 The marbles and sand represent two different substances made up of particles of two different sizes. Notice how the sand fills in the spaces between the marbles.

HOW THE PARTICLE MODEL EXPLAINS MIXING SUBSTANCES

The alcohol and water that the technician mixed together earlier are two different substances. They are made of different particles, and these particles are different sizes. When the two substances are mixed together, the smaller particles of one substance fill in the spaces between the larger particles of the other. Figure 2.12 shows a model of this situation.

The particle model can also explain why substances dissolve. The particle model states that particles are attracted to each other. However, particles in some substances are more attracted to particles in other substances than to each other. For example, consider the situation in Figure 2.10 at the beginning of this subsection. When potassium permanganate is placed in water, its particles are attracted to the water particles. This is the process called *dissolving*. In a solution, the particles of the solute (potassium permanganate) are attracted to the particles of the solvent (water). The solute dissolves in the solvent. This is why a solute seems to disappear when mixed with a solvent.

FACTORS AFFECTING THE RATE OF DISSOLVING

In the subsection 2.3, you investigated different factors that affected the solubility of a substance. You found out that the kind of solute, the kind of solvent, and the temperature all had roles in solubility.

Another important consideration in dissolving solutes is the rate of dissolving. How fast will a solute dissolve in a solvent? How can you make a solute dissolve more quickly? Look at Figures 2.13a)–c). They show how the particle model can explain the factors that affect the rate at which a solute dissolves.

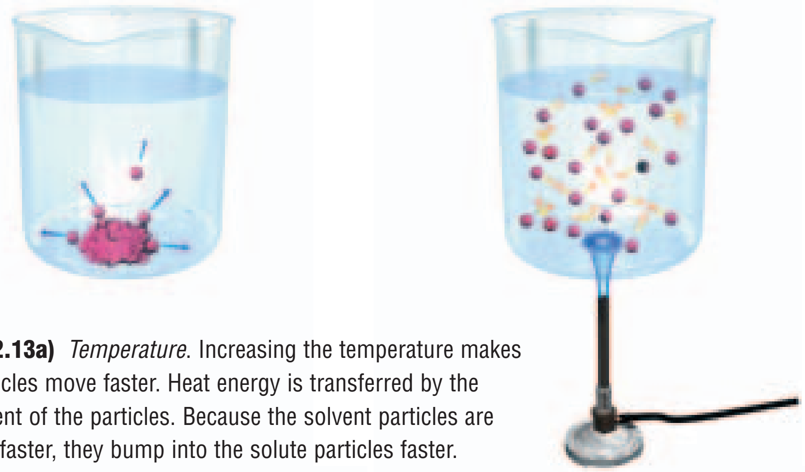


Figure 2.13a) *Temperature.* Increasing the temperature makes the particles move faster. Heat energy is transferred by the movement of the particles. Because the solvent particles are moving faster, they bump into the solute particles faster.

Figure 2.13b) *Size of Pieces.* Small pieces of solute dissolve more quickly than large pieces. All the smaller pieces together have more surface area among them for the solvent particles to bump into. Think of cooking a potato in water. If you put the whole potato in, it takes a long time to cook. If you cut the potato up into smaller pieces, the cooking time becomes much shorter.

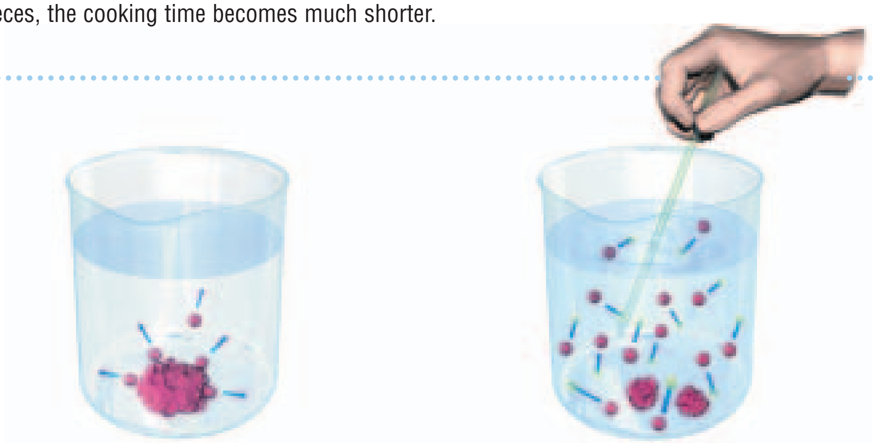


Figure 2.13c) *Stirring.* Stirring moves all the particles around, so the solvent particles bump into the solute particles.

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Atomic Structure

The particle model is a simple way of describing matter and its behaviour. Atomic structure is another way. You have probably heard about atoms. How are atoms related to particles? Find out about atomic structure.

Check and Reflect

1. Make a particle sketch showing how instant coffee dissolves in hot water.
2. You've been asked to try out a new type of fruit drink flavouring that comes in the form of a cube that dissolves in water. You're in a hurry to try it so you want to dissolve it as quickly as possible. Name three ways of speeding up dissolving. Explain each one using the particle model.
3. Figure 2.14 shows a Web page about the particle model that is still under construction. The text hasn't been added yet.
   a) In your notebook, complete the Web page with information that explains the picture. Include one hyperlink topic in the text of your Web page.
   b) Write one other Web page that explains your hyperlink. The text on this page should use the words *solubility* and *factors affecting the rate of dissolving*.

Figure 2.14 Question 3. Web page under construction

4. Why did the potassium permanganate crystals start to dissolve in water without being stirred?

Assess Your Learning

1. Give an example of a pure substance. Why is it a pure substance?

2. Think about examples of solutions made by combining different states of matter. Make a chart like this one, and fill it in with an example of each combination.

Substance	Substance	Solution Made	Other Examples
solid	*liquid*	table syrup	
solid	*solid*	steel	
liquid	*liquid*	perfume	
liquid	*gas*	tap water	

a) Which combination of substances was the most difficult to think of as a solution?

b) Which combination was the easiest?

3. In paper chromatography, is the substance being tested the solute or the solvent? Explain your answer.

4. Use the particle model to explain what happens to the rate at which a solute dissolves when the temperature increases.

5. A bucket of paint spills on your classroom floor. How could you use your knowledge of dissolving to help clean up the paint?

Focus On SCIENCE AND TECHNOLOGY

Scientific knowledge may lead to the development of new technologies, and new technologies may lead to scientific discovery. Think back to the information on using paper chromatography to separate substances in a solution.

1. What do you need to know about pure substances and solutions in order to use paper chromatography technology?

2. Use the library or the Internet to find other applications of chromatography.

3. After finishing your research, consider the following statement. Then write a brief response to it. *Understanding the scientific principles of paper chromatography is more important than developing uses for it.*

3.0 The properties of gases and liquids can be explained by the particle model of matter.

Key Concepts

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

- properties of fluids
- mass, volume, density
- viscosity and flow rate
- buoyancy

Learning Outcomes

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

- define viscosity and describe how temperature affects it
- calculate and compare densities and relate them to the particle model of matter
- describe methods of altering density in fluids
- explain buoyancy
- describe pressure and examples of its use
- compare the compressibility of liquids and gases

Most people think of liquids when they hear the word “fluids.” But gases are also fluids. A fluid is any matter that has no fixed shape—it takes the shape of its container. For example, the air in a bicycle tire takes the shape of the tire and water in a bottle takes the shape of the bottle.

Fluids have many properties that are useful. In this section, you will investigate the fluid properties of viscosity, density, buoyancy, and compressibility. Each of these plays a role in how a fluid may be used. For example, the Canadarm can move heavy objects using only gears while the space shuttle orbits Earth. On Earth’s surface, hydraulics provide an advantage that makes it possible for one person to lift and move huge loads. An engineer designing a hydraulic arm must understand how forces are transmitted through a fluid and how fluids behave under pressure. You will have the scientific knowledge to design a hydraulic arm at the end of this section.

