DISCOVERING SCIENCE 8 TEACHER'S RESOURCE

UNIT 3: FLUIDS

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McGraw-Hill Ryerson

UNIT 3: OVERVIEW

Fluids are all around us. They play an important role in the natural environment and in many of the technologies that we use every day. Understanding the properties of fluids will help students explain why some fluids flow faster than others, why some fluids float on top of others, and how the pressure of a fluid can help lift a truck! A unifying idea in this unit is the particle theory of matter. Using an understanding of the particle theory, students will investigate three important properties of fluids: viscosity (resistance to flow), density, and buoyancy. They will learn about the relationship among pressure, temperature, and volume in fluids that are gases and how an understanding of this relationship can be used to do work.

Chapter 7: Viscosity describes a fluid's resistance to flow.

A fluid is anything that flows. That means that gases and liquids are fluids, but solids are not normally considered fluids. Solids do, however, sometimes behave like fluids. You can pour sand from a pail or sugar from a spoon. Ice flows as glaciers.

Students begin their exploration of fluids by learning about the particle theory of matter. The particle theory states that:

- all matter is made up of very small particles
- all particles in a pure substance are the same
- there is space between the particles
- the particles are always moving
- the particles are attracted to one another

Students will learn that the differences among solids, liquids, and gases are due to differences in the particles' behaviour. The particles in a solid are very close together and have a very strong attraction to one another. The particles in a gas are very far apart, and have a weak attraction to one another. This allows gases to expand to fill a space, and to flow. When a substance is heated, the particles gain energy, and begin to move more quickly. They bump into one another with more force, and take up more space. If enough heat is added, a change of state occurs—from solid to liquid, or from liquid to gas.

As a fluid flows, particles slide by one another. The rate at which they can slide by is determined, in part, by their shape, their size, and their temperature. Students will test the flow rates (related to the viscosities) of a variety of common fluids. As students use the particle theory of matter to explain why fluids can flow, they will see why under some circumstances some solids, such as those in very small particles, also flow.

Students will learn about the importance of viscosity in some common household products and read about current research into "superfluids"—fluids with no viscosity at all!

Chapter 8: Density describes the amount of mass in a given volume of a substance.

The concept of density, or the amount of mass in a given volume of a substance, helps explain a lot of fluid behaviour. A substance with particles that are tightly packed together will have a greater density than a substance with loosely packed particles. A gas is less dense than a liquid and a liquid is less dense than a solid. But not all gases, liquids, or solids have the same density. Students will measure the mass and the volume of various substances, and use their measurements to calculate the density of each substance. In practice problems, they will use the relationship $\text{density} = \frac{\text{mass}}{\text{volume}}$ to calculate each of density, mass, and volume when the other two variables are known. Using the particle theory, they will explain what causes the density of a substance to change when temperature changes, and read about examples of changing densities in everyday life.

Chapter 9: Forces influence the motion and properties of fluids.

Balanced forces (equal and opposite forces) do not cause a change in the motion of an object, but unbalanced forces do. Many modern technologies make use of forces on fluids.

Gravity and buoyancy are both forces. A boat on the ocean will move up or down until the buoyant force acting on the boat is equal to the gravitational force acting on it. The force of gravity is essentially the same anywhere on Earth. The buoyant force depends on the mass of water displaced by the boat. Since salt water has a greater density than fresh water, it has a greater buoyant force, and boats (and people) will float higher in salt water than they will in fresh water. Students experiment with the factors that affect buoyancy by making a Cartesian diver and altering its average density to see how it behaves.

An understanding of the relationship between force and pressure has allowed the development of many technologies. Students learn that pressure is force per unit area, and that equal forces, applied to different areas, result in different pressures. Pascal's law states that a force applied to a fluid results in the same pressure everywhere in that fluid. This law, plus the principle of hydraulic multiplication, allows a small motor to exert a force on one part of a hydraulic lift that results in a larger force (but the same pressure) on another part, lifting an entire car or truck

Gases are fluids with special properties, because they are compressible. As the temperature of a gas rises, either the volume or the pressure of the gas also rises (depending on whether the gas is in an enclosed rigid container). As with other properties of fluids, this result can be explained using the particle theory. It has led to technologies such as compressed gas canisters and aerosol cans. Students use a variety of materials, including balloons and plastic bottles, to experiment with the relationship among temperature, pressure, and volume in gases.

MULTIPLE INTELLIGENCES CORRELATION FOR UNIT 3 ACTIVITIES AND INVESTIGATIONS

The table below identifies possible multiple intelligences that could be incorporated into activities and investigations in this unit. For more information about differentiated instruction and multiple intelligences, see the Introduction and Implementation section in this Teacher's Resource.

MULTIPLE INTELLIGENCES:	VL	VS	BK	MR	LM	N	E	IA	IE
UNIT 3: FLUIDS									
Find Out Activity: Fluid or Non-fluid		■	■						
Chapter 7: Viscosity describes a fluid's resistance to flow.									
Find Out Activity 7-1A: Magic Mud		■	■						
Find Out Activity 7-1B: Can Solids Flow, Too?		■	■						
Find Out Activity 7-2A: The Value of Viscosity	■		■		■				■
Core Lab Conduct an Investigation 7-2B: The Flow Rate of Liquids		■	■		■				■
Find Out Activity 7-3A: Cool It!		■	■		■				■
Think About It Activity 7-3B: Flowing Fluid Floods City		■							
Conduct an Investigation 7-3C: Viscosity Plunge			■		■				
Find Out Activity 7-3D: Cool Contraction		■	■						
Conduct an Investigation 7-3E: The Effect of Concentration on Viscosity		■	■		■				
Chapter 8: Density describes the amount of mass in a given volume of a substance.									
Find Out Activity 8-1A: Differing Densities	■	■	■						
Find Out Activity 8-2A: What is the Density of a Pencil?	■		■						
Core Lab Conduct an Investigation 8-2B: Determining Density	■		■		■			■	■
Think About It Activity 8-2C: Comparing Densities		■			■				
Think About It Activity 8-3A: Lava Lamps		■	■						
Find Out Activity 8-3B: Layers of Water	■		■		■				
Chapter 9: Forces influence the motion and properties of fluids.									
Find Out Activity 9-1A: The Amazing Floating Egg	■	■	■						
Find Out Activity 9-1B: Cartesian Diver	■	■	■						
Conduct an Investigation 9-1C: Build a Density Tower	■	■							
Think About It 9-1D Activity: Measuring Buoyancy					■				
Think About It Activity 9-2A: Pop 'em Quick!	■	■	■		■				
Find Out Activity 9-2B: Simple Hydraulics	■	■	■		■				
Find Out Activity 9-2C: Exploring Pneumatics	■	■	■		■				
Conduct an Investigation 9-2D: Bottle Squeeze	■	■	■						
Find Out Activity 9-3A: Hot and Cold Gases	■	■	■						

Multiple Intelligence codes:
VL = Verbal-Linguistic Intelligence; VS = Visual-Spatial Intelligence; BK = Body-Kinesthetic Intelligence; MR = Musical-Rhythmic Intelligence; LM = Logical-Mathematical Intelligence; N = Naturalist Intelligence; E = Existential Intelligence; IA = Intrapersonal Intelligence; IE = Interpersonal Intelligence

MULTIPLE INTELLIGENCES:	VL	VS	BK	MR	LM	N	E	IA	IE
Find Out Activity 9-3B: Lifting with Air	■		■						
Think About It Activity 9-3C: The Pressure is Rising		■			■				
Conduct an Investigation 9-3D: Putting on the Pressure	■	■			■				■
Unit 3 Project: Emergency Hovercraft	■	■	■		■				■

Multiple Intelligence codes:
VL = Verbal-Linguistic Intelligence; VS = Visual-Spatial Intelligence; BK = Body-Kinesthetic Intelligence; MR = Musical-Rhythmic Intelligence; LM = Logical-Mathematical Intelligence; N = Naturalist Intelligence; E = Existential Intelligence; IA = Intrapersonal Intelligence; IE = Interpersonal Intelligence

Planning Chart for Activities and Investigations for Unit 3: Fluids

ACTIVITY/ INVESTIGATION	ADVANCE PREPARATION	APPARATUS/MATERIALS	TIME REQUIRED
Unit 3: Fluids			
Find Out Activity: Fluid or Non-fluid	1 week before: – Begin collecting magazines with many illustrations. Look for magazines that cover nature and environment, consumer products, and science. 1 day before: – Make copies of BLM 3-6, Fluids or Non-fluids? (optional).	– large sheet of paper For each group: – 2–3 magazines or newspapers – 2–3 pairs of scissors – masking tape	• 20 min
Chapter 7: Viscosity describes a fluid's resistance to flow.			
Find Out Activity 7-1A: Magic Mud	1 day before: – Gather the materials: cornstarch, food colouring, sturdy spoons, mugs for mixing. Review definitions of solid, liquid, fluid, and viscosity	For each group: – 75 mL cornstarch – 45 mL water – food colouring – mug – sturdy spoon or stir stick	• 30–40 min
Find Out Activity 7-1B: Can Solids Flow, Too?	1 day before: – Gather sand, salt, sugar, rice, or another granular substance.	For each group: – 250 mL of granular solid – 250 mL of water – plastic cups, 250 mL – unbreakable plates, or metal pie plates	• 15 min
Find Out Activity 7-2A: The Value of Viscosity	1 week before: – Ask students to bring in half-empty bottles of hair conditioner, shampoo, hand lotion, liquid detergent, bubble bath, etc. – Ask students to also bring a recent price for the product. 1 day before: – Make copies of BLM 3-10, The Value of Viscosity (optional).	For each group: – 3 different examples of the same product – 3 small paper ketchup tubs	• 20 min
Core Lab Conduct an Investigation 7-2B: The Flow Rate of Liquids	1 week before: – Gather sufficient materials for student ramps: sheets of metal, plastic, or glass. – Gather sufficient volumes of liquids with a variety of viscosities. – Keep all fluids in the same location, overnight, to be certain that all are at the same temperature. 1 day before: – Make copies of BLM 3-11, the Flow Rate of Liquids (optional).	For each group: – 2 samples of liquids, 15 mL each (not water) – 1 plastic measuring spoon – 1 stopwatch – 1 ruler – 1 waterproof marker In addition, students will need sufficient amounts of: – paper towels, soap, water to clean the workstation – rubber gloves	• 40 min • In order to complete the activity in this time, students must come fully prepared.

ACTIVITY/ INVESTIGATION	ADVANCE PREPARATION	APPARATUS/MATERIALS	TIME REQUIRED
Find Out Activity 7-3A: Cool It!	Start your preparation at the same time as Activity 7-2B. – Gather sufficient materials for student ramps: sheets of metal, plastic, or glass. – Gather sufficient volumes of liquids with a variety of viscosities. – Chill the fluids within a cold water bath to a consistent temperature near 0°C. 1 day before: – Make copies of BLM 3-11, The Flow Rate of Liquids (optional).	For each group: – 2 samples of liquids, 15 mL each plus water – 1 plastic measuring spoon – 1 stopwatch – 1 ruler – 1 waterproof marker In addition, students will need sufficient amounts of: – paper towels, soap, water to clean the workstation – rubber gloves	• 40 min if done as a stand-alone lab, 20 min as an extension of Activity 7-2B • In order to complete the activity in this time frame, students must come fully pre-pared, with data tables drawn up and hypotheses written.
Think About It Activity 7-3B: Flowing Fluid Floods City	Immediately – All resources are included in the student textbook.	– student textbook, p. 291	• 25 min
Conduct an Investigation 7-3C: Viscosity Plunge	1 week before: – Be sure equipment is available. Obtain all necessary equipment. 1 day before: – Make copies of BLM 3-15, Viscosity Plunge (optional). 1 hour before: – Prepare beakers of corn syrup. Prepare the lab stations.	For each group: – lab stand, thermometer clamp, and iron ring – hot plate – thermometer, stopwatch, ruler – stirring rod, tongs – 250 mL beaker, corn syrup – 15–20 small metal balls	• 40 min • In order to complete the activity in this time, stu-dents MUST come fully prepared, with their data table drawn, a hypothesis written out, and the pro-cedure read.
Find Out Activity 7-3D: Cool Contraction	1 day before: – Gather the materials and apparatus. – Make copies of BLM 3-16, Cool Contraction (optional).	For each group: – Erlenmeyer flask – small round balloon – large bowl – ice – protective mitt – cold water – very hot water	• 40 min
Conduct an Investigation 7-3E: The Effect of Concentration on Viscosity	1 week before: – Gather sufficient materials for student ramps: sheets of metal, plastic, or glass. – Consider making up solutions ahead of time. 100 g sugar can dissolve in 100 mL of hot water, and then can be cooled. – Keep all fluids in the same location, overnight, to be certain that all are at the same temperature. 1 day before: – Make copies of BLM 3-17, The Effect of Concentration on Viscosity (optional).	For each group: – 150 g of sugar – 1 plastic measuring spoon – 1 stopwatch – 1 ruler – 1 waterproof marker In addition, students will need sufficient amounts of the following: – paper towels, soap, water to clean the workstation – rubber gloves	• 40 min • In order to complete the activity in this time, stu-dents MUST come fully prepared, with data tables drawn, a hypothesis written, and the procedure read.

ACTIVITY/ INVESTIGATION	ADVANCE PREPARATION	APPARATUS/MATERIALS	TIME REQUIRED
Chapter 8: Density describes the amount of mass in a given volume of a substance.			
Find Out Activity 8-1A: Differing Densities	2 weeks before: – Ask students, colleagues, and photo shop employees for empty film canisters. 1 week before: – Gather granular and liquid materials for the containers. (See suggestions below.) Prepare your master list of container numbers and contents. 1 day before: – Make copies of BLM 3-20, Differing Densities (optional).	For each group: – one set of film canisters – granular and liquid materials to put in the containers	• 10 min if students use the table on BLM 3-20, Differing Densities; 20 min if students make their own table as found in the student textbook
Find Out Activity 8-2A: What is the Density of a Pencil?	1 day before: – Gather the balances and graduated cylinders.	For each group: – 1 balance – 1 graduated cylinder – 1 long pencil	• 20 min
Core Lab Conduct an Investigation 8-2B: Determining Density	2 weeks before: – Obtain 4 L each of water, oil, glycerol, molasses, and sand. 1 day before: – Remind students to bring five different-coloured markers to the next class. – Make copies of BLM 3-25, Determining Density (optional).	For each group: – balance – 2 large graduated beakers – 500 mL of fluid or sand	This exercise is lengthy. You may wish to schedule it over two days. • 75 min for Part 1 • 25 minutes for Part 2
Think About It Activity 8-2C: Comparing Densities	1 day before: – Make copies of BLM 3-26, Comparing Densities (optional).	None	• 20 min
Think About It Activity 8-3A: Lava Lamps	1 week before: – Begin to search for at least one lava lamp in working order. Ask students and colleagues. Purchase one if necessary. 1 hour before: – Turn on the lava lamp, so that the wax can melt and circulate.	– Distribute lava lamps around the room (if you have more than one).	• 15 min
Find Out Activity 8-3B: Layers of Water	1 day before: – Gather the beakers, stirring rods, thermal mitts, spoons, and food colouring. Ensure you have a source of hot and cold water. 1 hour before: – Prepare the source of hot and cold water.	For each group: – two 250 mL beakers – 1 stirring rod, 1 spoon – food colouring – 1 pair of thermal mitts	• 20 min
Chapter 9: Forces influence the motion and properties of fluids.			
Find Out Activity 9-1A: The Amazing Floating Egg	1 day before: – Gather materials.	– 1 fresh egg per group – 75 g salt per group – clear drinking glasses, may be plastic – sugar (optional)	• 30 min
Find Out Activity 9-1B: Cartesian Diver	3 weeks before: – Start collecting 1 L plastic pop bottles with caps; ask students and colleagues to bring them as well. 1 week before: – Obtain medicine droppers for groups.	For each group: – one 1 L plastic transparent pop bottle – 1 medicine dropper – water	• 20 min

ACTIVITY/ INVESTIGATION	ADVANCE PREPARATION	APPARATUS/MATERIALS	TIME REQUIRED
Conduct an Investigation 9-1C: Build a Density Tower	1 week before: – Gather apparatus and materials. 2 days before: – Prepare kits of apparatus and materials. 1 day before: – Mix water and food colouring in sealable containers for transport. – Make copies of BLM 3-34, Build a Density Tower (optional).	– Tall, clear plastic jars with lids, or other transparent containers. Soft drink bottles with caps can be used if the solids are small enough to fit into the mouth of the bottle. – cork, wood chips, or toothpicks – paper clips – other small objects (for Extend Your Skills) – rubber gloves – water with food colouring – vegetable oil	• 60 min
Think About It 9-1D: Measuring Buoyancy	None	None	• 30 min
Think About It Activity 9-2A: Pop 'em Quick!	3 days before: – Gather balloons and straight pins. 1 day before: – Ask students about latex allergies.	For each group: – 2 small balloons – 1 straight pin	• 15 min
Find Out Activity 9-2B: Simple Hydraulics	2 weeks before: – Obtain syringes, and plastic tubing to fit.	For each group: – 2 modified syringes (syringes with no needle) – 15 cm plastic tube	• 20 min
Find Out Activity 9-2C: Exploring Pneumatics	2 weeks before: – Obtain syringes, plastic tubing to fit.	For each group: – 2 modified syringes (various sizes) – 15 cm plastic tube	• 30 min
Conduct an Investigation 9-2D: Bottle Squeeze	2 weeks before: – Collect 500 mL pop bottles, with twist-off caps. 1 week before: – Obtain a quantity of clean, dry sand.	For each group: – 500 mL beaker, or measuring cup – 3 empty plastic pop bottles with twist-off caps, 500 mL each – water – sand	• 40–50 min
Find Out Activity 9-3A: Hot and Cold Gases	2 weeks before: – Collect 500 mL pop bottles, with twist-off caps. 1 week before: – Obtain sufficient balloons and elastic bands. 1 hour before: – Prepare buckets of ice water and hot water.	For each group: – one empty 500 mL plastic pop bottle – safety goggles – 1 balloon – 1 elastic band For the class: – large bowls or buckets – ice water – hot water	• 20 min
Find Out Activity 9-3B: Lifting with Air	1 week before: – Gather straws, balloons, tape, chewing gum, and elastic bands.	For each person: – 1 balloon or large plastic food bag – 1 straw – 1 piece of chewing gum – tape, string, elastic bands – textbooks	• 20–30 min
Think About It Activity 9-3C: The Pressure is Rising	1 day before: – Advise students to bring graph paper, and obtain some for students who may not bring their own. – Make copies of BLM 3-43, The Pressure is Rising (optional).	– coloured pencils, pens, markers – ruler	• 20 min
Conduct an Investigation 9-3D: Putting on the Pressure	2 weeks before: – Gather the specialized lab equipment, including the syringes, lab stands, test tube clamps, and masses. 1 day before: – Make copies of BLM 3-44, Putting on the Pressure (optional).	For each group: – plastic syringe with covered tip – lab stand – clamps – set of masses up to 2 kg – 100 mL beaker – water – vegetable oil	• 40–60 min

ACTIVITY/ INVESTIGATION	ADVANCE PREPARATION	APPARATUS/MATERIALS	TIME REQUIRED
Project: Emergency Hovercraft	2–3 days before: – Gather materials. You might ask students to bring cardboard and plastic soft drink bottles with screw caps from home.	For each pair or group: – plastic soft drink bottle with screw cap – square piece of cardboard – pencil – scissors – balloon For the class: – electric drill – hot glue gun or tape	• 20–30 min to design the hovercraft • 30–60 min to assemble the hovercraft • additional time for presentations and reporting

TALKS AND TOURS

Speaker and field trip recommendations for Unit 3:

- If there is a glassblower in your area, consider arranging a trip to his or her studio, or inviting the artist to talk to your class about the properties of glass that make glassblowing possible.
- Invite a SCUBA diver to show students some of the equipment that enables humans to dive deep underwater, and to talk about some of the preparations that ensure a safe dive, especially those related to fluids, pressure, and buoyancy.
- A trip to a local automobile repair garage can provide a concrete illustration of hydraulic multiplication at work. A diagram of a hydraulic lift appears on page 358, but seeing the real thing in action can emphasize the dramatic effect of applying a small force to a small area, and having it multiplied over a larger area to lift an entire car.

UNIT 3 BLACKLINE MASTERS

CONTENT-RELATED BLACKLINE MASTERS	ASSESSMENT-RELATED BLACKLINE MASTERS
Unit BLM 3-1, Unit 3 Summary BLM 3-2, Unit 3 Key Terms BLM 3-47, Unit 3 Concept Map BLM 3-48, Unit 3 Review BLM 3-49, Unit 3 BLM Answers	Assessment Checklist 6, Developing Models Process Skills Rubric 1, Developing Models Process Skills Rubric 4, Problem Solving Assessment Rubric 3, Co-operative Group Work Assessment Rubric 11, Communication Assessment Rubric 12, Using Tools, Equipment, and Materials
Chapter 7 BLM 3-3, Chapter 7 Key Terms BLM 3-6, Fluids or Non-fluids? BLM 3-7, The Particle Theory of Matter BLM 3-8, Identifying Changes of State BLM 3-9, Magical Morphing BLM 3-10, The Value of Viscosity BLM 3-11, The Flow Rate of Liquids BLM 3-12, Viscosity and the Real World BLM 3-13, Controlling Viscosity BLM 3-14, Viscosity in Action BLM 3-15, Viscosity Plunge BLM 3-16, Cool Contraction BLM 3-17, The Effect of Concentration on Viscosity BLM 3-18, Chapter 7 Review BLM 3-19, Chapter 7 Concept Map	Assessment Checklist 1, Making Observations and Inferences Assessment Checklist 2, Asking Questions Assessment Checklist 3, Designing an Experiment Assessment Checklist 4, Laboratory Report Assessment Checklist 6, Developing Models Assessment Checklist 13, Concept Map Assessment Checklist 14, Events Chain or Flowchart Assessment Checklist 16, Science Portfolio Assessment Checklist 17, Science Math Connect Assessment Checklist 18, Data Table Assessment Checklist 19, Graph from Data Assessment Checklist 20, Assessment Record Form Assessment Checklist 21, Project Self-Assessment Assessment Checklist 22, Project Group Assessment Assessment Checklist 23, Learning Skills Assessment Checklist 24, K-W-L Assessment Checklist Assessment Checklist 25, Safety Checklist Process Skills Rubric 1, Developing Models Process Skills Rubric 2, Hypothesizing Process Skills Rubric 3, Controlling Variables Process Skills Rubric 5, Fair Testing Process Skills Rubric 6, Designing Experiments Process Skills Rubric 7, Predicting Process Skills Rubric 8, Interpreting Data Process Skills Rubric 9, Questioning Process Skills Rubric 10, Measuring and Reporting Assessment Rubric 1, Concept Assessment Rubric 4, Scientific Drawing Assessment Rubric 5, Conduct an Investigation Assessment Rubric 6, Design Your Own Investigation Assessment Rubric 11, Communication Assessment Rubric 12, Using Tools, Equipment, and Materials

CONTENT-RELATED BLACKLINE MASTERS	ASSESSMENT-RELATED BLACKLINE MASTERS
Chapter 8 BLM 3-4, Chapter 8 Key Terms BLM 3-20, Differing Densities BLM 3-21, Calculating Density Practice Problems BLM 3-22, Working with Density Measurements BLM 3-23, Densities Calculations BLM 3-24, What is the Density of a Tennis Ball? BLM 3-25, Determining Density BLM 3-26, Comparing Densities BLM 3-27, Bone Density BLM 3-28, Chapter 8 Review	Assessment Checklist 1, Making Observations and Inferences Assessment Checklist 2, Asking Questions Assessment Checklist 4, Laboratory Report Assessment Checklist 6, Developing Models Assessment Checklist 7, Scientific Drawing Assessment Checklist 9, Oral Presentation Assessment Checklist 13, Concept Map Assessment Checklist 16, Science Portfolio Assessment Checklist 17, Science Math Connect Assessment Checklist 18, Data Table Assessment Checklist 19, Graph from Data Assessment Checklist 20, Assessment Record Form Assessment Checklist 21, Project Self-Assessment Assessment Checklist 22, Project Group Assessment Assessment Checklist 23, Learning Skills Assessment Checklist 24, K-W-L Assessment Checklist Assessment Checklist 25, Safety Checklist Process Skills Rubric 1, Developing Models Process Skills Rubric 2, Hypothesizing Process Skills Rubric 3, Controlling Variables Process Skills Rubric 4, Problem Solving Process Skills Rubric 5, Fair Testing Process Skills Rubric 6, Designing Experiments Process Skills Rubric 7, Predicting Process Skills Rubric 8, Interpreting Data Process Skills Rubric 9, Questioning Process Skills Rubric 10, Measuring and Reporting Assessment Rubric 1, Concept Assessment Rubric 2, Science Notebook Assessment Rubric 3, Co-operative Group Work Assessment Rubric 4, Scientific Drawing Assessment Rubric 5, Conduct an Investigation Assessment Rubric 10, Presentation Assessment Rubric 11, Communication Assessment Rubric 12, Using Tools, Equipment, and Materials
Chapter 9 BLM 3-5, Chapter 9 Key Terms BLM 3-29, Buoyancy Diagram BLM 3-30, Swim Bladder and Submarine BLM 3-31, Mass vs. Weight Calculations BLM 3-32, Identifying Buoyancy BLM 3-33, Zebra Mussels BLM 3-34, Build a Density Tower BLM 3-35, Calculating Pressure BLM 3-36, Pressure Problems BLM 3-37, How the Heart Works BLM 3-38, Safety with Fluids BLM 3-39, The Sphygmomanometer BLM 3-40, Particles in Motion Skit BLM 3-41, Poetic Pressure BLM 3-42, Wacky Straw Design BLM 3-43, The Pressure is Rising BLM 3-44, Putting on the Pressure BLM 3-45, Working Underwater Poster BLM 3-46, Chapter 9 Review	Assessment Checklist 1, Making Observations and Inferences Assessment Checklist 3, Designing an Experiment Assessment Checklist 4, Laboratory Report Assessment Checklist 6, Developing Models Assessment Checklist 7, Scientific Drawing Assessment Checklist 13, Concept Map Assessment Checklist 18, Data Table Assessment Checklist 19, Graph from Data Assessment Checklist 20, Assessment Record Form Assessment Checklist 21, Project Self-Assessment Assessment Checklist 23, Learning Skills Assessment Checklist 24, K-W-L Assessment Checklist Assessment Checklist 25, Safety Checklist Process Skills Rubric 2, Hypothesizing Process Skills Rubric 3, Controlling Variables Process Skills Rubric 5, Fair Testing Process Skills Rubric 6, Designing Experiments Process Skills Rubric 7, Predicting Process Skills Rubric 8, Interpreting Data Process Skills Rubric 9, Questioning Process Skills Rubric 10, Measuring and Reporting Assessment Rubric 1, Concept Assessment Rubric 2, Science Notebook Assessment Rubric 4, Scientific Drawing Assessment Rubric 5, Conduct an Investigation Assessment Rubric 6, Design Your Own Investigation Assessment Rubric 12, Using Tools, Equipment, and Materials

Teaching Notes
for
Pages 262 to 383 of the Student Textbook

UNIT 3 OPENER, pp. 262–263

USING THE UNIT OPENER

A good starting point of discussion for this unit may be to ask students, "What fluids are you breathing right now?" Many students may answer that they are not breathing any fluids, because many of them will equate the word "fluid" to "liquid." This scenario is a good opportunity to rectify that misconception, and also to discuss how substances can change state.

Students understand that they are breathing oxygen, but they might not recognize the oxygen in the photograph. At first, this image is difficult to understand. What is happening here? Ask students some questions abut the features of the photograph. "What objects can you identify?" They can probably recognize the test tube and the clamp. The black and silver cones on either side of the diagram will be more difficult. They are actually very strong magnets. "What fluids can you see?" Both the liquid being poured, and the foggy vapours around it are fluids, that is, they flow. "What is the liquid?" Most students will propose water or a similar common liquid. When you point out (or when students read in the caption) that the liquid is actually liquid oxygen, students may begin to generate many questions of their own. Here are a few discussion points that might arise in your classroom. If students do not ask these questions, perhaps you could.