 For Web links relating to 3.0, visit **www.pearsoned.ca/scienceinaction**

3.1 Viscosity and the Effects of Temperature

One property of fluids is how they move or flow. Think about the fluids you have used in the last couple of days. What would happen if they didn't flow the way they usually do? For example, what if soda pop was like a thick syrup or ketchup was like water? In both these situations, the properties of the fluids are very different. With your partner, identify three fluids that you have used, and describe what they would be like if they were thicker or thinner. Here is an example:

Fluid	Thicker	Thinner
shampoo	– hard to get out of bottle	– would probably use more to wash hair

How quickly fluids flow is a property called **viscosity**. It is determined by a fluid's internal resistance or friction that keeps it from flowing. Recall from the particle model that the particles in a liquid slide around and roll over each other. In a gas, the particles move around even more easily. The greater the friction or rubbing between particles in any fluid, the higher the viscosity. Fluids with high viscosity do not flow as easily as fluids with a low viscosity.

Figure 3.1 Juice has a low viscosity. Ketchup has a high viscosity.

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What grade of motor oil is this?

Multi-grade Engine Oil

The Society of Automotive Engineers (SAE) assigns all motor oils a viscosity number between 5 and 50. The higher the number, the higher the viscosity. SAE 30 oil is suitable for summer use, while SAE 10 oil can be used for winter driving. Multi-grade motor oil, such as SAE 10W30, has compounds added to it that allow the oil to flow easily at cold temperatures, but prevent it from thinning out too much when the weather becomes hot.

The Effect of Temperature on Viscosity

Earlier in this section, you thought about different fluids and what would happen if their viscosity changed. What might cause a fluid's viscosity to change? Temperature is one factor that can have a big effect on viscosity. Look at Figures 3.2a)–d). What will happen to the viscosities of these fluids in the situations shown?

Figure 3.2a) Table syrup poured on hot pancakes

Figure 3.2b) Hot tar spread on a road

Figure 3.2c) Olive oil placed in a refrigerator

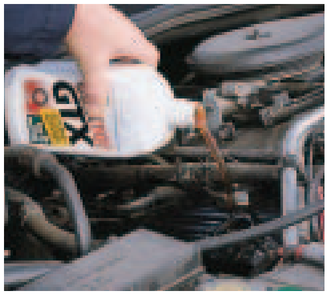

Figure 3.2d) Room temperature engine oil poured into a hot engine

Measuring Viscosity with the Ramp Method

The *ramp method* of testing viscosity involves pouring a fluid down a ramp and timing how long it takes to get to the bottom. By pouring the same amount of another fluid and timing it, you can compare the viscosities of different fluids. You can also investigate the effect of temperature on viscosity by testing the same fluid at different temperatures. First, you test it at room temperature. Then, you warm it in hot water or cool it in an ice bath, and test it again.

Give it a TRY — ACTIVITY

How Fast Can It Go?

You will use the ramp test to determine the effect of temperature on the viscosity of four fluids.

Design a fair test that will allow you to collect evidence to demonstrate the effect of temperature on viscosity. (See Toolbox 2 for more information on designing a fair test.)

Write a procedure and show it to your teacher for approval. Then carry out your tests.

When you have completed your tests, create a one-page summary poster of your results. Include one graphic illustrating your results.

Caution!
Handle hot water carefully. If you spill any on your skin, immediately run cold water over the area.

Materials & Equipment

- shampoo
- pancake or table syrup
- vegetable oil
- Teflon-coated cookie sheet
- thermometer
- hot water
- cold water
- beakers
- a stopwatch

UNDERSTANDING VISCOSITY AND TEMPERATURE

Recall that viscosity is a fluid's internal resistance or friction that keeps it from flowing. A fluid with a high viscosity has a large amount of internal resistance or friction. As the temperature of a liquid increases, its viscosity decreases. The opposite is also true. As the temperature of a liquid decreases, its viscosity increases. If you did the ramp method activity, your data will show that the warmer the fluid, the faster it flows.

The particle model of matter can help you understand why this change in viscosity happens. Recall that in the particle model, a liquid is made of particles that can slide and roll over each other. When energy or heat is added to the liquid, the particles slide and roll more quickly. As a result, the fluid flows more readily—its viscosity decreases. The reverse is also true. As the temperature of the liquid drops, the particles slow down. The result is that the viscosity increases—the fluid flows more slowly.

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Fluids from the Environment

In Alberta, Aboriginal peoples used to use the thick, viscous bitumen of the oil sands to seal their canoes. Aboriginal peoples all over North America also used tree sap to make a glue for building canoes. Find out how Aboriginal peoples made glue from tree sap. In what other ways did Aboriginal peoples use their knowledge of fluid characteristics?

CHECK AND REFLECT

1. Write a short paragraph to describe viscosity. Include at least two examples of fluids, and use the words *flow*, *fluid*, *particles*, and *viscosity* in your description.
2. Describe two substances that are useful because of their viscosity.
3. In a fair test, you have to keep all the variables the same except one. That way, you can see the effect of the one variable. If you had to do a ramp test for viscosity:
   a) What would you change during the tests?
   b) What things would you keep the same for each test?
4. You are given three samples of the same shampoo at three different temperatures: 35°C, 50°C, and 75°C. Which sample would have the highest viscosity? Which sample would have the lowest?
5. You are making cookies that call for 3 tablespoons of molasses. But you are having trouble measuring out the thick, syrupy liquid. What could you do to make it easier to pour and measure this fluid?

3.2 Density of Fluids

Figure 3.3 Why isn't this grape floating?

Recall that at the beginning of this unit, you had an opportunity to answer an e-mail from the president of GeeWHIZ Beverage Ltd., asking you to find out if a piece of fruit could be suspended in a fluid. Here is an example of some data that was collected in this activity. One student, Emma, used cranberry juice, tomato sauce, peach juice concentrate, and a grape in her research.

Fluid	*Grape Sank*	*Grape Floated on Top*	*Grape Floated in Middle*
cranberry juice	✓		
tomato sauce			✓
peach juice concentrate		✓	

Why did the grape sink in some liquids and not in others? The reason for the difference is a property of fluids called density. **Density** is the amount of matter in a given volume. Think about density as you examine the results of Emma's investigation above.

Give it a TRY ACTIVITY

DENSE AND DENSER

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

Make a list, ranking them in order of highest density to lowest density. You may use any method you like to determine this ranking, but you cannot open the jars.

The list here tells you what is in each jar. If a substance has been changed, your teacher will tell you.

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

What ranking did you choose? Be prepared to explain your reasons for the order of your ranking. Keep your ranking handy because you will be testing these substances later. You will be able to compare your ranking with your test results.

Understanding Density

As you probably realize, not all substances have the same density. Recall that the particle model of matter states that all matter is made of tiny particles. It also states that different substances are made of different particles. So the particles in each fluid are different from the particles in every other fluid. The density of a fluid or any other kind of substance depends on the particles it is made of.

Think about Emma's results again on page 42. If the density of the grape was *greater* than the density of the fluid, the *grape sank*. If the density of the grape was *less* than the density of the fluid, the *grape floated*. Look at the graph of the densities of some common materials in Figure 3.4. You'll notice that some solids are less dense than some liquids. That's why wood floats on water. It's the kind of particles in a substance that are important in determining a substance's density.

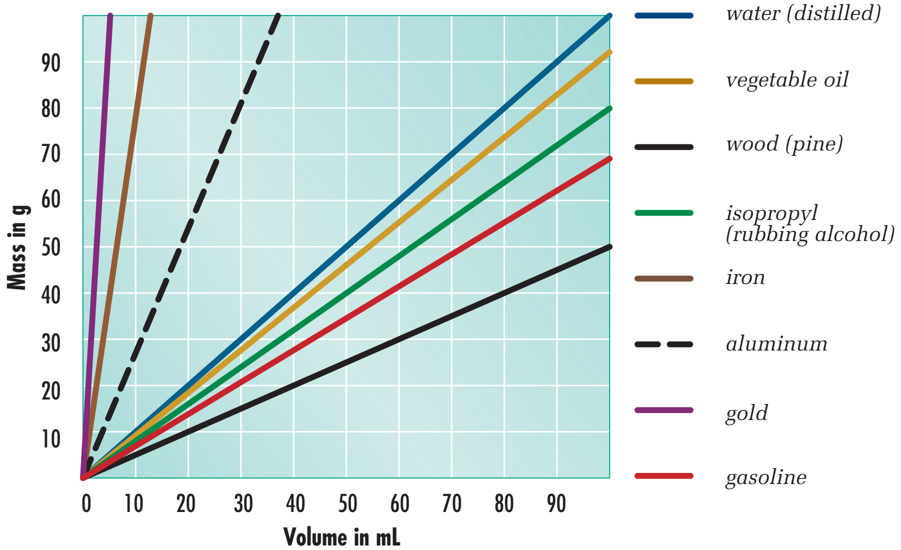

Figure 3.4 Densities of some common substances at 20°

Calculating Density

Density is the mass per unit of volume, which can be measured in mL or cm^3. Density is calculated by dividing the mass of a substance by its volume.

$$\text{Density } (d) = \frac{\text{Mass } (m)}{\text{Volume } (V)}$$

The units for the density of liquids and gases are usually grams per millilitre (g/mL) or kilograms per litre (kg/L). The units for the density of solids are usually grams per cubic centimetre (g/cm^3).