- "Is it hot or cold?" The appearance of the clouds between the test tube and the magnets could indicate something hot like steam, or something very cold.
- "What evidence of temperature can you see?" The frost on the test tube is evidence that the test tube is very cold. A clamp can be seen grasping the test tube containing the liquid oxygen.
- "What would be the consequences of holding the test tube of liquid oxygen with your bare hands?" Besides instantly freezing and damaging many layers of skin, grasping the test tube would likely cause rapid heating of the liquid oxygen, causing it to boil violently, perhaps spraying dangerously out of the test tube.
- "Where do you get liquid oxygen?" The air we breathe in the atmosphere is mostly oxygen and nitrogen. If air is repeatedly compressed and cooled, it can be changed into the liquid state: liquid air. The nitrogen in the liquid air will begin to boil away at a temperature of –196°C. The oxygen must be heated a little more, to –183°C, in order to boil. At temperatures between –196°C and –183°C, the nitrogen evaporates away, leaving the pure liquid oxygen behind.

Another interesting feature of the unit opener photograph is that when the liquid oxygen is poured between the poles of the magnet, it "hangs" between them.

- "Why does the oxygen stick to the magnet?" Oxygen particles are very slightly magnetic. In the presence of a strong magnet, they experience an attractive magnetic force. The additional force of the strong magnet somehow causes the liquid oxygen to stop flowing.
- "Why would magnetism stop something from flowing?" Magnets apply magnetic force to the object in the opposite direction than the force that causes it to flow.

Pages 262 and 263 provide many examples of fluids. Ask students to find things that behave like fluids and things that do not behave like fluids. There are also examples of changes of state on the opening spread. Ask students to find examples of vaporization and condensation.

Move on to the Key Ideas, and ask students to make connections between the Key Ideas and the photographs.

You may want to hand out BLM 3-1, Unit 3 Summary, and BLM 3-2, Unit 3 Key Terms, to help students record their understanding of the unit and Key Terms.

GETTING STARTED, pp. 264–265

USING THE TEXT

The scenario on student textbook page 264 describes many of the characteristics of fluids. We can see the two great environmental fluids: the air and the water that flow over the surface of our planet. The whale is immersed in both fluids. Ask students, "What is similar, and what is different, about the two fluids?" Together, compare the fluids' resistance to the whale's motion. Compare the two fluids' ability to support the whale's great body. Are there connections between resistance and the ability to support the whale?

Ask, "Is the whale a solid, or does it have fluid parts as well?" Students may identify blood and other fluids inside the whale's great body, including air and water.

Have students identify any examples of fluids being transformed or changing their properties in the photograph. Consider the iceberg: it consists of water in the solid form, which is not a fluid. Gradually, it is being transformed into a liquid by melting. The clouds are also examples of water vapour, a very thin fluid, being transformed by condensation into tiny droplets of liquid water.

Using the Activity

Find Out Activity

Fluid or Non-fluid, p. 265

Purpose

- Students relate the concepts of "fluid" and "non-fluid" to photographs and illustrations found in magazines and newspapers.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 week before	Begin collecting magazines with many illustrations. Look for magazines that cover nature and environment, consumer products, and science.	– large sheet of paper For each group: – 2–3 magazines or newspapers – 2–3 pairs of scissors – masking tape
1 day before	Make copies of BLM 3-6, Fluids or Non-Fluids? (optional).	

Time Required

- 20 min

Safety Precautions

- Remind students to be cautions when using scissors.

Science Background

The term "fluid" means "able to flow." Non-fluids cannot flow; fluids can flow.

Liquids are the fluids with which students are most familiar. Water is a fluid, of course, but all thin runny things that can be poured, such as rubbing alcohol, gasoline, and vegetable oil are also fluids. Some liquids that are less likely to be chosen by students are very thick fluids such as shampoo, hand cream, and molasses. Even less likely to be chosen by students are semi-solids such as honey or peanut butter, both of which can flow when they are warm.

Students are less likely to choose gases, such as air. A few seconds' reflection might convince students that wind is caused by flowing air. Certainly, air behaves as a fluid when it is blown through a straw. All gases are fluids.

Solids are clearly not fluids, as they maintain their shapes. However, if a solid is ground into fine particles, like salt or sugar, the bulk material can flow. You can pour salt and sugar from a container. The individual grains are still solid, but those particles flow around each other. In such cases, as long as the granular solid is flowing, it exhibits fluid behaviour.

Activity Notes

- Place a large sheet of paper at the front of the room, with two columns labelled "Fluids" and "Non-fluids." If paper is not available, use a bulletin board, a whiteboard, or even the chalkboard or a door.
- Have students organize into pairs or groups of three.
- Instruct students to select images from the magazines depicting fluids and non-fluids. They should select equal numbers of fluids and non-fluids.
- Tell students to cut out the images, and put a masking tape loop on the back of each image.
- Once students have selected several images for each category, ask each group in turn to bring up two favourites from each category, and stick them on to the paper at the front of the room.
- Ask students to explain why they chose each image, and start a discussion about the characteristics of fluids.
- For additional practice, students can sort the items pictured on BLM 3-6, Fluids or Non-fluids?.

Supporting Diverse Student Needs

- The visual images present an opportunity for English language learners to link shared images to words and concepts. The exercise could be extended for such learners by adding labels to each diagram, and by further subdividing the categories "fluid" and "non-fluid" into "solid," "liquid," and "gas."
- To accommodate body-kinesthetic learners, a selection of various substances could be made available for examination. For example, one container of water, one container of a viscous liquid like oil or liquid honey, and one box of salt would be enough to provide examples of fluid behaviour.
- To extend the exercise, ask students to sort the pictures into other sub-categories that appear important to them. Some examples of such categories are fluids at high and low temperatures; fluids of various kinds of mixtures; or fluids sorted in order of decreasing fluidity, from very fluid to solid.

What Did You Find Out? Answers

1. Students' answers will vary considerably. Invite students to challenge the placement of individual pictures. Students who disagree about the classification of a picture must provide reasons for moving the picture to the other category. The rest of the class must approve of the change. It is often the case that the most controversial examples provide the most instructive examples.

2. A fluid can flow, that is, it can be poured or conducted through an opening. A non-fluid cannot flow. It maintains its own shape. Such substances are most likely to be categorized as solids.

Extension Answer

3. Students' tests could include attempting to pour the substance, stir it, spread it, or provide a "leak," for example by puncturing the container and observing if the contents flow out.

CHAPTER 7 OPENER, pp. 266–267

USING THE PHOTO AND TEXT

You can use the photograph of glass blowing that introduces this chapter as an opportunity to talk with students about the wide range of properties of very common substances such as glass. At room temperature, glass is hard, durable, and usually clear. Heat-resistant glass, like baking dishes, can be heated to 400°C and remain solid. Other kinds of glass may soften or change colour at that temperature. Ordinary glass will gradually soften as it is heated, becoming soft enough to flow at about 1000°C.

Molten glass is not exactly a liquid. It is a very viscous fluid, that is, a fluid that flows very slowly. At high temperatures, the viscosity of glass is low enough that it can be squeezed into molds to make dishes and drinking glasses, rolled into glass sheets for windows, and inflated like bubble gum to make bottles and light bulbs.

Molten glass is also very sticky. If two blobs of molten glass touch each other even for an instant, they will stick to each other. The stickiness of the glass is related to its viscosity when it is hot, and its hardness when it is cold.

Glass also varies in density. Lead crystal water glasses are much more massive than similar everyday drinking glasses. What is it that makes the difference?

You may be able to make contact with glass artisans in Newfoundland who can discuss and illustrate the art of glassblowing in greater detail. Glass blowing is an excellent example of combining art and science. Discuss with students what artistic and scientific principles are needed to be a successful glass blower.

USING THE WHAT YOU WILL LEARN / WHY IT IS IMPORTANT / SKILLS YOU WILL USE

Encourage students to read the Skills You Will Use points. Take this opportunity to discuss observation skills and why careful observation is important in any scientific experiment. Ask students to think about and share their observations of evidence of thermal contraction and expansion. This evidence might include the liquid in a thermometer expanding, the liquid in a jar freezing and breaking the jar, or paved roads expanding and buckling in the summer sun.

USING THE FOLDABLES™ FEATURE

See the Foldables section of this resource.

7.1 DESCRIBING FLUIDS

BACKGROUND INFORMATION

When discussing the question "What makes something a fluid?", all discussions must end up at the particle theory. Students will need to have a very thorough grasp of the differences between solids, liquids, and gases at the level of particle behaviour in order to understand how each one will behave in different situations. The particle theory has been covered in Discovering Science 7, Chapter 5. Students will review the concepts briefly in this section.

	GAS	LIQUID	SOLIDS
Motion of particles	Particles move freely, rarely collide.	Particles collide frequently, but move freely.	Particles are locked in position, vibrate in that position.
Spaces between particles	Particles do not touch. Space between is much larger than particles themselves.	Particles touch, but are not tightly packed. Spaces are smaller than particles themselves.	Particles are usually packed as close as possible. Spaces are very small.
Attraction between particles	Very weak	Weak to medium	Strong

A fluid is a substance that can be made to flow. Gases are fluids. Gases can easily be made to flow (e.g., blowing air through a straw), because of the large spaces and weak forces between them. Liquids are fluids. Liquids can be made to flow, because the particles are not locked in place and can move around each other. Solids do not usually behave as fluids; however, even solids can be made to flow. If particles of sand are shaken or poured, then the spaces between the sand grains grow and the sand grains can move around each other. Each grain of sand behaves like one particle in a liquid. The bulk of sand behaves as a fluid, but the individual sand particles still behave as solids. If gravel is dumped from a truck, the space between the gravel stones is increased, the motion of the gravel stones increases, and the stones can move around each other. The load of gravel flows as a fluid, but each stone is still a solid. Finally, if enough pressure is applied to a solid, the forces of attraction between particles in the solid can be overcome. The particles can be forced to move past and around each other, and the solid can flow. Glaciers flow in this way. The face you see on a penny was pressed into the copper by using pressure to force the copper particles to flow.

Fluidity is a behaviour, not a fixed property.

COMMON MISCONCEPTIONS

- Students might think of fluidity as a property, much like smell or colour. Strategy: Speak of fluidity as a behaviour, or something that matter can be made to do, and not an inherent property of matter.
- Students might think that all fluids are liquids. They are relying on the first examples that come to mind when they think of things that flow. Because we often simplify models of fluidity to show liquids flowing and solids and gases not flowing, students tend to internalize the idea that gases and solids cannot be made to flow. Strategy 1: Have students represent flowing behaviour in particle diagrams, showing particles rolling around each other. Strategy 2: Use a bowl of marbles to model fluid behaviour. When the marbles are stirred or poured, each marble in the bowl behaves as a particle. Explain that water behaves as a fluid because its particles move around like the marbles in the bowl. Sand being poured from a dump truck behaves as a fluid because the sand grains move around each other, much like the marbles in the bowl.
- Students might think that only a substance that can be squeezed from a container is a fluid. Strategy: Use a tube of toothpaste, or caulking compound, to illustrate this perception. Then extend it to show that substances like ice, lava, and aluminum can also flow under extreme pressure.

ADVANCE PREPARATION

- Check the activities: you will need salt, sugar, and starch, as well as some lab equipment.
- Augment your presentation with demonstrations. Pouring small ball bearings or sand from one container to another can serve as a great model for fluid behaviour. You will also need a tuning fork.
- Consult the Unit front matter for a list of BLMs that can be used when teaching this section.

INTRODUCING THE SECTION, pp. 268–269

Using the Text

Have students list as many things as they can that appear to flow. Most of the examples will clearly be liquids, or watery mixtures like mustard. Some of the examples will be surprising, like traffic, digestion, or even text. What is it that is meant by the word "flow"? It is a surprisingly elusive concept that can only be understood by discussing many examples.

Using the Key Terms and Section Summary

At the beginning of each section in the student textbook are the Key Terms and section summary. Both can be used as a pre-reading strategy and a review tool. Before reading the text in the section, students should be able to define the Key Terms by scanning the text and using the Glossary. The Key Terms include terms from the curriculum outcomes and additional terms that are important for students to know and understand.

The section summary provides an overview of the key concepts being covered in the section. Students may not know all the concepts and terms described in the summary, but they can use this information to help guide them through their reading.

After reading the section, students can go back to the Key Terms and section summary to consolidate their understanding and identify areas that require clarification. At the end of the chapter or unit, students can use the Key Terms and section summary for review. BLM 3-2, Unit 3 Key Terms, and BLM 3-3, Chapter 7 Key Terms, can be used to assist students.

Find Out Activity 7-1A

Magic Mud, p. 269

Purpose

- Students investigate a mixture of a solid (starch) and a liquid (water). The resulting mixture is a fluid that exhibits a wide range of surprising properties through changing viscosities, from nearly liquid to nearly solid.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather the materials: cornstarch, food colouring, sturdy spoons, mugs for mixing. Review definitions of solid, liquid, fluid, and viscosity.	For each group: – 75 mL cornstarch – 45 mL water – food colouring – mug – sturdy spoon or stir stick

Time Required

- 30–40 min

Safety Precautions

- Always provide eye protection.

- Even though starch and water are generally regarded as safe, they may become contaminated in the lab, and therefore students should not taste or eat these materials.
- Ensure students avoid breathing dust.

Science Background

Starch particles are very long chains of hundreds or even thousands of sugar molecules. Each sugar molecule can strongly attract water molecules; notice how easily the starch is dampened. Each long starch chain is covered by a layer of water. If you try to move the mixture slowly, each starch molecule can slide past the others. If you try to move the mixture quickly, however, the individual starch chains cannot untangle fast enough, and you can experience the increased resistance. Compare this process to gently untying a very tangled rope, as opposed to pulling on the tangles violently. Pulling hard causes the tangled starch chains to become even more knotted.

Activity Notes

- Have students add the starch to the water, a little at a time. The mixture will never be perfectly smooth. When all of the starch is wet, have students turn the whole mixture out into their hands.
- Urge students to alternate between actively shaping the mixture and letting the mixture relax and flow. The greater the variety of movements they attempt, the greater the number of different experiences they will have.
- All of the substances in this lab can be safely disposed of in the solid waste container.

Supporting Diverse Student Needs

- This activity is particularly appealing to students with dominant learning styles that are visual-spatial and body-kinesthetic. These students may benefit from being paired with students who are strong readers, and who can read the instructions and the questions in the activity aloud.
- Students who have difficulty expressing themselves grammatically in writing can probably correctly answer questions such as, "Show me what happens when you hold the mixture in your hand. Is it runny, or solid? Would you call that fluid or non-fluid?

What Did You Find Out? Answers

1. Responses will vary, but students should provide reasons why they would classify Magic Mud as a liquid or a solid. For example, Magic Mud behaves as a solid and breaks into pieces when I try to stir or move it quickly. The same mixture behaves as a liquid and takes the shape of its container when subjected to weak forces like gravity or gentle prodding. Because weak forces make it behave as a liquid, I think Magic Mud is a liquid.

TEACHING THE SECTION, pp. 269–274

Using Reading

States of Matter and the Particle Theory

Pre-reading—K-W-L (Know, Want to Know, Learned)

Set up small groups for a quick class discussion. Probe students' current understanding by having each group discuss their answers to a few questions, e.g., "What is matter made of? What are the properties of solids, liquids, and gases? What makes a solid behave as a solid?" Have students write down those things that they currently believe they know (5–10 min).

Individually, have each student write two or three aspects of the questions that they wish to learn more about (2 min). Have them share their ideas within their group, and build a larger list of things to learn (3 min).

Assign the reading.

During Reading—Note Taking

Divide a sheet of paper into thirds, and label each third "gas," "liquid," and "solid." Have students write brief notes in each section to summarize what they read (20 min).

Encourage students to draw diagrams as part of their notes.

Supporting Diverse Student Needs

- Students can trade the notes they make about this section with a partner, and discuss any differences. They can then revise their own answers to add to or clarify the information.
- Body-kinesthetic learners may be better able to internalize the differences between the particles in a solid, a liquid, and a gas if they have an opportunity to act them out. You could call out "solid," "liquid," or "gas" and have students move around like the particles in that state of matter, for example, far from others, independently of others, and quickly for a gas.

After Reading—Complete the K-W-L strategy.

Ask students, "What did you learn? What is different than what you believed before the reading?" Collate results on the board, and use a class discussion to focus, refine, and correct the learning as you go (20 min).

- Students can summarize and apply what they have learned about changes of state on BLM 3-7, The Particle Theory of Matter, and BLM 3-8, Identifying Changes of State. They can extend what they have learned to explore special effects in movies using BLM 3-9, Magical Morphing.

Reading Check Answers, p. 272

1. A fluid is a substance that can be made to flow. If the material pours, it is a fluid. Try to stir it: if the material can be stirred, it is behaving as a fluid. Key idea: "Flowing" is a behaviour, not a fixed property of matter.
2. 1. All matter is made up of very small particles.
   2. All particles in a pure substance are the same. Different substances are made of different particles.
   3. There is space between the particles. (You may wish to point out that the space is a pure vacuum.)
   4. The particles are always moving. As the particles gain energy, they move faster.
   5. The particles in a substance are attracted to one another. The strength of the attractive force depends on the type of particle.
3. When sand grains move slowly, are close together, and experience great forces of friction, the pile of grains behaves as a solid. These conditions are met in a sand pile. The same grains of sand will flow like a fluid when three conditions are met. The space between the grains must be increased, as when we pour the sand through air. The speed of the grains must be increased, as when we shake the sand. The attractive forces between the grains must be decreased, as when we dry the sand out to make it less sticky. Under these conditions, each sand grain behaves like one particle in a larger body of fluid.
4. The particles in a liquid (like orange juice) have spaces between them, so they have only weak-to-medium forces of attraction. Because of the spaces and the weak forces, the particles can roll past each other. Also, the particles are constantly in motion. They tend to roll past each other until they have settled in the lowest possible position, no matter the shape of the container.
5. All particles at room temperature have the same kinetic energy, so they have very similar average speeds. Only the particles of gas are completely free to move because they have very weak attractive forces. Their kinetic energy can help them move in any direction, even against gravity. Particles of solids and liquids are held in place by attractive forces. At the same temperature, these particles also move at the same speed, but are not free to move as far.

Changes of State

Pre-reading—K-W-L (Know, Want to Know, Learned)

(5–10 min) Probe students' current understanding by asking questions such as, "What changes of state can you describe? What would make a solid change into a gas?" Have students write down those things that they currently believe they know.

Individually, have students write two or three aspects of the question that they wish to learn more about (2 min). Have them share their ideas, and build a larger list of things to learn (3 min).

Assign the reading.

During Reading—Note Taking

Have students draw a triangle about $\frac{1}{4}$ the width of the page, and label the corners "solid," "liquid," or "gas." They can write notes summarizing what they read on the diagram (20 min).

Encourage students to draw diagrams as part of their notes.

After Reading—Complete the K-W-L strategy.

Ask students, "What did you learn? What is different from what you believed before the reading?"

Collate results on the board, and use a class discussion to focus, refine, and correct the learning as you go (20 min).

Reading Check Answers, p. 274

1. A change of state is a transformation from one state of matter to another, by adding or removing energy.
2. Responses may vary. Ice cubes dry up in your freezer. Snow dries up on the picnic table without melting. Mothballs change into a smelly vapour without melting.
3. solidification
4. Evaporation is the change from liquid to gas, caused by the addition of energy. Condensation is the change from gas to liquid state, caused by the loss of energy.
5. (Student answers are likely to focus on an example.) It is important for people who work in a candle factory to know the melting point of wax. If they did not know the melting point of wax, they might let the pot get too cool, and all of the wax would become solid before it could be poured into molds.

USING THE ACTIVITIES

- Activity 7-1A on page 269 of the student textbook is best used before beginning the reading "States of Matter and the Particle Theory" on pages 269 to 272.

- Activity 7-1B on page 271 of the student textbook is best used after the reading “States of Matter and the Particle Theory” on pages 269 to 272.
- Detailed notes on doing the activities follow.

Find Out Activity 7-1B

Can Solids Flow, Too? p. 271

Purpose

- Students investigate the fluid-like behaviours of solid substances. A mass of small grains of a solid substance can be made to flow like fluids if they have enough space between them, have small enough forces between them, and have sufficient motion.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather sand, salt, sugar, rice, or another granular substance.	For each group: – 250 mL of granular solid – 250 mL of water – plastic cups, 250 mL – unbreakable plates, or metal pie plates

Time Required

- 15 min

Safety Precautions

- Remind students to keep their work station clean and to wipe up any spills immediately.
- Granular substances on the floor can behave as little ball bearings, and cause students to slip on the floor. Sweep up any spills immediately.
- Protective eyewear is always required.

Science Background

Liquid water flows. We cannot see the particles, but the fluid behaviour of water depends on the thermal motion of the water particles to provide enough space between the particles to reduce the attractive forces between them. Granular solids can actually behave as models of a liquid. Think of a grain of sand as a model of a water particle. Shaking the grains models temperature: the faster the shaking, the higher the temperature. As the grains get slightly farther apart, the force of friction between the grains is reduced. The grains can move around and past each other. The whole collection then flows as a liquid. As the grains come to rest on a pile on the plate, however, they behave more like a typical solid. They no longer flow.

Activity Notes

- Have students work in groups of no more than two or three. This activity is very simple, and there is no need for larger groups.
- Have students pour each substance slowly. They can more readily see the transition from behaving as a solid to behaving as a liquid.
- When the granular solid has formed a heap on the plate, have one of the students “drum their fingers” on the edge of the plate to provide some vibration. How does the “solid” behave when more energy is supplied?

Supporting Diverse Student Needs

- This activity is particularly appealing to students with dominant learning styles that are visual-spatial and body-kinesthetic. Such students may benefit from being paired with students who can read the instructions and the questions in the activity aloud.
- To help English language learners understand the instructions and access the vocabulary needed to formulate written answers, have them work with fluent English speakers.
- Suggest that students who have trouble organizing their thoughts in writing use a T-chart with the headings “Sand” and “Water” to contrast the behaviours in What Did You Find Out? question 1.
- Students who have difficulty with written or spoken language are more likely to be able to correctly respond to questions that require a demonstration of fluid or solid behaviour, e.g. “Show me how to make rice behave like a fluid.” Students might pour the rice or stir it.

What Did You Find Out? Answers

1. When I started to tip the cup, the water flowed immediately, but the granular solid did not. When I tipped the cup farther, however, both substances flowed. The particles of the granular solid were moving past one another so quickly that they looked like a liquid. When the water landed on the plate, it continued to flow, spreading out evenly all over the plate. When the granular solid landed on the plate, it stopped flowing and piled up.
2. The substance must flow in order to be a fluid. Being a fluid is not necessarily a permanent property of a substance. (The substance can change with different circumstances.)

Using a Demonstration

Take a large, low-frequency tuning fork (256 Hz or lower), strike it, and hold the stem end (not the fork end) against a metal plate or bowl containing a small amount of dry sand. The vibrations will cause the sand to flow almost as a liquid. Relate this phenomenon to how wet soil can flow during earthquakes and avalanches.

USING THE FEATURES

www Science: Spooky Change of State, p. 275

Stage fog is all about drama. The most dramatic way to present this material to students is to demonstrate it!

Using a Demonstration

A safe, dramatic demonstration of dry ice stage fog can easily be done in your classroom, depending on the availability of dry ice. Be prepared to do the demonstration on the day that the dry ice arrives. It will not keep overnight. Possible sources of dry ice: compressed gas vendors, ice cream vendors, large refrigeration specialists, hospitals, medical or other laboratories, and university or college outreach programs. Call a distant supplier to find out if there is a customer in your community who receives dry ice.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
3 weeks before	Find a supplier of dry ice in your community, or within a few hours' drive.	– several lumps of dry ice, about 500 g total
1 week before	Order the dry ice to arrive on a mid-week day. If it arrives on a Friday afternoon, it will all be evaporated by Monday.	

Time Required

- 10 min, can last almost 60 min

Safety Precautions

- Do not permit students to handle the dry ice at all.
- Do not handle the dry ice with your bare fingers.
- Use tongs to handle the ice, or very thick oven mitts.
- Small amounts of carbon dioxide are not toxic. (Consider carbon dioxide in soft drinks.) However, do not permit students to breathe the carbon dioxide deeply. It contains no oxygen, so students may become faint.

Science Background

The solid carbon dioxide is more dense than water, so it will sink to the bottom of a container of water. Carbon dioxide sublimates at temperatures greater than –78°C. Even cold water at 0°C is very much hotter than the sublimation temperature of carbon dioxide. To solid carbon dioxide, ice water is hot! Carbon dioxide submlimates at a great rate, producing lots of foggy white bubbles in the water. The cold carbon dioxide causes the water vapour to condense into foggy clouds in the air. The mixture of cold carbon dioxide gas plus water droplet fog will spill over the sides of the container, fall onto the desktop, and then pour over the edge onto the floor. Very cool!

What to Do

Obtain a large, Pyrex™ glass container, such as a Pyrex™ coffee pot or a 1 L beaker. Half-fill the container with warm, not hot, water. Using gloves or tongs, drop chunks of dry ice into the water.

Reading Strategy

The reading can be done without the demonstration. If you do choose to do the demonstration, the reading can be done either before or after the demo. Have students read the text and study the accompanying illustrations.

While they are reading, draw the outline of a large beaker on the board, about 1 m high. Outline the water level, about halfway up. Add one or two lumps of dry ice sitting on the bottom of the beaker. Above the lumps, draw two or three round bubbles in the water rising from the dry ice.

As students finish the reading, instruct them to copy the diagram onto a page, and add pictures of 10 to 20 particles for each of the following: the liquid water, the solid carbon dioxide, the carbon dioxide gas, air, water vapour, and droplets of water in the cloud. Have students label the diagram with information from the reading.

Ask students how they would make use of a lump of dry ice.

National Geographic: Visualizing Atmospheric Layers, p. 276

This feature can be used to promote the idea of fluids in an unfamiliar environment and to show how different fields of scientific study can be combined in a real life context. Ask students questions like these:

1. We cannot see the air around us, but it is a form of matter. The atmosphere consists of particles, like all other matter. What are the particles doing in each layer of the atmosphere? Are they moving quickly or slowly? Are they close together or far apart? Do forces of attraction play a role in each layer, or not?
   (Accept a variety of student answers. Use this question to initiate student discussion. Particles will move more slowly in cooler layers. They will be farther apart in upper layers where atmosphere is thinner.)
2. In its normal orbit, the space shuttle moves at about 11 km per second! The space shuttle orbits for weeks at 150 km above the Earth's surface

without slowing down. If its path dips into the stratosphere, it begins to glow red hot, and is slowed to 1 km per second in a very short time. What is the difference between the two situations? (There are very few gas molecules at 150 km, so the space shuttle can move through them without slowing down much. At 50 km, the shuttle encounters a thousand times more air molecules. Pushing through that much gas causes resistance, slowing the shuttle down.)

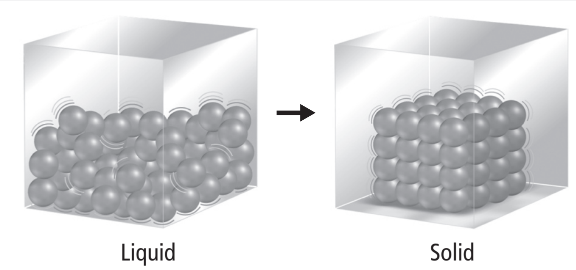
3. Passenger airplanes burn a great deal of fuel to fly at an altitude of 10 k. If the jet engines stop burning fuel, the plane will quickly fall to Earth. The space shuttle, however, can orbit for weeks at 150 km without burning any fuel at all. What is the difference between the two situations? (Even 10 km high in the troposphere, gas molecules are very plentiful. Jet airplanes have to push through this atmosphere, much like a boat has to push through water. At 150 km, the gas particles are so scarce that the space shuttle moves through them with very little resistance at all. It takes weeks for this thin atmosphere to slow the shuttle down.)