*info***BIT**

Now That's Dense!

Mercury, like water, is a liquid at room temperature. Water's density at this temperature is 1.00 g/mL. Mercury's density at this same temperature is 13.55 g/mL!

*re***SEARCH**

What's the Difference?

A can of diet soda pop will float in water, but a can of regular pop will not. Find out why.

Inquiry Activity

CALCULATING MASS/VOLUME RATIO

The Question

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

The Hypothesis

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

Hint: Recall that density is the mass of a substance in a given volume.

Materials & Equipment

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

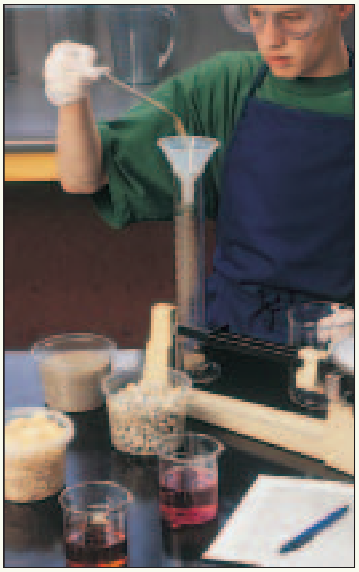

Figure 3.5 Step 2. Pour 50 mL of one substance into the beaker and record the volume in the table.

Procedure

TOOLBOX

1. Measure the mass of the beaker and record it in your table. (See Toolbox 5 for information on measuring mass.)
2. Pour 50 mL of one substance into the beaker and record the volume in the table. (See Toolbox 5 for information on measuring volume.)
3. Place the beaker containing the substance on the balance and measure the mass. Record the mass in your table.
4. Repeat steps 2 and 3 for the same substance with volumes of 100 mL, 150 mL, 200 mL, and 250 mL.
5. Repeat this procedure for each of the other substances.
6. Clean and return your equipment to the proper location.

Collecting Data

7 In your notebook, make a table like the one shown below to record your data. Use a table like this for each substance.

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

Analyzing and Interpreting

8 When you have finished taking your measurements, enter your data into a spreadsheet program.

9 Find the mass of each substance by subtracting the mass of the beaker from the total mass of the beaker and substance together.

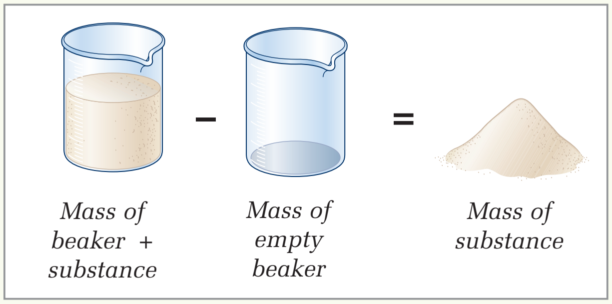

Figure 3.6 How to calculate the mass of the substance

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

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

12 Compare the slopes of the lines. Which slope is the steepest? Which slope is the shallowest?

13 Find the ratio of the mass to the volume by dividing the mass of the substance by the volume for each volume measured. What is the average ratio for each substance? This ratio is the density of each substance.

For example:

- 200 mL of a substance has a mass of 400 g
- the mass to volume ratio is $\frac{400\text{ g (mass)}}{200\text{ mL (volume)}}$
- Density = $\frac{400\text{ g}}{200\text{ mL}} = \frac{2.00\text{ g}}{1\text{ mL}}$

14 Can you see any relationship between the average ratio for each substance and the slope of each line on your graph?

15 Compare your calculated densities for the substances with the predictions you made when you did the Give It a Try Activity at the beginning of this subsection. Was the order of the densities you predicted the same or was there a difference? Suggest reasons for any differences.

16 Use your graph to determine the answers to the following questions:

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

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

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

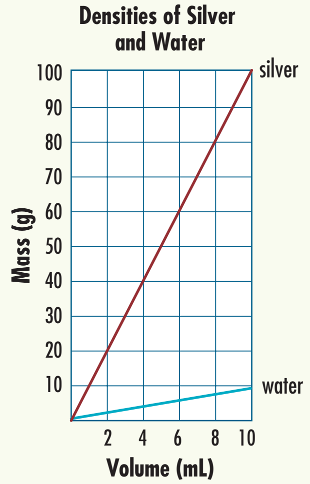

Figure 3.7 Step 10. How will you determine what scale you will use for each axis?

Forming Conclusions

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

Applying and Connecting

If a boat is heavier than water, why does it float on water? The answer is in the concept of average density. Each of the materials that make up the boat might sink in water, but the average density of the whole boat is less than the average density of the water. The average density of the boat includes the boat's total volume, which not only contains the solid parts of the boat, but also the air in the cabins, the hold, and other spaces.

Check and Reflect

1. The table below shows mass and volume data for baby oil. What happens to the mass of the baby oil as the volume changes?

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

2. a) What is the density of the baby oil?
   b) What happens to the density as the mass and volume change?
3. Suppose you were to graph the baby oil data on a graph with mass on the vertical axis and volume on the horizontal axis. Would the slope of the line for the baby oil be shallower or steeper than one for water? (The density of water is 1.0 g/mL.)
4. What is the density of each of the following substances?
   a) 2.0-mL of mercury has a mass of 27.1 g
   b) 0.5-mL of silver has a mass of 5.25 g
   c) 2.5-mL of lead has a mass of 28.5 g
5. If you had 100 mL of each substance in question 4, which one would have the greatest mass?

Careers and Profiles

Soft-Drink Manufacturer

To make a soft drink, you need to experiment with different combinations of water, sugar, and flavourings to make a syrup. Flavours come from fruits and berries, as well as from tree bark, herbs, and roots. Once you've got exactly the right taste, this syrup will be your own secret formula!

Next, you'll carefully purify the water for your drink. Then, you'll mix your secret syrup with the right amount of water. Your drink is a solution, since the sugar and flavourings dissolve in water.

The last step is pumping your water and syrup solution into a machine called a carbonator. This machine mixes carbon dioxide gas into your solution under very high pressure. Now your drink is a mixture of a gas and a liquid! The drink goes straight from the carbonator into the bottle or can, which is then sealed so the gas won't escape.

- What would you need to know about science and technology to develop a soft drink?

3.3 Density, Temperature, and Buoyancy

Earlier in this unit, you discovered that viscosity changes with temperature. Does density also change when the temperature changes? The particle model of matter states that for each substance, the number of particles in a given volume remains constant if the temperature is kept constant. Density does not change as long as the temperature stays the same.

Give it a TRY — ACTIVITY

MEASURING DENSITY CHANGES

Is there a difference in density between a cup of cold water and a cup of hot water? You can test the question by using a hydrometer. A hydrometer is a device for measuring the density of liquids.

Caution!
Handle hot water carefully. If you spill any on your skin, immediately run cold water over the area.

Use a hydrometer to determine if the density of cold water is the same as the density of hot water.

You will need two beakers for the water and a hydrometer.

In a short paragraph, summarize your results. Use the particle model to help explain what you observed.

THE PARTICLE MODEL AS AN EXPLANATION FOR DENSITY CHANGES

Think about swimming in a lake on a hot summer day. The water on the surface of the lake is noticeably warmer than the water below it. The warm water floats on the cold water because it has a lower density than the cold water has.