SECTION 7.1 ASSESSMENT, p. 277

Check Your Understanding

Checking Concepts

1. When liquid water is put into the tray, its particles are travelling at high speeds, there are significant distances between particles, and the force between particles is not very strong. As the water is cooled, the particles move more slowly, and get closer together. The forces between particles become stronger. At some point, the attractive forces hold the particles in place. The liquid water has turned to solid ice.
2. Tiny grains of salt are solid. Salt can be made to flow if we increase the spaces between salt grains, reduce the forces (like friction) between salt grains, and increase the speed of the salt grains. If we follow these steps, the salt will behave as a fluid. When it stops pouring, it behaves like a solid again and piles up.
3. Water particles in a flood or spill will have spaces between them and will have small forces between them. Therefore, water particles can move around each other as they respond to the force of gravity pulling them down toward the drain, then down the drain. The water will behave as a fluid. We can be confident that water will flow down the drain in response to gravity.
4. The air molecules are moving very quickly (450 m/s), have large spaces between them (20 times larger than molecules), and small forces of attraction. There is a lot of space between the air particles for the perfume particles to move. In a short time, the perfume particles move past many air particles and across the room.
5. When you left the car at night, there was plenty of water vapour outside the car. The water particles were moving quickly, had large spaces between them, and were not attracted to each other. Overnight, the particles cooled and slowed down. Each time a slow-moving particle struck the car, it was strongly attracted to the other particles, and stuck there. Gradually a layer of solid frost was built up.
6. In the liquid state, the atoms of mercury are moving fast enough to provide spaces between the atoms. The forces between the particles are medium. As the mercury is cooled, its particles move more slowly, and the spaces between the particles decrease. Eventually, the attractive forces between the particles cause the atoms to settle into a fixed position. The mercury is changed to the solid state. Students' diagrams should show particles with some movement and some space between them (liquid), then particles with little movement and little space between them (solid).

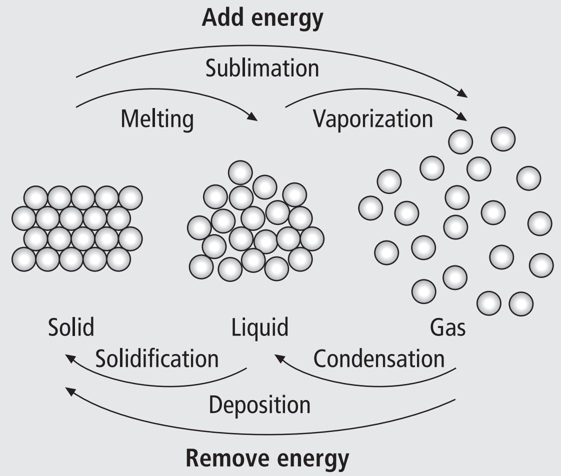


Understanding Key Ideas

7. Students may conclude that evaporation and boiling are the same, because they both involve particles of a liquid gaining energy, moving more rapidly, and changing to a gas. Some students may point out that evaporation happens only at the surface of a liquid, so only

those particles are gaining enough energy to change state, while boiling happens throughout the liquid, so we see bubbles of gas forming and rising to the surface.

8. Several answers are possible. Students' diagrams should show all the elements of this example.



Pause and Reflect Answer

Students' answers may vary. Students might suggest that water vapour condenses directly, forming larger and larger droplets that eventually fall to the ground. Another suggestion is that the tiny droplets that make up the cloud combine into larger droplets. Scientists believe that rain begins as tiny ice crystals that form at the very highest, coldest altitudes in a storm cloud. As the ice crystals fall in the cold air, the water droplets in the cloud stick to the ice crystals. These ice crystals fall more quickly, gathering more tiny water droplets. In a very short time, the rapidly-falling drop can strike a large number of water droplets. The drops quickly grow, and a downpour begins.

- Consult the Unit front matter for a list of applicable Assessment BLMs.

7.2 VISCOSITY AND FLOW RATE

BACKGROUND INFORMATION

Viscosity of liquids is both a practical and an aesthetic factor that can affect the value of the product. A product is developed for a specific use. It must be easy to use, fulfill the need, and in the case of foods or personal-care products, the texture and consistency must be sensually pleasing, too.

Oils that are used to lubricate motors and engine parts must do their job and be easy to apply. Hand creams or face lotions must be rich (viscous) enough to feel pleasantly creamy but not gummy on the skin. Shampoo must have ingredients that make it viscous enough to cling to hair, but it has to rinse out eventually.

People tend to associate quality and value in foods and personal-care products with the viscosity of the products. A rich ice cream is more expensive than orange sherbet. A creamy hand soap is valued more than a watery liquid soap.

INTRODUCING THE SECTION, p. 278

Using the Text

Initiate a discussion of viscosity. "Think of all of the things that you can spread on toast. Which one is the most viscous?"

Try this body-kinesthetic activity: Have students stand up. Make an enclosure out of the desks, just large enough to contain the students. Instruct students to move around within the space, with their arms straight down at their sides. Instruct all those with even birthdays to move to one side, those with odd birthdays to move to the other. How long does that take? Now instruct students to put their hands on their hips, with elbows extended. Repeat the exercise. The extended elbows slow the flow of the fluid, and increase its viscosity.

Using the Key Terms and Section Summary

At the beginning of each section in the student textbook are the Key Terms and section summary. Both can be used as a pre-reading strategy and a review tool. Before reading the text in the section, students should be able to define the Key Terms by scanning the text and using the Glossary. The Key Terms include terms from the curriculum outcomes and additional terms that are important for students to know and understand.

The section summary provides an overview of the key concepts being covered in the section. Students may not know all the concepts and terms described in the summary, but they can use this information to help guide them through their reading.

After reading the section, students can go back to the Key Terms and section summary to consolidate their understanding and identify areas that require clarification. At the end of the chapter or unit, students can use the Key Terms and section summary for review. BLM 3-2, Unit 3 Key Terms, and BLM 3-3, Chapter 7 Key Terms, can be used to assist students.

Using a Demonstration

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 week before	Gather clear detergent bottles, preferably all the same kind.	– 3 plastic tubs – 3 clear plastic detergent bottles, with squeeze caps – three 250 mL beakers, or other identical cups

Prepare three plastic tubs, three 250 mL beakers or measuring cups, and three clear plastic detergent squeeze bottles. The first squeeze bottle should be completely filled with water and perhaps some food colouring for visibility. The second squeeze bottle should be completely filled with dish detergent. The third should be completely filled with blackstrap molasses (not the fancy molasses, which is thinner). These detergent bottles correspond to low, medium, and high viscosity.

Choose three student volunteers. Assign the strongest student to the molasses, and the most delicate student to the water. Ask students, "which student can squeeze 100 mL of fluid in the shortest time? Have the class make predictions.

Put the beakers into the plastic tubs, to control spillage. Provide students with the squeeze bottles, and instruct them to squeeze the fluid into the beaker to the 100 mL mark. "Ready; Set; Go!"

The molasses will be slowest, no matter how strong the student is. The range of student strength is not very wide. The stronger person would be about 5 times stronger than a weaker student. Viscosity, however, varies by an enormous factor. If the viscosity of water is 1 cP (centipoise), the viscosity of detergent is about 1000 cP, and that of molasses about 5000 cP. The student who is 5 times stronger has to deal with a fluid that has 5000 times more viscosity than water. No wonder the "water person" wins!

TEACHING THE SECTION, pp. 278 – 281

Using Reading

Pre-reading—K-W-L (Know, Want to Know, Learned)

Set up small groups for a quick class discussion. Have students scan the text silently for one minute, jotting down a few words that seem important as they go. For the next minute, they share their words with each other, to build a more complete list. Following that, have students write down those things that they currently believe they know (5–10 min).

Individually, have students write two or three aspects of the question that they wish to learn more about (2 min). Have them share their ideas, and build a larger list of things to learn (3 min).

Assign the reading.

During Reading—Note Taking

Students use the subtitles to structure their notes. For each subtitle, each student should write at least two notes that explain or provide examples (20 min).

Encourage students to draw diagrams as part of their notes.

Supporting Diverse Student Needs

- Remind students, if necessary, that they can use the Reading Check questions to help them decide whether they have learned the most important information in the section. If they find they cannot give a full answer to one of the Reading Check questions, they should go back and look for information to help them answer it in the section. You could have students do this in pairs, to model reading skills.

After Reading—Semantic Mapping

Ask students, "What is the central idea in this section? What are the surrounding ideas? What examples, evidence, or explanations do you know that support each of the surrounding ideas?"

Have students draw a semantic map of the central idea and the related surrounding, or supporting, ideas.

Collate results on the board, and correct the learning as you go (20 min).

Reading Check Answers, p. 280

1. Viscosity is a fluid's "resistance to flow." We experience viscosity as the thickness or the thinness of a fluid.
2. Internal friction would be the friction between one part of a fluid and a neighbouring part of the same fluid, all inside the same fluid. In a fluid with great internal friction, the particles can only slide by each other reluctantly. Such a fluid would display high viscosity.
3. The performance of many products depends on viscosity. Imagine toothpaste as thin as milk, or rubbing alcohol as thick as honey. Each product must have carefully controlled viscosity in order to perform well.
4. There are many answers here. Anyone who designs, tests, or uses food products, cosmetics, drugs, cleaners, paints, glues, hydraulics, fuels, or gases must have some knowledge of viscosity. Experts would need specialized knowledge. When you operate a boat, you encounter the viscosity of water and wind, fuel

and oil, lubricants and waxes, paints and glues, as well as personal protective materials like sunscreen.

Reading Check Answers, p. 281

1. Flow rate is a measure of the time it takes for a fluid to flow from one point to another. The shorter the time is, the greater the flow rate is.
2. The greater the viscosity is of a liquid, the lower its flow rate is. For example, white glue has high viscosity, and flows very slowly.
3. Several tests are possible. 1. Drop identical marbles into cylinders of fluids. The greater the viscosity is, the more time it takes for the fluid to reach the bottom. 2. Pour the fluid into a container with a small hole in the bottom, and measure the volume of fluid that comes out in one minute. The greater the viscosity is, the smaller the flow rate is.
4. Low viscosity fluids: many alcohols, gasoline, water, butane in a butane lighter
   High viscosity fluids: vegetable oil, motor oil, molasses, syrup, paint, glue, etc.

USING THE ACTIVITIES

- Activity 7-2A on page 280 of the student textbook is best used immediately after the reading. Alternatively, it could be assigned to be done at home.
- Activity 7-2B on page 282 of the student textbook is best used after the reading has been completed, and student understanding has been verified. You may wish to have students complete activities 7-3A and 7-3B in Section 7.3 at the same time as Activity 7-2B, since the equipment will all be in place.
- Detailed notes on doing the activities follow.

Find Out Activity 7-2A

The Value of Viscosity, p. 280

Purpose

- Students relate the concept of viscosity to a variety of consumer products.
- This comparison is qualitative only.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 week before	Ask students to bring in half-empty bottles of hair conditioner, shampoo, hand lotion, liquid detergent, bubble bath, etc. Ask students to also bring a recent price for the product.	For each group: – 3 different examples of the same product – 3 small paper ketchup tubs
1 day before	Make copies of BLM 3-10, The Value of Viscosity (optional).	

Time Required

- 20 min

Safety Precautions

- Most cleaners tend to be strong bases, and can irritate the eyes, so eye protection is required.
- Food products may be contaminated with bacteria, especially if they have been stored from previous years. Ensure students do not taste these food products.

Science Background

This activity is a qualitative investigation so that students can experience viscosity in some consumer products, and compare viscosity among three different manufacturers.

Students will also calculate the cost per unit volume, and inquire if there is a correlation between cost/volume and viscosity. There may or may not be a correlation between cost per volume and viscosity.

Activity Notes

- Each student should prepare a table like the example in the text on page 280.
- Working in a small group of two or three students, they invent a test for viscosity, e.g., the "shake test," the "pour test," or the "squirt test" as they pour or squirt a sample of each product into a small paper ketchup tub.
- The viscosity of each product should be both described (high, medium, low) and also ranked (1, 2, 3). All three products might have high viscosity, but they could still have small variations in their rankings.
- Complete the table, and answer the questions.
- Students can record their observations and conclusions using BLM 3-10, The Value of Viscosity.

Supporting Diverse Student Needs

- This activity includes opportunities for body-kinesthetic, logical-mathematical, and interpersonal learning. Establish groups that include learners of different styles, and challenge them to use listening skills and cooperation to ensure that everyone in the group has a meaningful role.
- Additional experience building verbal-linguistic intelligence can be provided by having each group of students produce one 30 second commercial, in which every person has a speaking role.
- English language learners could provide the word for the product class to those students proficient in English, so that every student writes the name of the product class in at least two languages.
- Enriched or gifted students might modify the viscosity test to obtain more quantitative information about each product.
- After the activity, use a variety of question types to probe student understanding. Questions requiring high verbal performance can be directed at students who are capable of speaking. Students who have trouble with language could be asked performance questions such as, "Which one do you think is the slowest?" Other questions may require a partner, such as, "I need two people to show us the fastest and slowest fluids in a race. Who can help?"

What Did You Find Out? Answers

1. There may or may not be a relationship between viscosity and cost per volume. That being said, many personal products are described as "richer" if they have greater viscosity.
2. A variety of answers is possible. Products that are more useful with higher viscosity are grease, shaving cream, toothpaste, face cream, etc. Products that are more useful with lower viscosity are paint thinner, window cleaning spray, mouth wash, beverages.

Core Lab Conduct an Investigation 7-2B

The Flow Rate of Liquids, pp. 282–283

Purpose

- Students investigate the flow rate of three different substances, using a scale for flow rate based on measurements of distance and time. You might consider doing Activity 7-3A at the same time, as it uses the same equipment.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 week before	Gather sufficient materials for student ramps: sheets of metal, plastic, or glass. Gather sufficient volumes of liquids with a variety of viscosities. Keep all fluids in the same location, overnight, to be certain that all are at the same temperature.	For each group: – 2 samples of liquids, 15 mL each (not water) – 1 plastic measuring spoon – 1 stopwatch – 1 ruler – 1 waterproof marker In addition, students will need sufficient amounts of: – paper towels, soap, water to clean the workstation – rubber gloves
1 day before	Make copies of BLM 3-11, The Flow Rate of Liquids (optional).	

Time Required

- 40 min
- In order to complete the activity in this time, students must come fully prepared.

Safety Precautions

- Ensure students keep their hands away from their face and mouth. Ensure students do not eat or drink any substances in the science laboratory.
- Have students wipe up all spills immediately. Ensure they do not leave floors wet.
- Ensure students dispose of all materials properly, according to your instructions.

Science Background

The exact measure of viscosity is beyond the ability of students at this grade level. Instead of viscosity, students will measure a related quantity: flow rate. Flow rate is considered a "proxy" measurement: if we determine the flow rate of a substance, we have, in effect, measured its viscosity. Unfortunately, even flow rate is beyond the ability of students with this equipment. Instead of actual "flow rate," student will measure the speed of the progress of a dribble of a liquid. Measured in this way, "dribble rate" is a proxy for flow rate.

So, students are actually measuring a proxy of a proxy of viscosity, but dribble rate will be sufficient for them to rank viscosities.

Students are also developing good laboratory practice. Neatness, accuracy, reproducibility, precision, and measurement are all challenged in this lab. These personal values are vital for student success in science. Be sure to emphasize the importance of high standards as students make these measurements.

Activity Notes

- Arrange students in groups of two, three, or four. Read and discuss the instructions, and prepare a hypothesis.
- Draw a carefully ruled table, as shown in the lab on page 282.
- Construct a measuring instrument. Students will have to draw directly on the glass, metal, or plastic ramp, using waterproof ink. Two marks, parallel to the bottom of the ramp, are needed: the start line and finish line of the dribble race, exactly 10.0 cm apart. A third line, the spoon line, is drawn about 1 cm above the start line.
- Set up the ramp, and record its exact construction. Which books did you use? How did you secure the ramp? What part of the ramp was in contact with the books? You will have to use the same ramp again in Activity 7-3A on page 287.
- With the measuring spoon brim full, place the bottom of the spoon on the "spoon line" above the start line.
- The roles of Marshall, Spoon Student, Timer, and Recorder are assigned at this time. The Marshall, Timer, and Recorder roles can be combined in any combination to suit the number of students in the group.
- The timer counts down to zero, and starts the stopwatch exactly as the Spoon Student rocks the spoon downward smoothly and quickly. The contents of the spoon will spill out right on the start line, just as the timer is started.
- The timer stops the clock when the dribble reaches the finish line, regardless of the amount of fluid that actually reaches the line.
- The procedure is repeated on a clean surface of the ramp.
- Clean up the ramp, and dispose of all materials as directed by the teacher.
- Students can record their observations and conclusions using BLM 3-11, The Flow Rate of Liquids.

Supporting Diverse Student Needs

- The instructions are quite complex, and students with reading difficulties might need considerable support. Place English language learners with fluent English speakers. Be sure that each student has a significant role.
- In a group of three, students will have a choice of roles to play, including spoon student, timer, and marshall. Each role offers opportunities for students with different dominant intelligences.
- Students who have trouble following written instructions might benefit from having key steps demonstrated for them before they begin. To ensure they know how to set up the equipment, follow step 1 and part of step 2 of the Procedure as a demonstration.
- To help students with weak mathematics skills, use an example to demonstrate how to select the appropriate data on the data table and use it to calculate flow rate.
- Students who see opportunities to improve the measurement should be encouraged to quickly draw up a plan, present it to the teacher for approval, and then proceed with the modification.

Analyze Answers

1. The analysis is quite simple. Record **d** (10.0 cm) and **t** (e.g. 5.0 s). Calculate flow rate as $\frac{\mathbf{d}}{\mathbf{t}}$. For example,
   $\frac{\mathbf{d}}{\mathbf{t}}$ = (10.0 cm)/(5.0 s)
   = 2.0 cm/s
   Once three numerical values are obtained, it is easy to rank the results.
2. From slowest to fastest flow rates: molasses, corn syrup, honey, liquid detergent, cooking oil, apple juice, or vinegar.
3. Infer the viscosities for each fluid from (2), and rank the viscosities. These should be the reverse of (2).
4. Sources of error: human incompetence, such as spilling, sloppy work, etc., are never acceptable as sources of error. Unavoidable human limitations, such as small timing errors due to perception, reflexes, or muscle speed are legitimate sources of error. Finally, limits to the precision of the lines, placement of the spoon, speed of release of fluids, irregularities in the ramp surface, etc. are all legitimate sources of error. Students should suggest realistic and effective strategies to reduce or eliminate each source of error they identify.

Conclude and Apply Answers

5. Students might measure three different flow rates, for example, of 15, 2, and 1 cm/s. The median rate of flow is the middle measurement, that is 2 cm/s. The mean rate of flow is the average of the three, or 6 cm/s, i.e., ((15 + 2 + 1) ÷ 3).
6. The greater the flow rate, the lower the viscosity. Water has a low viscosity and a high flow rate. Honey has a high viscosity and a very low flow rate. This relationship is an inverse relationship.
7. The very fast and the very slow liquids are both difficult to measure. Two solutions to

this problem can be suggested. First, adjust the slope to obtain the best range of values for time. Second, repeat each measurement a number of times, to improve your measuring technique.

8. Generating a bar graph is a fine exercise in representing the data. Bar graphs will vary, but should show bar lengths that correspond to the flow rates of the fluids.

USING THE FEATURE

www Science: Superfluids, p. 284

This feature provides an opportunity to wonder. After students have read this section, ask a few "starter questions."

- Can a superfluid pass through aluminum foil? What is the smallest hole that a particle could pass through in the superfluid condition?
- If superfluids have no friction, how big is the attractive force between them? But if the attractive force is zero, then what holds the particles in the liquid state?
- If superfluids have no resistance to flow, then how fast do they move? How fast are the particles moving?
- Do particles in the superfluid condition ever actually collide with each other?

Questions like these can elicit more questions from students as they try to fit this very odd substance into the models for matter that they already have in their minds.

SECTION 7.2 ASSESSMENT, p. 285

Check Your Understanding Answers

Checking Concepts

1. The viscosity of paint is very important to the painter. Paint should be smooth enough to brush on easily, without being sticky or gummy. Brush marks should flow easily over a few minutes to provide a smooth surface. Paint should not flow so easily that it runs down the wall, or drips from the brush. Paints with the most carefully controlled viscosities will give better results, and probably cost more.
2. Perhaps there is something inconsistent in their experiment. Students could look for differences in the way that the oil is measured, prepared, or tipped. There might be small differences in the surface of the metal. Are different students using the stopwatch each time? These and many other differences could be checked, and the inconsistencies removed.
3. There are several acceptable possibilities. A descriptive set of categories might be "watery, oily, greasy," or "thin, creamy, thick." Any set of categories that contains a consistent set of examples is acceptable.
4. Containers are made to be water-proof to prevent the evaporation of the water. More generally, containers are designed to be impervious to the solvents and solutes in the product. To keep a product in its proper condition, seal the container, keep it out of high temperatures (like inside a car), keep it out of light (which can cause chemical changes), and keep it away from constant vibration, (which can shake the components apart).

Understanding Key Ideas

5. Any test that provides both a constant force and a constant resistance to flow can be used to determine flow rate. A constant weight on a tube of toothpaste could provide the constant force. A consistent hole in the toothpaste tube could provide constant resistance. In our experiments, we used constant gravity (slope) to provide the force, and constant surface (ramp) to provide the resistance.
6. Many acceptable answers are possible. Many people use a "drip test": plunge some kind of stick or spoon into the fluid, and observe how quickly the substance drips from the stick. Others use a "stir test": how much resistance can you feel if you stir the fluid?
7. The completed table will include two additional columns, and have the following values:

SUBSTANCE	LENGTH OF RAMP (CM)	TIME OF FLOW (S)	FLOW RATE (CM/S)	RANKED VISCOSITY
A	20	2	10	lowest
B	20	10	2	highest
C	20	5	4	middle

Pause and Reflect Answer

This exercise demands that the student imagine a number of factors, separate them, and model each factor independently in their minds. Some factors are the following:

Length: The longer the straw, the greater the total resistance to flow.

Diameter: The wider the straw, the lesser the total resistance to flow.

Smoothness: A plastic straw is smoother, and has less resistance, than a paper straw.
Stiffness: A flexible straw can collapse if it is too hard to draw the fluid up.
Structure: A wide straw collapses more easily than a narrow straw.
Edges: Smooth or corrugated edges offer different resistance.
Other factors may also be explored. The student must consider each factor in turn, and explain their overall decisions.

Other Assessment Opportunities

- Consult the Unit front matter for a list of applicable Assessment BLMs.

7.3 FACTORS AFFECTING VISCOSITY

BACKGROUND INFORMATION

Many substances are included in food and personal care products simply because they contribute to the viscosity of the product. A soft drink can contain some ingredients that increase the viscosity, so that a creamy froth appears. The same soft drink can contain other ingredients that lower viscosity, so that the froth disappears in a pleasant way.

The particles that change the viscosity of a substance are used because they have the following properties.

1. Size: They are larger than the solvent particles that surround them.
2. Shape: They are longer, or more complex, than the surrounding particles.
3. Attractive forces: Viscous molecules have stronger attractions to their surroundings.
4. Concentration: The greater the concentration, the greater the viscous effect.

Viscosity of a gas actually increases at a higher temperature. The hotter the gas is, the lower its flow rate through a tube is. This result goes against student intuition. An analogy may be useful: The runners in a marathon race have low random kinetic energy (like low temperature). The participants in a riot have large random kinetic energy (like high temperature). The runners in a marathon race move smoothly through the city streets for 26 miles. The rioters move randomly about, but do not get far. Gases behave in a similar way. The greater their random motion, the less they are able to flow.

INTRODUCING THE SECTION, p. 286

Review particle theory and ask students to predict how each point in the theory might affect viscosity.

Using the Key Terms and Section Summary

At the beginning of each section in the student textbook are the Key Terms and section summary. Both can be used as a pre-reading strategy and a review tool. Before reading the text in the section, students should be able to define the Key Terms by scanning the text and using the Glossary. The Key Terms include terms from the curriculum outcomes and additional terms that are important for students to know and understand.

The section summary provides an overview of the key concepts being covered in the section. Students may not know all the concepts and terms described in the summary, but they can use this information to help guide them through their reading.

After reading the section, students can go back to the Key Terms and section summary to consolidate their understanding and identify areas that require clarification. At the end of the chapter or unit, students can use the Key Terms and section summary for review. BLM 3-2, Unit 3 Key Terms, and BLM 3-4, Chapter 8 Key Terms, can be used to assist students.

TEACHING THE SECTION, p. 286

Using Reading

Four factors affecting viscosity are explored. Temperature, concentration, attractive force, and particle size are all examined. Use the reading strategies to maximize the student's ability to compare and contrast these four factors.

Pre-reading—Key Word Concept Maps

Key Word Concept Maps help students broaden their understanding of key word concepts. Before reading, new words and concepts can be pre-taught or clarified. During reading, they can be linked to text. After reading, students can identify word concepts they wish to learn more about.

Set up small groups. Provide students with the key words in the list below. Instruct students to work together to identify those words that need clarification (5–10 min).

Fluid Viscosity Internal Friction Flow Rate	Concentration Particle Size Particle Shape	Particle Theory Particles Spaces Forces Kinetic Energy

Organize the key words into a concept map. Students should write in the meaning of each link between concepts, e.g., (Fluid) "is made of" (Particles). The particle theory will probably display the largest number of links. Some of the key words will probably appear to be weakly connected to the concept map.

Identify those concepts that are not well connected to the concept map. Instruct students to pay particular attention to those concepts as they read, and to try to find the missing connections. Assign the reading.

Supporting Diverse Student Needs

- Students could build the concept map as a write-around activity in a group. One student could begin by drawing some links, then others could take turns adding other links, and explaining them to the group.
- Remind students to use the Glossary at the end of the student textbook to clarify the meaning of any Key Terms they are unsure of.

During Reading—Note Taking

Students use the subtitles to structure their notes. For each subtitle, each student should write at least two notes that explain or provide examples (20 min).

Encourage students to draw diagrams as part of their notes.

After Reading—Semantic Mapping

Identify the "missing links." Pay special attention to linking the concepts of Fluid, Viscosity, and Flow Rate to the particle theory, concentration, particle size, and particle shape.

Ask students, "What is the central idea in this section? What are the surrounding ideas? What examples, evidence, or explanations do you know that support each of the surrounding ideas?" (The central idea is the particle theory. The surrounding ideas are speed of particles, concentration of particles, attractive forces between particles, and size of particles. All of the rest is evidence.)

Have students draw a semantic map of the central idea and the related surrounding ideas.

Collate results on the board, and correct the learning as you go (30 min).

- Students can summarize and apply what they have learned using BLM 3-12, Viscosity and the Real World, and BLM 3-13, Controlling Viscosity.
- Some students may enjoy extending their understanding of viscosity using BLM 3-14, Viscosity in Action to design a new product.

Reading Check Answers, p. 290

1. Kinetic energy is the energy that a particle has due to its motion. The greater a particle's motion is, the greater its kinetic energy is. The average kinetic energy of a collection of particles is also known as temperature.
2. The average kinetic energy of the particles in a glass of water can be increased by heating the water to a higher temperature. Likewise, the average kinetic energy can be reduced by cooling the water to a lower temperature.
3. Students should list three of the following factors: temperature, state, concentration of its components, attractive forces between particles, and the size of particles.
4. Increasing the temperature of a gas increases the random motion of its particles. This finding results in more collisions with the walls of the container and other particles.
5. The greater the concentration of flour particles in cake batter is, the greater the viscosity of the batter is. Other examples abound.

USING THE ACTIVITIES

- Activity 7-3A on page 287 of the student textbook could be done at the same time as Activity 7-2B on pages 282 and 283. Since the equipment is already assembled, Activity 7-3A can be done quickly right after the reading.
- Activity 7-3B on page 291 of the student textbook is best used as a short discussion starter just before or after the reading.
- Activity 7-3C on on pages 292 and 293 of the student textbook is the key activity in this section. It could be used either before or after the main reading.
- Activity 7-3D on page 294 of the student textbook can be used anywhere in this section to elaborate on the ideas of the particle theory. It could also be used as an enrichment activity.
- Activity 7-3E on page 295 of the student textbook can be combined with activities 7-2B and 7-3A. It could be used either before or after the main readings in the chapter.
- Detailed notes on doing the activities follow.