According to the particle model, particles in a substance move more quickly when energy is added. As a solid changes to a liquid and eventually to a gas, the particles move faster and faster. This affects the density of the substance. As particles become more active, they move away from each other, and the space between them increases. This causes the volume to increase, but the number of particles stays the same. With the same number of particles in a larger volume, the density decreases. Recall that density is the ratio of mass to volume.

Different Temperature, Different Density

One substance, then, can have different densities depending on its temperature. What happens to a substance as it is heated? It changes state: at low temperatures, it will be a solid, and at higher temperatures, it will be a liquid, and at even higher temperatures, a gas. A substance (except water) has a greater density in its solid state than in its liquid state and gas state. Figure 3.8 shows how the particle model explains this.

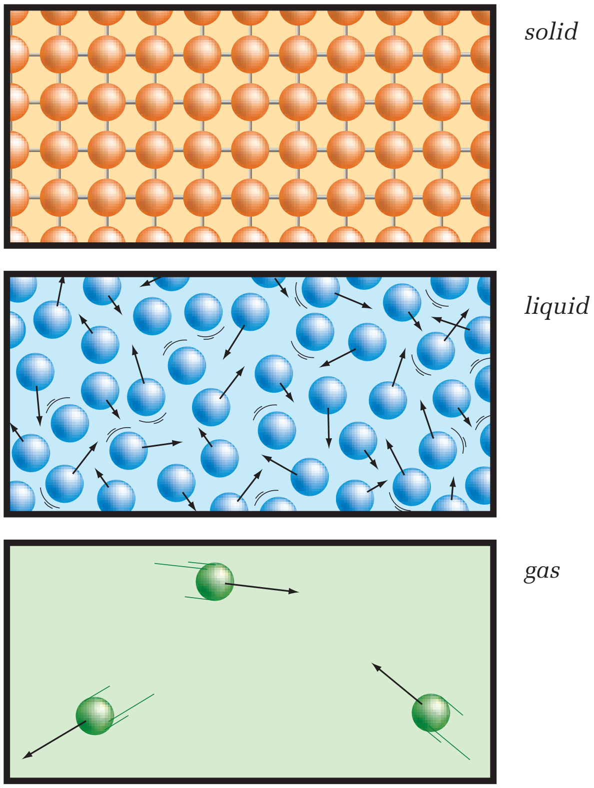

Figure 3.8 The particle model of matter describes particles in a solid and a liquid being packed close together compared with particles in a gas. A gas has more space between particles. This explains why a substance is most dense when it's a solid and least dense when it's a gas.

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Galileo's Thermometer

The thermometer shown here is Galileo Galilei's thermometer (or *thermoscope*), first invented in the 1590s. Can you determine how it works? Each temperature bulb acts like a hydrometer and floats to the top when the water's density is greater than that of the bulb.

Figure 3.9 Why is this swimmer floating so easily?

CHANGING DENSITY BY CHANGING CONCENTRATION

Have you ever tried to float in a lake, a river, or a swimming pool? How easy was it? It probably wasn't as easy as it is for the person in Figure 3.9. This person is floating in the Dead Sea in Israel. The Dead Sea is one of the saltiest bodies of water on Earth. Why do you think it might be easier to float in salt water than in fresh water?

Earlier, you learned that density depends on the number and kind of particles in a given volume. Distilled water has a density of 1 g/mL. What do you think would happen if you added salt to this water? Recall from the particle model of matter that dissolving one substance (salt) in another (water) increases the number of particles in a given volume. By adding more particles, you increase the density of the water solution. Increasing the concentration of salt in the solution increases the density. That means denser objects can float in the solution now than could in the distilled water.

So far, you have learned how density determines if one object will float in another. Less dense objects float in more dense substances. But is density the only factor that affects floating?

Buoyancy

In this unit, you have seen that an object sinks when its density is greater than the density of the fluid it is in. What is the connection between the object's density and the forces that act on it in a liquid? When an object is in a liquid, the force of gravity pulls it down. The liquid, however, exerts an opposite force, called the **buoyant force**, that pushes the object upward.

What happens when the density of the liquid is greater than the density of the object? The buoyant force of the liquid on the object is greater than the force of gravity pulling down on the object. The object floats.

What happens when the density of the object is greater than that of the liquid? The force of gravity acting on the object will be greater than the buoyant force of the liquid. The object sinks. **Buoyancy** is the tendency of an object to float when placed in a fluid. The buoyant force is the force in fluids that acts against gravity.

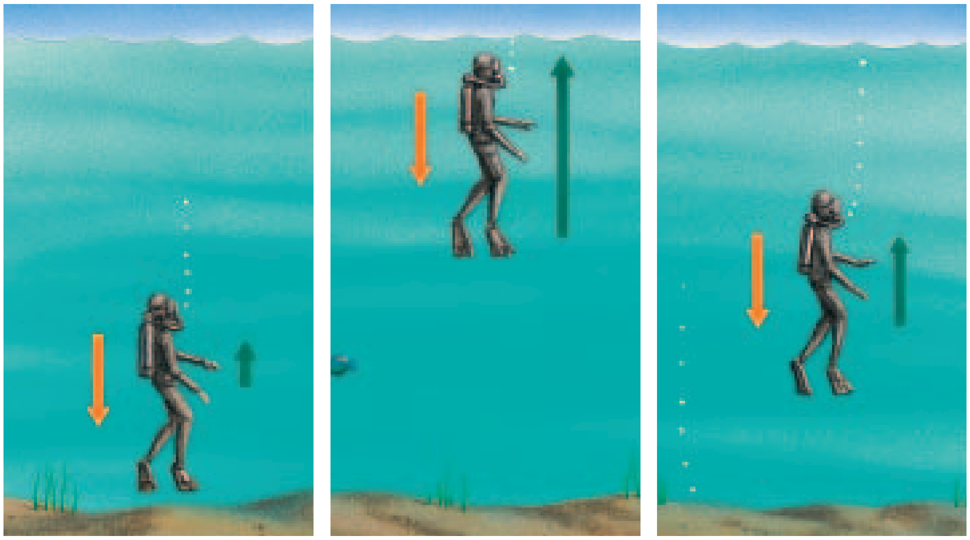


Figure 3.10a) The diver is able to move downward because of a combination of forces. The force of gravity acting on her, along with the force of her leg movement, is greater than the buoyant force of the water.

Figure 3.10b) The diver can move upward because the buoyant force, combined with the force of her leg movement, is greater than the force of gravity.

Figure 3.10c) The diver can float suspended in the water where the force of gravity equals the buoyant force. This situation is called *neutral buoyancy*.

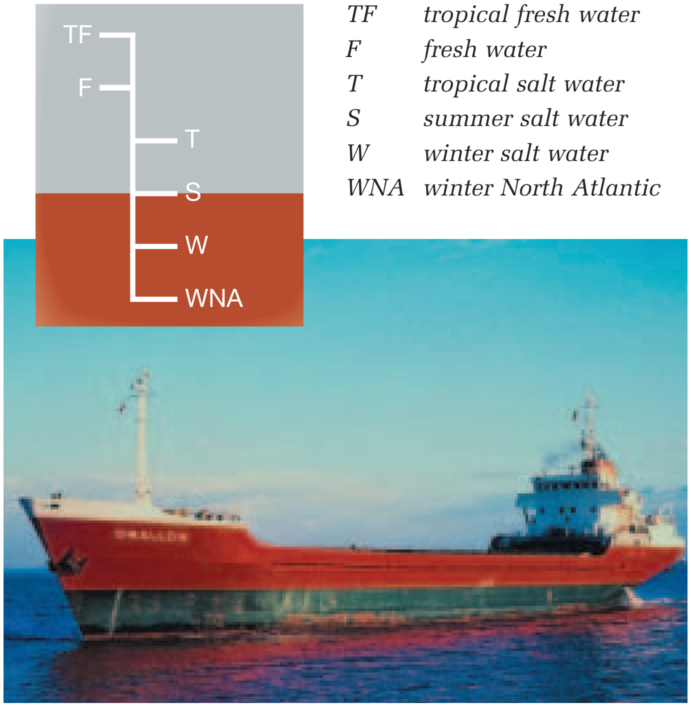
Applications of Buoyancy

Buoyancy is an important factor in some transportation technologies. For example, ships are designed to float safely all over the world. But what happens when a ship moves from more dense to less dense water?

Plimsoll Line

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

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



Legend

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

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

Hot Air Balloons

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

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Airships

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

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

The Hindenburg

Check and Reflect

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

Figure 3.12 Question 3. Air mattress warning tag

TRY This at Home ACTIVITY

Sink or Swim

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

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

3.4 Compression of Fluids

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

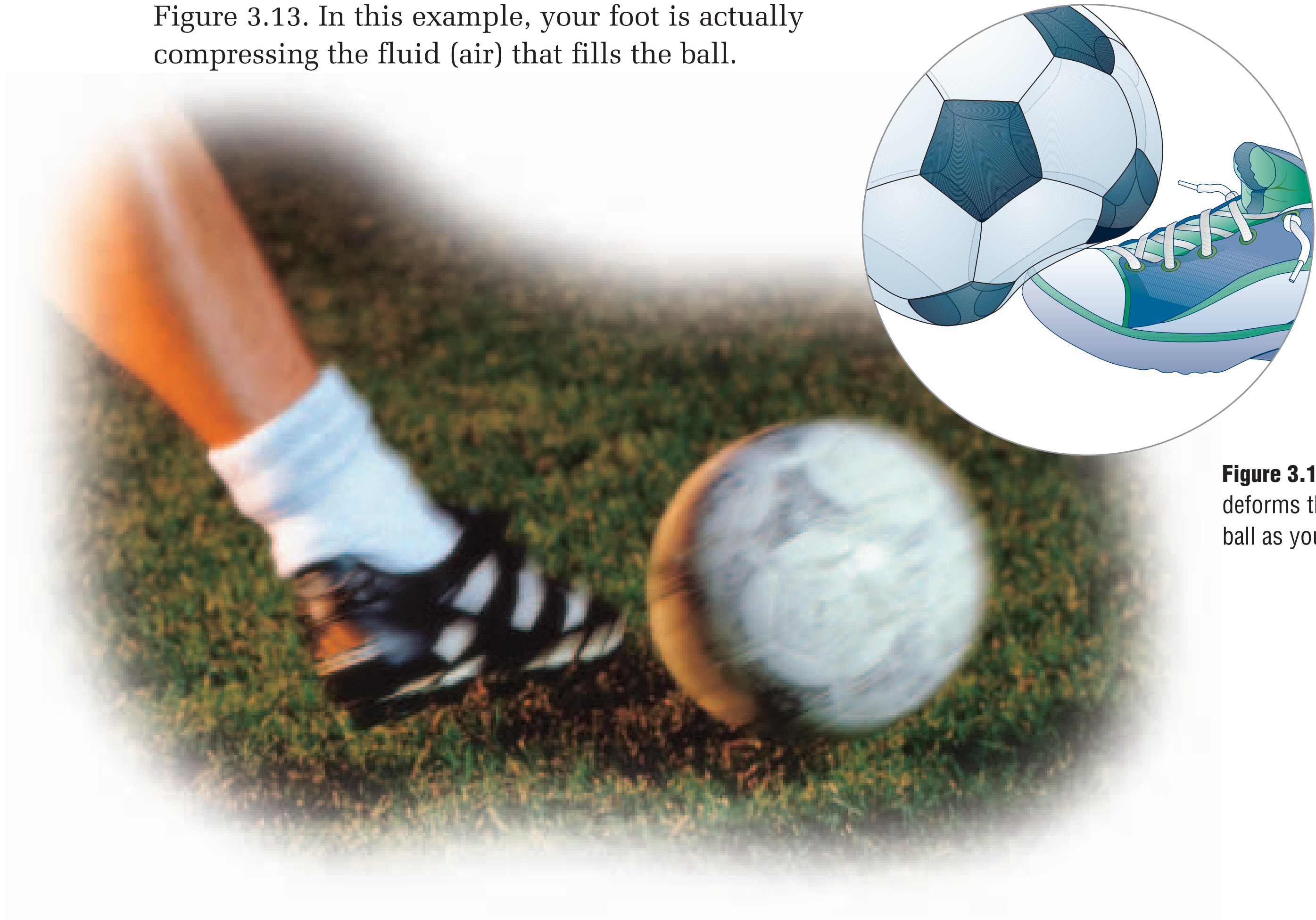

Figure 3.13 Your foot deforms the soccer ball as you kick it.

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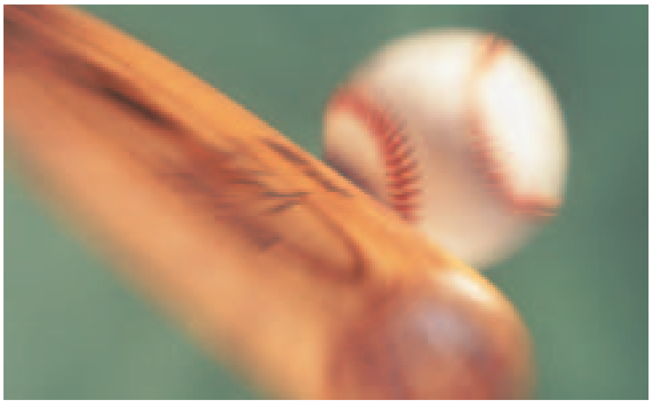
Compressing Solid Objects

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



The effect of a baseball bat on a baseball

Inquiry Activity

COMPRESSING FLUIDS

The Question

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

Procedure

Part 1 Compressing Air

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

Part 2 Compressing Water

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

Materials & Equipment

Part 1

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

Part 2

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

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

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

12 Remove all the masses.

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

14 Clean and return your equipment to the appropriate location.

Collecting Data

Part 1

15 Record your predictions in your notebook.

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

Part 2

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

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

Analyzing and Interpreting

18 How did your predictions compare with your results?

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

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

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

Forming Conclusions

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

Applying and Connecting

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

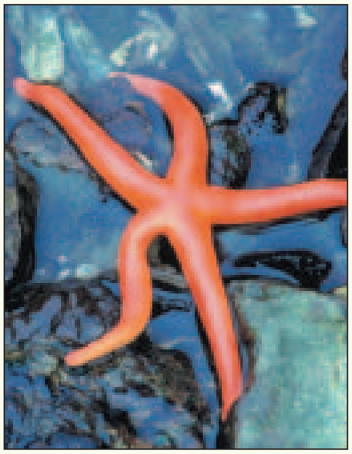


Figure 3.16 Starfish

reSEARCH

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

Differences in Compressibility between Gases and Liquids

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

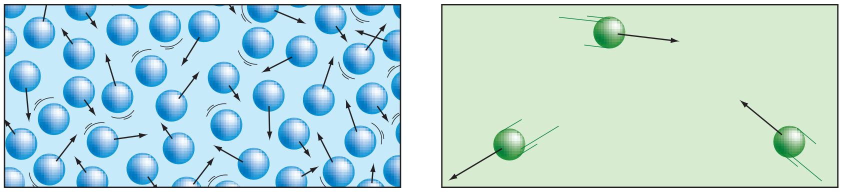


Figure 3.17 There is much more space between particles in a gas than there is between particles in a liquid.

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

Check and Reflect

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

3.5 Pressure in Fluids — Pascal's Law

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

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

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

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

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

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Examples of Pressure

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

Blaise Pascal Investigates

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

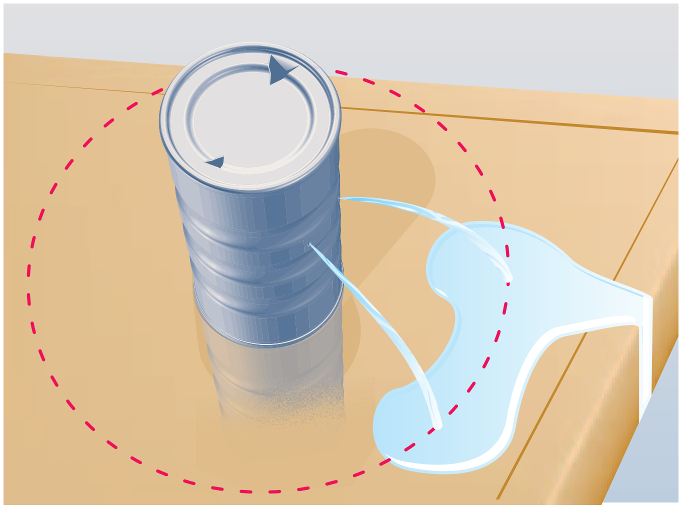

Figure 3.18 Why does the water flow out of the can in this way?