Find Out Activity 7-3A

Cool It!, p. 287

Purpose

- Students investigate the effect of temperature on the viscosity of three fluids. This activity can be undertaken as an extension of Investigation 7-2B.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
Start your preparation at the same time as Activity 7-2B.	Gather sufficient materials for student ramps: sheets of metal, plastic, or glass. Gather sufficient volumes of liquids with a variety of viscosities. Chill the fluids within a cold water bath to a consistent temperature near 0°C.	For each group: – two samples of liquids, 15 mL each plus water – 1 plastic measuring spoon – 1 stopwatch – 1 ruler – 1 waterproof marker In addition, students will need sufficient amounts of: – paper towels, soap, water to clean the workstation – rubber gloves
1 day before	Make copies of BLM 3-11, The Flow Rate of Liquids (optional).	

Time Required

- 40 min if done as a stand-alone lab, 20 min as an extension of Activity 7-2B
- In order to complete the activity in this time frame, students must come fully prepared, with data tables drawn up and hypotheses written.

Safety Precautions

- Ensure students keep their hands away from their face and mouth. Ensure students do not eat or drink any substances in the science laboratory.
- Have students wipe up all spills immediately. Ensure students do not leave floors wet.
- Ensure students dispose of all materials properly, according to your instructions.

Science Background

Most liquids become more viscous as they cool, because the particles are slower, are closer, and experience stronger attractive forces. A 10°C decrease in temperature from Activity 7-2B to Activity 7-3A will not affect all fluids in the same way. Water will become a little more viscous; molasses and honey will almost stop flowing altogether.

The ramp will be much warmer than the cool fluids. If the flow time is longer than about 30 seconds, the fluids will be warmed by the ramp, and the difference in flow rates will not be as dramatic. Best fluids for this lab will be water, vegetable oil, detergent, glycerine, but not molasses or honey.

Activity Notes

- Have students set up their ramps exactly as Activity 7-2B (see teaching notes on page 3-14).
- Instruct students to prepare the samples immediately before each test, so that the fluids do not have a chance to warm up.
- Instruct students to wash all of the ramps with warm, soapy water; dry them; and put them away. Have students dispose of all materials safely.

Supporting Diverse Student Needs

- The instructions are quite complex, and English language learners might need considerable support. Place English language learners with fluent English speakers. Be sure that each student has a significant role.
- In a group of three, students will have a choice of roles to play, including spoon student, timer, and marshall. Each role offers opportunities for students with different dominant intelligences.
- Have students who have trouble recording use the data table template on BLM 3-11, The Flow Rate of Liquids, once again, instead of creating their own.
- Students who see opportunities to improve the measurement should be encouraged to quickly draw up a plan, present it to the teacher for approval, and then proceed with the modification.

What Did You Find Out? Answers

1. Students are likely to observe that fluids flow more slowly when they are cooled.
2. In the cool fluids, the particles are moving more slowly, are closer together, and experience larger forces of attraction. These factors increase the viscosity of the fluid.

Think About It Activity 7-3B

Flowing Fluid Floods City, p. 291

Purpose

- Students relate the concept of viscosity to a historical disaster.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
Immediately	All resources are included in the student textbook.	student textbook, p. 291

Time Required

- 25 min

Science Background

Students will need a working familiarity with the factors affecting viscosity. Molasses has a very great viscosity because it has a solution with a very high

concentration of sugars. The sugar particles are relatively large, which increases the viscosity further. The force of attraction between sugar and water is also quite great, further increasing the viscosity.
Molasses is also very dense, about twice the density of water. The tank was 15 m deep, so the pressure under the molasses would be about three atmospheres. This pressure is about twice that in your car's tires! The greater the pressure is, the greater the tendency to flow is.

The molasses might have been quite warm, perhaps because the temperature was high that day, and perhaps because of other factors. The molasses was constantly fermenting, and may have been filled with foamy bubbles at the time. Whatever caused the tank to burst, the entire volume of molasses fell 15 m (about four storeys!) to the street.
We have found that shaking a substance makes it flow more readily. Whatever the viscosity of the molasses is, its ability to flow was probably increased by its motion through the streets.

Activity Notes

- Have students read question 1, parts (a) to (e), before they read the newspaper article.
- Have a student read the newspaper article out loud. Reread any parts that need emphasis. Have students answer each part of question 1 in writing as they read.
- After students have read the entire article, have them complete the activity by answering the remaining questions.

Supporting Diverse Student Needs

- Many students may have never seen a tank of this size. Obtain visuals of tanks that are similar to the tank that held the molasses to show the class.
- Have students read out loud, and repeat parts that need emphasis to help students with perceptual difficulties.
- Review the answers orally. Involve English language learners as appropriate to provide speaking practice.
- Pairs of students might work together to check each other's spelling and writing.
- Visual-spatial learners may benefit from creating a diagram, including the tank and some people, as part of their answer to What Did You Find Out? question 3.

What Did You Find Out? Answers

1. (a) The date was January 15, 1919.
   (b) The weather was unusually warm.
   (c) The first clue that something was about to happen was a low rumbling sound, followed by an explosive "crack."
   (d) The molasses poured out of the tank at a speed of 60 km/h.
   (e) The United States Industrial Alcohol Company was accused of being responsible for the accident.
2. Students might mention that the fermentation might have sped up by the warm temperatures or that the gases in the tank might have expanded in the warm temperatures.
3. The temperature of the molasses was warmer than normal on that January day. The kinetic energy of the sugar and water particles was a little greater than ordinary. These particles would be slightly farther apart, and would experience slightly less attractive force. When the tank broke, the molasses fell 15 m (four storeys) to the street, increasing its kinetic energy.
   The combination of the higher temperature, and the additional kinetic energy from the fall, provided enough kinetic energy to allow the molasses to flow as fast as 60 km/h.

Conduct an Investigation 7-3C

Viscosity Plunge, pp. 292–293

Purpose

- Students conduct a quantitative investigation into the relationship between the temperature of a liquid and its viscosity.
- This is an opportunity to learn safe handling of hot liquids.
- This is an opportunity to learn and improve graphing skills.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 week before	Be sure equipment is available. Obtain all necessary equipment.	For each group: – lab stand, thermometer clamp, and iron ring – hot plate – thermometer, stopwatch, ruler – stirring rod, tongs – 250 mL beaker, corn syrup – 15–20 small metal balls
1 day before	Make copies of BLM 3-15, Viscosity Plunge (optional).	
1 hour before	Prepare beakers of corn syrup. Prepare the lab stations.	

Time Required

- 40 min
- In order to complete the activity in this time, students MUST come fully prepared, with their data table drawn, a hypothesis written out, and the procedure read.

Safety Precautions

- Thermal Safety: high temperatures. Insulated gloves are required. Instruct students not to touch the hot plate or the hot syrup.
- Eye Protection is required.
- Lab coat is required.
- Allow corn syrup to cool before disposal.
- To prevent dangerous spills of hot liquid, use an iron ring or a large clamp to secure the beaker on the hot plate.
- Avoid the use of larger marbles; they might break the bottom of the beaker.
- Students must not drop the marbles, but should release them gently at the top of the liquid.

Science Background

The temperature of the corn syrup is a measure of the average kinetic energy of the particles in the syrup. When the temperature of the syrup is increased, the kinetic energy of the particles increases. As the particles increase in kinetic energy, they speed up, move apart, and experience weaker attractive forces. The viscosity should decrease.

In general, viscosity does not decrease in proportion with the temperature change. The last 10°C increase may affect viscosity more than the first 10°C increase.

Activity Notes

- Have students set up the equipment, being sure to secure the beaker with an iron ring or large clamp to prevent spills.
- Do not fill the beaker more than three-quarters full of corn syrup.
- Set the heat to medium at first. The syrup may burn if heated too quickly.
- The metal marbles for this activity are easily obtained at any local hardware store. The product is actually slingshot ammunition, and packages containing many marbles are very affordable.
- It is important to stir gently. If heating is not even, the results will be affected.
- It may be more practical to wait until the next class day for students to clean up and put away the apparatus.
- It is possible to do a "prepared" version of this activity by using sealed tubes. Obtain sealable test tubes and fill them almost to the top with corn syrup. Make sure to leave some room for thermal expansion. Add one metal marble to the tube and seal it. Instead of heating corn syrup on the hot plate, use a beaker deep enough to submerge the test tubes. Monitor the temperature of the water with a thermometer. As temperature values are reached (as noted in step 7 of the procedure), briefly remove and invert the test tube. Record the time it takes for the marble to reach the other end of the test tube. Put the test tube back into the water and repeat the process. The advantages of this technique are that there is less mess than with corn syrup filled beakers, and the test tubes can be re-used without the need for re-filling. The drawback to this technique is the corn syrup temperature is not directly taken, so it is not as accurate. Also, the corn syrup in the test tubes will not heat as evenly as stirred corn syrup in a beaker.
- You may want to hand out BLM 3-15, Viscosity Plunge, for students to record their data.

Supporting Diverse Student Needs

- Allow English language learners to prepare their data tables with the materials close by so that they may match terms with the actual materials.
- Body-kinesthetic learners will enjoy conducting this experiment. Students who have good logical-mathematical abilities will excel at performing the calculations. Ensuring that each group includes these two types of learners will help all students experience success.
- Students who have difficulty with math conventions may find the arithmetic easier if you replace (cm / s) with (cm ÷ s).
- Remind students that a best-fit line shows trends in data and passes through the centre of the data, but not necessarily through any of the data points.
- To help students with weak graph-reading skills, discuss answers to Conclude and Apply question 5 as a class. Have students justify each of their answers by referring to the diagram.
- As an extension, have students research the meaning of the term "extrapolation." Have students extrapolate their graphs and provide predictions of flow rate at higher and lower temperatures than were recorded in the activity. Have students answer the question, "How will temperature extremes affect the relationship between flow rate and temperature?" The answer to this question is challenging—if the corn syrup continues to be heated, eventually it will boil, and flow rate would increase dramatically. On the other temperature extreme, if corn syrup were to solidify, there could

be no flow rate, as marbles would not be able to pass through.

Analyze Answers

1. The rates of fall will depend on experimental results, but the rates of fall should increase with the increasing corn syrup temperature.
2. The independent variable is temperature. The dependent variable is flow rate. The controlled variables are type of fluid, distance to fall through fluid, and type of object dropped.
3. Graphs will vary according to experimental results, but graphs should rise as the rate of fall increases with temperature.

Conclude and Apply Answers

1. The rate of fall increases with temperature.
2. The rate of fall increases as the viscosity of the corn syrup decreases.
3. Viscosity decreases as temperature increases.
4. Answer will be determined by the individual graph results. Students will need to find 55°C on the horizontal axis of their graph, then follow that line up to the best-fit line on their graph. Follow along a horizontal line from the point at which they met the best-fit line to the vertical axis. The point at which they meet the vertical axis indicates the rate of fall.
5. (a) 40°C
   (b) Liquid B
   (c) Liquid A

Find Out Activity 7-3D

Cool Contraction, p. 294

Purpose

- Students observe evidence of thermal contraction.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather the materials and apparatus. Make copies of BLM 3-16, Cool Contraction (optional).	For each group: – Erlenmeyer flask – small round balloon – large bowl – ice – protective mitt – cold water – very hot water

Time Required

- 40 min

Safety Precautions

- Hot water can burn. Students must wear a protective mitt when handling the flask with hot water.
- Have students check that the flask does not have any chips or cracks in it.
- Be aware of any latex allergies if the balloons are made of latex.

Science Background

The hot water is used to heat the interior of the flask. By doing so, the particles of air and water vapour inside the flask move faster and farther apart (expansion), and some particles leave the flask.

When the flask is sealed by the balloon and then cooled, the air and water vapour particles inside lose energy and move closer together (contraction). Any water vapour molecules inside the flask also condense and become much closer together. This situation creates an area of low pressure inside the flask. Consequently, the relatively higher pressure in the room pushes the balloon into the flask.

Activity Notes

- Long, "pencil" balloons will not work for this activity. Use a regular round-shaped balloon.
- Demonstrate the technique for placing the balloon on the flask and placing the flask gently into the ice water bath.
- After the balloon is placed on the flask and the flask is placed into the ice water bath, the particles inside the flask reduce in volume, creating an area of low pressure. This process should force the balloon into the flask. Occasionally, however, the pressure will cause the balloon to flatten completely, and it may not enter the flask. Holding the tip of the balloon upright sometimes solves this problem.

Supporting Diverse Student Needs

- Have visual-spatial learners draw a diagram to explain how the particle theory supports their answer to What Did You Find Out? questions 2 and 3. They can use BLM 3-16, Cool Contraction, to do this.
- For enrichment, consider posing the problem of getting a hard-boiled egg into the flask without physically pushing on the egg. Place a boiled egg (shell removed) on top of the flask to illustrate that the egg will not fit through. Then ask for student responses to the problem. Some students may suggest pushing on the egg. This action is futile, however, because forcing the egg simply breaks the egg into pieces. The solution to the problem is to create a low-pressure area inside the flask, as was done in the activity. Quickly placing the egg on the heated flask and then cooling the flask will cause atmospheric pressure to force the egg into the flask. An alternative method of heating the air

in the flask is to light a small piece of paper on fire and toss it into the flask, and immediately place the egg on top. If you use this method, be sure to take the necessary fire safety precautions.

What Did You Find Out? Answers

1. The temperature of the air inside the flask was at first increased by the hot water and then decreased when the flask was put into the ice water bath.
2. The kinetic energy of the particles was high when the hot water was in the flask, but then much reduced when the flask was put into the ice water bath.
3. When the balloon was first put on the flask, the high kinetic energy of the particles made the particles take up as much space as possible, forcing the balloon outward. When the flask was put into the ice water bath, the decreasing kinetic energy of the particles in the flask made the particles move closer together and take up less space. As a result, the balloon was forced into the flask by the pressure of the atmosphere above it.
4. (a) and (b) Students' answers may vary but should describe techniques for re-heating the flask. Re-heating will increase the kinetic energy of the particles in the flask, increasing their motion and the space they take up, thereby pushing the balloon outward and inflating it.