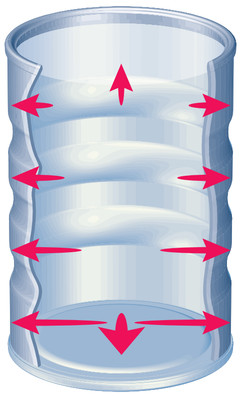

Figure 3.19 The water exerts pressure in all directions in the container.

Pressure and Depth

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

The Greater the Depth, the Greater the Pressure

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

Pascal's Law

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

Hydraulic Devices

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

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

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

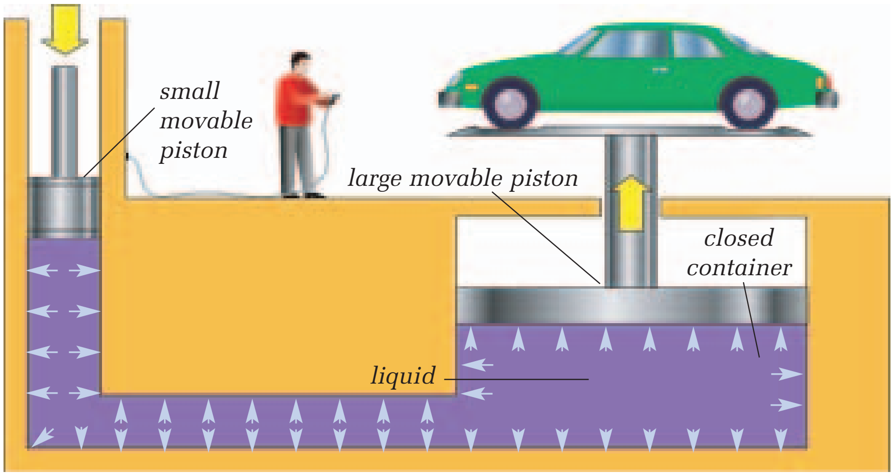

Figure 3.20 A car lift or hoist. The arrows in the liquid indicate the pressure transmitted throughout the system. Hoists are used in repair garages so that mechanics can work under cars more easily.

Pneumatic Devices

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

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

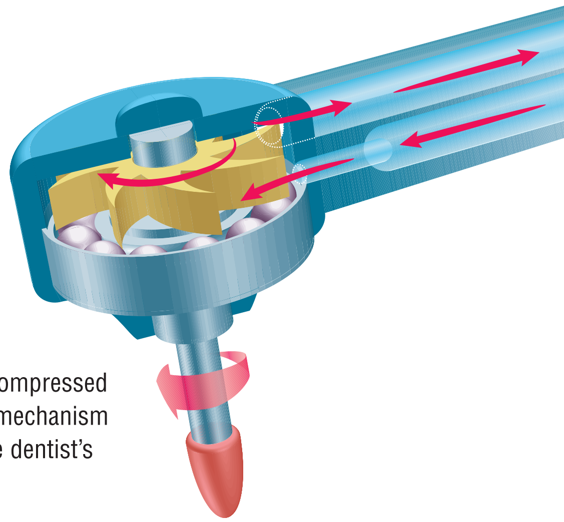

Figure 3.21 Compressed air drives the mechanism that makes the dentist's drill spin.

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Ultrahigh-Pressure Water Systems

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

Maintaining the Pressure

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

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

Check and Reflect

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

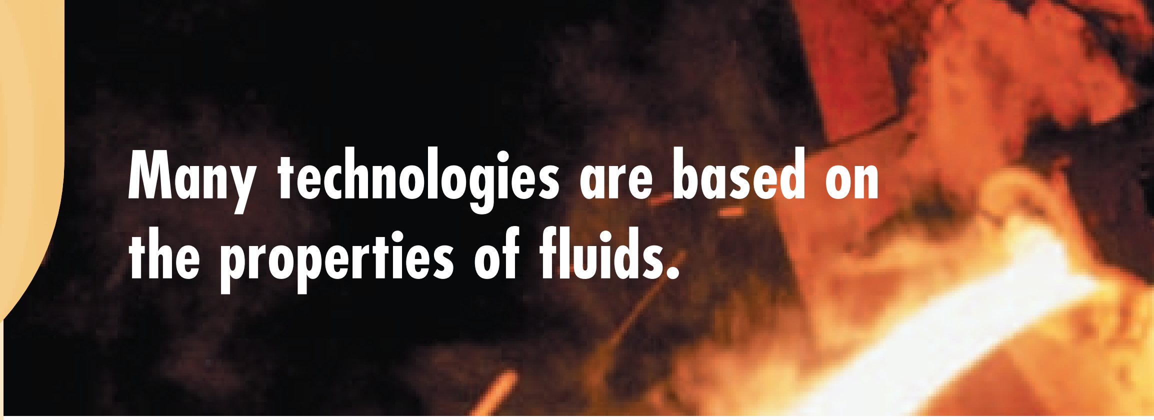
Assess Your Learning

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

Focus On SCIENCE AND TECHNOLOGY

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

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



4.0 Many technologies are based on the properties of fluids.

Key Concepts

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

- properties of fluids
- fluid technology applications

Learning Outcomes

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

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

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

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

4.1 Technologies Based on Solubility

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

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

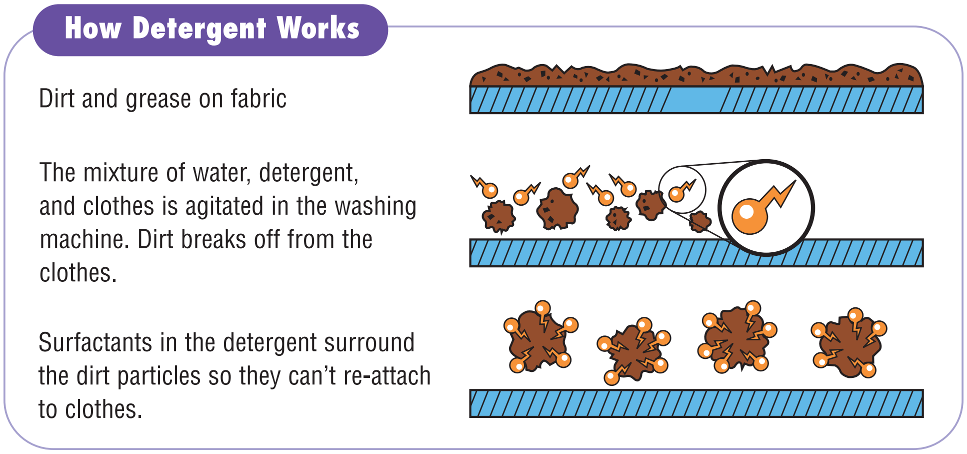


Figure 4.1 Detergents use surfactants to carry away dirt.

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

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Ingredients in a Typical Laundry Detergent

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

Inquiry Activity

Cleaning Solvents

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

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

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

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

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

Collecting Data
6 Make a chart of your observations.

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

8 Did the lipstick dissolve in each solvent? Explain.

9 Did the chocolate dissolve in each solvent? Explain.

10 Did the detergent help the water dissolve the stains?

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

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

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

Diving and Decompression

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

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

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

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

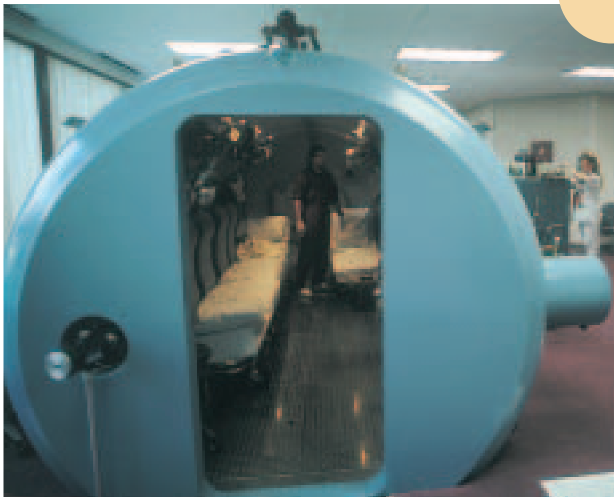

Figure 4.3 This person is in a hyperbaric chamber to cure a case of "the bends." *Hyperbaric* means high pressure.

Check and Reflect

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

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Dry Cleaning

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

4.2 Technologies Based on Flow Rates and Moving Fluids

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

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

Two Types of Pumps—Diaphragm and Archimedes Screw

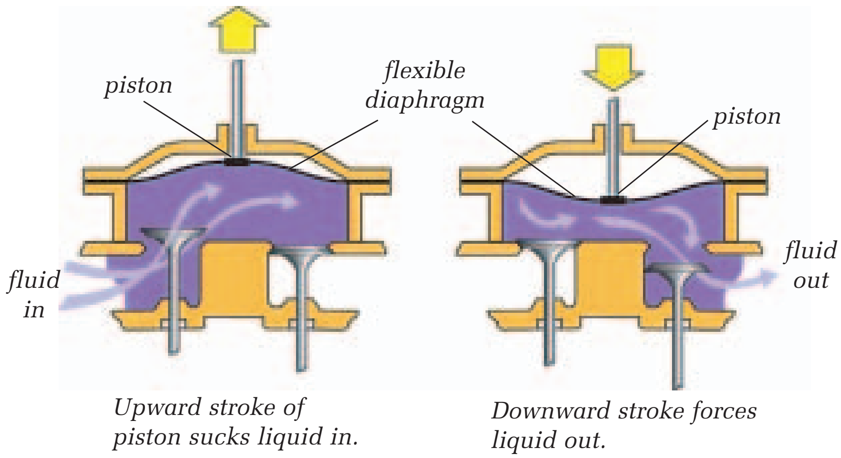

Figure 4.4 Diaphragm pumps are used for both liquids and gases, such as the air pumped into this aquarium.

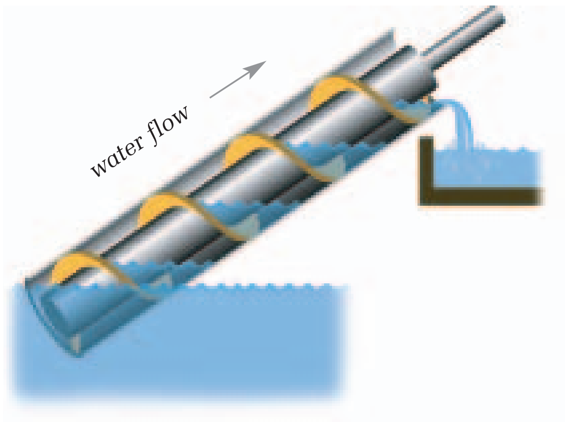

Figure 4.5 The Archimedes screw is a pump supposedly invented by Archimedes to remove water from the hold of a ship. Here it is used as a sand washer on a construction site.

The Bicycle Pump

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

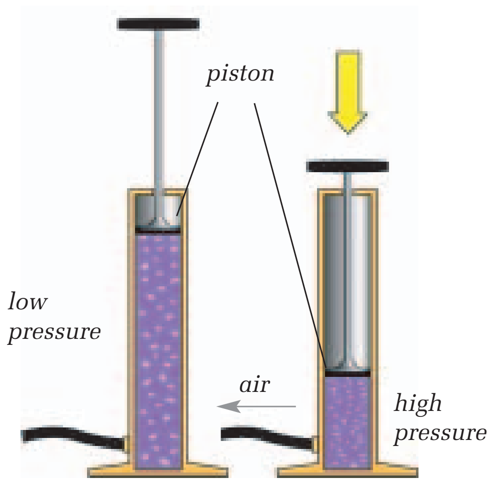

Figure 4.6 When force is applied to the air in the cylinder, the pressure increases.

Pipeline Pigs

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

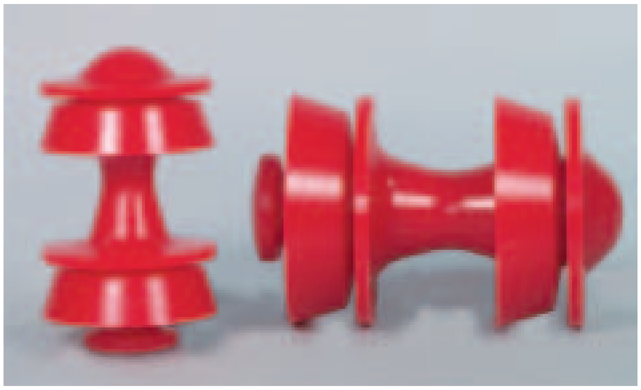

Figure 4.7 A pipeline "pig" relies on the flow of the fluid to move it through the pipeline.

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Oil Sands Production

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

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Artificial Hearts

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

Valves

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

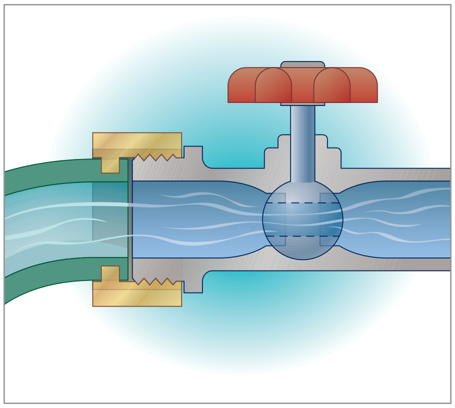

Figure 4.8 A ball valve works by turning. In one direction, it allows water to flow through. If you turn it in another direction, it stops the flow. This ball valve is in a hose.

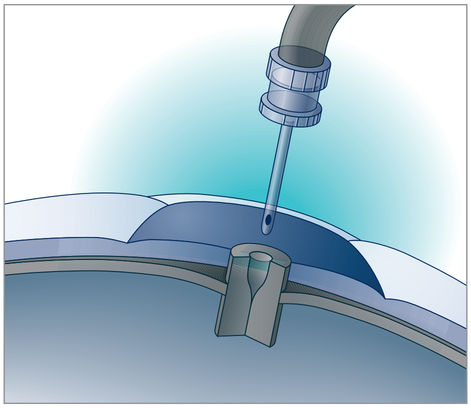

Figure 4.9 This type of valve allows you to inflate a ball, but also keeps air from leaking out. To open the valve, you insert a hollow pin. You inflate the ball by pumping air through the pin. You deflate the ball by allowing air to escape through the pin.

Check and Reflect

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

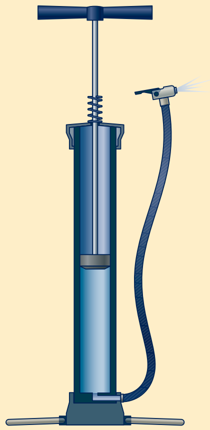

Figure 4.10 Question 2. A hand pump

4.3 Designing a Working Model of a Fluid-Using Device

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

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

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Changing Buoyancy Naturally

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

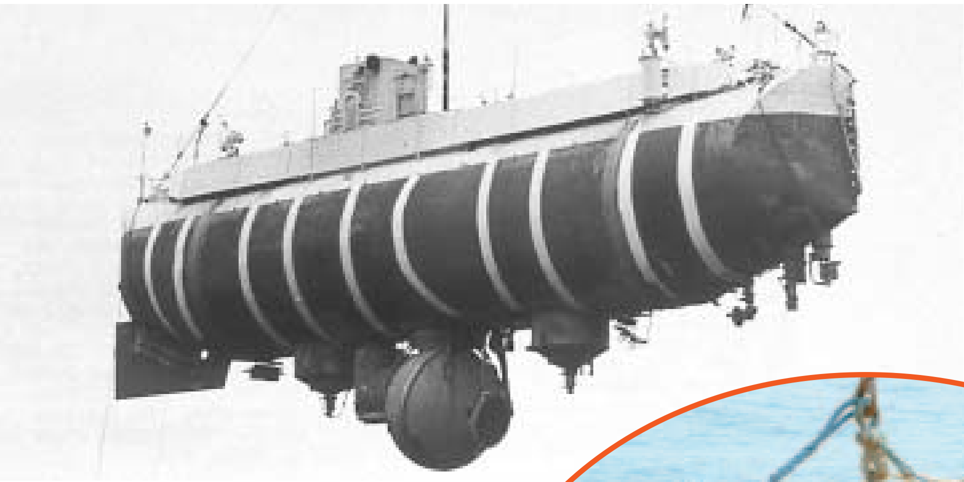


Figure 4.11 The bathyscaph *Trieste* made it to the bottom of the Marianas Trench in 1960. A bathyscaph consists of a large float with a metal sphere underneath. The sphere is where the people sit.

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

Problem Solving Activity

Diving Deeply

Recognize a Need

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

The Problem

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

Criteria for Success

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

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

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

Brainstorm Ideas

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

Build a Prototype

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

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

Test and Evaluate

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

Communicate

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

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

How a Submarine Works

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

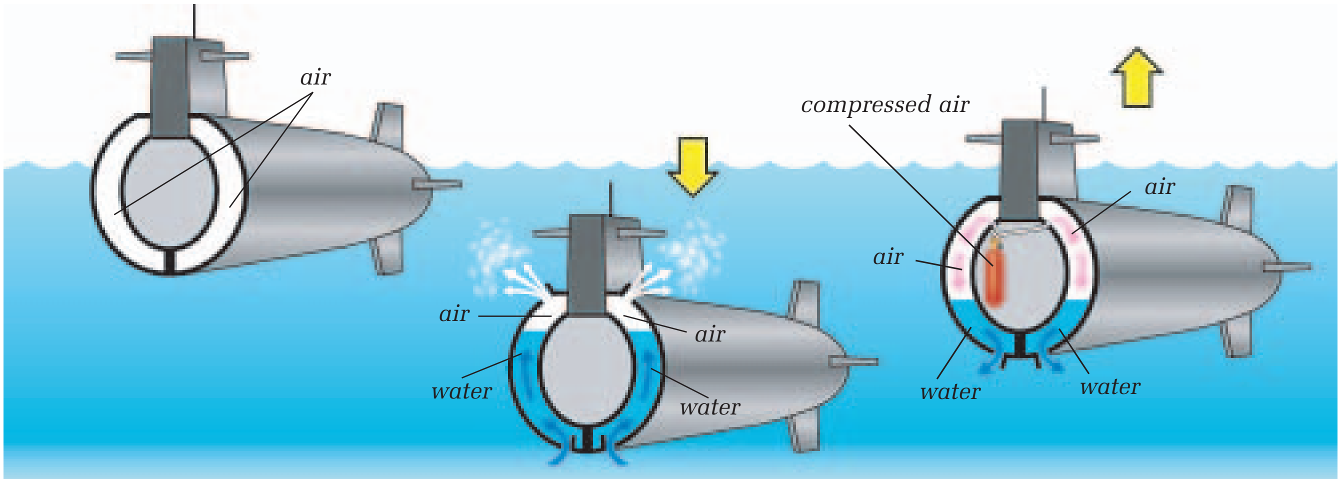


Figure 4.14a) On the Surface. When the submarine is on the surface, its ballast tanks are full of air. The average density of the submarine is less dense than the density of the water, and it floats.

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

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

Check and Reflect

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

Experiment ON YOUR OWN

Design and Build a Hydraulic or Pneumatic Elevator

Before You Start ...

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

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

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

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

The Question

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

Design and Conduct Your Experiment

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

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

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

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

Figure 4.15 Elisha Graves Otis and his "safety elevator"

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

Assess Your Learning

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

Focus On SCIENCE AND TECHNOLOGY

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

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

The Alberta Oil Sands Deposits

The Issue

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

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

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

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

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

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

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

Go Further

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

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

In Your Opinion

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

Unit Summary: Mix and Flow of Matter

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

PROJECT

CREATING DRINKIT

Getting Started

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

Your Goal

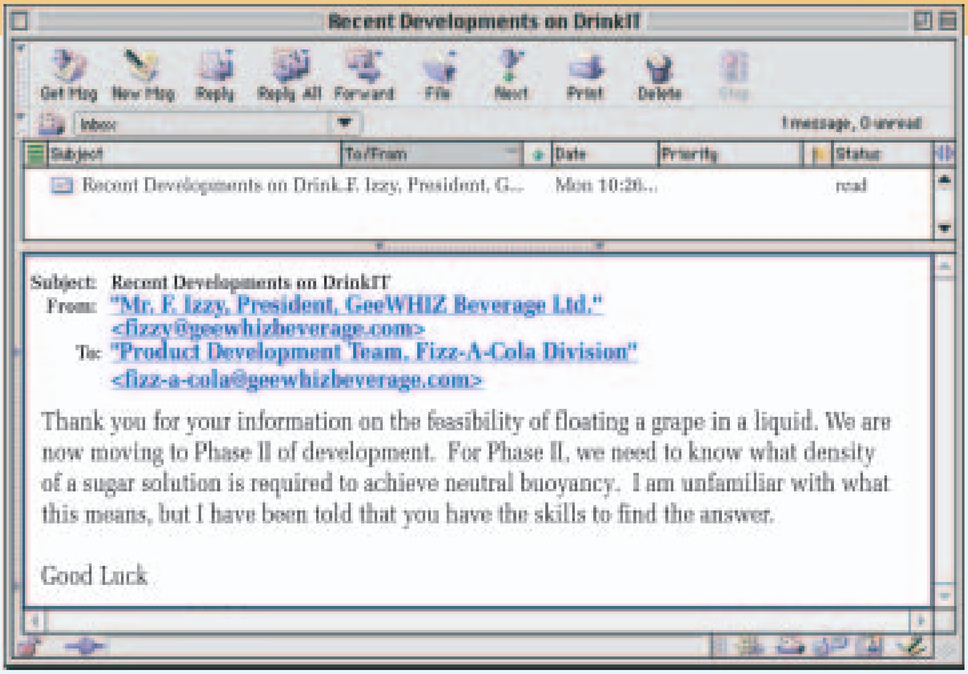
Your goal is to design and carry out a procedure that will allow you to determine the density of a sugar solution that can suspend a grape.

What You Need to Know

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

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

Caution! Remember not to taste anything in the lab.


Recent Developments on DrinkIT

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

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

Good Luck

Steps to Success

1 Work with your group to design a procedure for completing your assigned task. After you design your procedure, show it to your teacher for approval.

2 Collect the equipment you need and carry out your plan.

3 Make modifications to your plan as necessary. Write down any changes to your plan as you work through it.

4 Record the tests you made and your observations of the results.

5 Verify your results by making a fresh solution based on the results you recorded.

How Did It Go?

6 Describe the procedure you used when you were trying to determine the best sugar solution to use. Did you follow a specific procedure or did you just keep trying until you found the answer?

7 How did you determine the point where you had the appropriate solution concentration?

8 Could you have improved on your method of finding the appropriate solution concentration? Suggest changes you would make if you were to repeat this activity.

9 In any investigation, errors result. For example, after you determined the mass of sugar to add, some of the sugar may have spilled out before it was added to the beaker. What possible sources of error could have occurred in this activity? Why is it important to identify these sources of error when reporting your results?

Unit Review: Mix and Flow of Matter

Unit Vocabulary

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

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

Check Your Knowledge

1.0

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

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

2.0

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

3.0

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

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

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

UNIT REVIEW: MIX AND FLOW OF MATTER

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

4.0

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

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

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

Connect Your Understanding

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

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

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

22. You have two samples of the same liquid. One is at 50°C and one is at 30°C.
   a) What will happen if you pour the same amount of each liquid down a ramp? Which flow rate would be faster? Use the particle model to explain your answer.
   b) If you poured the same amount of this liquid at 70°C down the ramp, what would happen?

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

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

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

Practise Your Skills

26. Plan an experiment that would test the compressibility of three different fluids.
   a) What materials would you need?
   b) What procedure would you use?
   c) What variables would you need to control?

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

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

a) What is the density of a copper penny?

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

Self Assessment

Think back to the work you did during this unit.

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

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

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

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

Focus On Science and Technology

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

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

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

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

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

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