Conduct an Investigation 7-3E

The Effect of Concentration on Viscosity, pp. 295–296

Purpose

- Students investigate the flow rate of three different concentrations of a fluid, using a scale for flow rate based upon measurements of distance and time. This activity is very similar to Investigation 7-2B.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 week before	Gather sufficient materials for student ramps: sheets of metal, plastic, or glass. Consider making up solutions ahead of time. 100 g sugar can dissolve in 100 mL of hot water, and then can be cooled. Keep all fluids in the same location, overnight, to be certain that all are at the same temperature.	For each group: – 150 g of sugar – 1 plastic measuring spoon – 1 stopwatch – 1 ruler – 1 waterproof marker In addition, students will need sufficient amounts of the following: – paper towels, soap, water to clean the workstation – rubber gloves
1 day before	Make copies of BLM 3-17, The Effect of Concentration on Viscosity (optional).	

Time Required

- 40 min
- In order to complete the activity in this time, students MUST come fully prepared, with data tables drawn, a hypothesis written, and the procedure read.

Safety Precautions

- Students should keep their hands away from their face and mouth and should never eat or drink any substances in the science laboratory.
- Ensure students wipe up all spills immediately. Ensure they do not leave the floors wet.
- Be sure students are aware of proper disposal procedures for the materials they will be using.

Science Background

White table sugar is sucrose. One sucrose molecule is 25 times larger than a water molecule, and 10 times stickier! Adding sucrose to the water will tangle up the water particles, making them less able to move. The greater the number of big, sticky sugar particles in the solution, the greater the viscosity.

The concentration is expressed as grams of sugar per millilitres of water. We expect that the viscosity of the solution will increase as the concentration increases.

The independent variable is the concentration. The dependent variable is the flow rate, or viscosity.

Because we are using only one kind of solute, the size and the stickiness of the sugar molecules are the controlled variables.

Activity Notes

- Arrange students in groups of two, three, or four. Have them read and discuss the instructions, and prepare a hypothesis.
- Have a member of each group draw a carefully ruled table, as shown in the lab on page 295.
- Have students measure two masses of sugar, the first 20 g and the second 45 g. These masses are to be added to 100 mL of water, and stirred until completely dissolved. Some students should calculate the concentrations while others mix the solutions. The second solution should be roughly twice the concentration of the first. Compared to water, the difference in viscosity will not be very dramatic, unless the concentrations of sugar are quite high.
- Instruct students to set up the ramp, and rule two lines 10 cm apart as in Activities 7-2B and 7-3A.
- With the measuring spoon full of one of the solutions, place the bottom of the spoon on the "spoon line" above the start line.
- The roles of marshall, spoon student, timer, and recorder are assigned at this time. The marshall, timer, and recorder roles can be combined in any combination to suit the number of students in the group.
- The timer counts down to zero, and starts the stopwatch exactly as the spoon student rocks the spoon downward smoothly and quickly. The contents of the spoon will spill out right on the start line, just as the timer is started.
- The timer stops the clock when the dribble reaches the finish line, regardless of the amount of fluid that actually reaches the line.
- The procedure is repeated on a clean surface of the ramp.
- Give students instructions for cleaning up the ramp and disposing of all materials.
- Students can record their results on BLM 3-17, The Effect of Concentration on Viscosity.
- Alternatively, students could do a "prepared" version of this activity by using sealed tubes. Prepare five solutions, with different concentrations of sugar, in warm water. Obtain sealable test tubes. Label each tube with the concentration, and fill them almost to the top with warm solution. Add one metal marble to the tube, and seal it with a soft rubber stopper. As the solution cools, it will be drawn tightly into the test tube.
  To perform the test, invert the tube and record the time it takes for the marble to reach the bottom. Students must trade test tubes to measure all five solutions. The advantages of this technique are that there is less mess than an open ramp, and the test tubes can be re-used without the need for refilling.

Supporting Diverse Student Needs

- The instructions are quite complex, and English language learners might need considerable support. Place English language learners with fluent speakers of English. Be sure that each student has a significant role.
- In a group of four, students will have a choice of roles to play. Each role offers opportunities for students with different dominant intelligences.
- Students who see opportunities to improve the measurement should be encouraged to quickly draw up a plan, present it to the teacher for approval, and then proceed with the modification.

Analyze Answers

1. Students' answers may vary.
2. The most concentrated solution has the lowest flow.
3. The most concentrated solution is the most viscous.
4. Equipment errors include such things as variations in the smoothness of the ramp and the slope of the ramp. Human errors include errors of perception in timing and measuring, variations in the way the liquid was tipped, etc. Students should give clear instructions to reduce or eliminate each error.

Conclude and Apply Answers

1. The median flow rates will be that of the smaller concentration of sugar. The mean flow rate should also be very close to this number.
2. The greater the concentration of a large, sticky particle in a solution is, the slower the flow rate is in that solution.
3. Viscosity is proportional to concentration of solute.

SECTION 7.3 ASSESSMENT, p. 297

Check Your Understanding Answers

Checking Concepts

1. The cornstarch is a thickener. It increases the viscosity of the gravy.
2. During the hot summer months, pavement is less viscous. It is easier to pack, and settles more completely as the traffic rolls over it.

3. Place the container of molasses into a large bowl of hot water. As the molasses warms up, it becomes less viscous. Alternatively, add some of the water from the recipe to the container. The diluted molasses flows more readily.
4. Tar is much more viscous when it is cool. During the winter, the tar is a glassy solid.
5. Summer oil is more viscous than winter oil. Modern motor oils have additives that actually get thicker as the temperature increases, keeping the oil about the same viscosity for both winter and summer.
6. Warm the bottle of maple syrup in a bowl of hot water.

Understanding Key Ideas

7. As the temperature increases, the particles move more quickly. This process increases the spaces between the particles, and reduces the attractive forces between the particles. The resistance to flow is reduced. Students' diagrams should show speed, spaces, and forces.
8. Large particles do not flow past each other as easily as small particles.
9. The viscosity of gas actually increases with greater temperature. The random motion of the oxygen particles slows the flow along a tube. This effect is the opposite of liquids. To increase the viscosity of oxygen at room temperature, I would raise the temperature.

Pause and Reflect Answer

Students' answers could be quite complex. Increasing the pressure on a fluid, or increasing the concentration of something dissolved in it might affect its viscosity. A fluid that consists of many different sizes of particles can be much more resistant to motion than a fluid with only one size of particle. Think how much more difficult it is to shovel soil than sand. Particles that are long, and capable of tangling, will be more viscous than round particles. Particles that can link up, like gelatin, can make a solution extremely viscous. Students should explain their reasoning.

Other Assessment Opportunities

- Consult the Unit front matter for a list of applicable Assessment BLMs.

CHAPTER 7 ASSESSMENT, pp. 298–299

PREPARE YOUR OWN SUMMARY

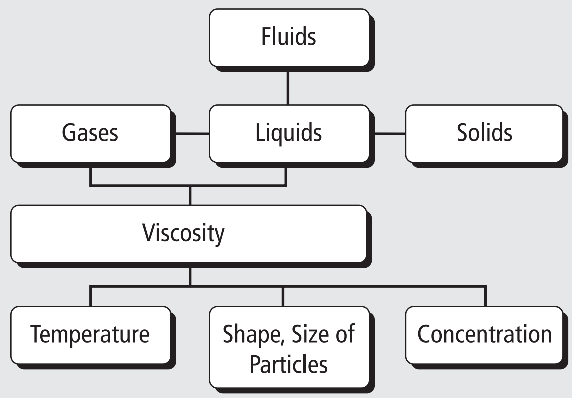
Students' summaries should incorporate the following main ideas:

1. The Particle Theory of Matter
   - All matter is made up of very small particles.
   - All particles in a pure substance are the same. Different substances are made of different particles.
   - There are empty spaces in between particles.
   - The particles of matter are always moving. As particles gain energy, they move faster.
   - The particles in a substance are attracted to one another. The strength of the attractive force depends on the type of particle.
2. Changes of State of Matter
   - As a substance in the solid state is heated, the energy it gains makes the space in between particles get larger.
   - If enough energy is added, a solid will melt, and in turn, the liquid will turn into a gas.
   - If a substance in the gas state loses energy, the gas can turn to liquid, then solid, as the particles lose energy, move slower, and get closer together.
3. Measuring Flow Rate of Fluids
   - Flow rate is the speed of a fluid as it flows from one point to another.
   - The greater the viscosity of a fluid is, the lower its flow rate is.
   - The greater the flow rate of a fluid is, the lower its viscosity is.
4. Effects of Temperature on Fluids and Their Viscosities
   - Increasing temperature increases kinetic energy and speed of the particles.
   - As particles move faster, they move farther apart and experience less attractive force.
   - Increasing temperature causes viscosity of liquids to decrease.
5. Effects of Temperature on Gases and Their Viscosities
   - The particles in a gas are free to move at high speeds.
   - Increasing the temperature of a gas increases the random motion of the particles.
   - As the particles collide more frequently, they flow less readily, and their viscosity increases.

CHAPTER REVIEW ANSWERS

Checking Concepts

1. A fluid is any substance that can flow.
2. The particles in solids are held close together by strong, attractive forces, and cannot move around and between each other. In liquids and gases, the spaces between the particles are larger, the forces are weaker, and the particles are able to move around each other. Gases and liquids are free to flow; solids are not.
3. (a) The particles of a solid are close together, strongly attracted, and vibrate about fixed positions. As energy is added, the particles vibrate more quickly, and over a greater distance. The particles gradually become farther apart, causing the forces between them to decrease. Eventually, the particles move fast enough to overcome the forces of attraction and move around each other.
   (b) In a gas, the particles are far apart, experience very weak attractive forces, and are totally free to move about at great speed. As the gas is cooled, the particles are slowed down. Eventually, the particles are moving slowly enough that the attractive forces are able to hold the particles together. At this point, the gas becomes condensed to a liquid.
4. In condensation, energy is removed. The particles move more slowly and are attracted more strongly to each other. The gas becomes a liquid. In evaporation, energy is added to a liquid, causing its particles to move farther apart. This process weakens the attractive forces. With enough kinetic energy, the particles separate into a gas.
5. Students' answers may vary. If the bottom of a bowl is pressed into the bucket of sand, the bowl does not cause the sand to flow. The sand behaves as a solid. If a small amount of water is added to the sand to dampen it, the attractive force increases between the sand grains. The sand does not pour, and behaves like a solid.
6. resistance to flow
7. (a) and (b) The main factors that affect the viscosity of fluids are the following:
   - Size of the particles: The greater the size, the more difficult it is for particles to move past each other.
   - Nature of the particle: Particles that are sticky, or are long and able to tangle, will reduce the ability of a substance to flow.
   - Concentration: The greater the concentration of a solute is, the greater its effect is on the viscosity. The more particles of a substance that are present, the more they will affect the viscosity.
   - Temperature. The greater the temperature of a fluid is, the greater the kinetic energy of its particles is. At high kinetic energies, liquids flow faster, and are less viscous. Gases become more viscous at high temperatures because the random high-speed motion of the gas particles increases the chaos of the flowing gas, and causes it to flow more slowly.
8. Students can record their answer on BLM 3-19, Chapter 7 Concept Map.



9. At colder temperatures inside the refrigerator, particles experience slower motion, smaller spaces, and greater attractive forces. Therefore, they flow more slowly.
10. Kinetic energy is the energy due to the motion of a particle.

Understanding Key Ideas

11. The particles in a gas are free to move large distances. As they are heated, the random motion of gas particles increases, and the gas particles collide more frequently with each other and with the sides of the container. This process increases the internal friction of the gas, and the viscosity.
12. Oil molecules are much larger and longer than water molecules. If a water molecule is a bead, then an oil molecule is like 20 beads on a string. Each long, narrow oil particle can tangle with, and be attracted to, many other particles, which causes resistance to flow.

13. The greater the flow rate is, the less the viscosity is. This relationship is called an inverse relationship.
14. (a) Mechanic: Many fluids like motor oil, brake fluid, and transmission fluid are used in motor vehicles. Each fluid has a special viscosity to do a particular job.
    (b) Candy maker: Chocolate, caramel, nougat, and gum drops all flow in their own ways. These materials can be handled and shaped only by someone who understands how their viscosities change with temperature.
    (c) Baker: From thin batters to thick doughs, the baker must know how each substance will behave when mixed, shaped, and heated.
15. (a) The microwave oven gave more kinetic energy to the air and water particles trapped in the bubbles in the marshmallow. As the particles moved faster, they pushed the bubbles outward causing expansion.
    (b) Cooling the marshmallow slowed the air and water particles in the bubbles. At slower speeds, they could not push the bubbles outward, so the bubbles collapsed under the atmospheric pressure.
16. (a) Substance 3 is the most viscous; substance 2 is the least viscous.
    (b) Substance 3 is most likely to be a solid at room temperature.
    (c) Substance 2 has very low viscosity, like water or alcohol. Its particles already move quickly around and past each other. Warming this substance a few degrees has little additional effect on viscosity.

CHAPTER 8 OPENER, pp. 300–301

USING THE PHOTO AND TEXT

Perhaps students have dreamed of flying. Have them close their eyes, and imagine floating upward. Ask, "What does your body feel like as you are gently lifted into the sky? Do you feel 'lighter'? Do you feel yourself 'spread out,' like a dandelion seed?" Explain that when you dream of flying, your intuition can grasp some of the ideas of density.

Tell students that one of the factors that affects density is mass. Explain that in our imagination, we know that we could only float on air if our mass was smaller than that of the air. Then explain that another factor that affects density is volume.

The mass of the balloon on page 300 is quite small, about the same as a camper trailer. When it is fully expanded, the balloon's volume is huge, as much as two houses! When its small mass is spread out over its very large volume, the balloon can be lifted away from the Earth by the air around us.

The intuitive, dreamy experience of floating through the air is something that students should keep with them as they study the science of density.

Using a Demonstration

The difference in the density of gases can be dramatically shown with three balloons. You will need three balloons and one fresh 2 L bottle of carbonated water, or soda water. The first balloon should be filled with helium. Fill the second balloon with air, perhaps giving the task of inflating the balloon to a student. The third balloon should be filled with carbon dioxide from the bottle of soda water. Open the bottle carefully. Stretch the neck of the balloon over the neck of the open bottle, and snap it on. You can get the soda water to give up carbon dioxide gas by tapping the side of the bottle with a pencil or ruler. The balloon should inflate in a few minutes. Twist the neck of the balloon to seal it, remove it from the bottle, and tie it shut.

The balloon containing helium will rise to the ceiling. The balloon containing air will behave in a familiar way. The balloon containing carbon dioxide will fall quickly to the floor.

If the balloons are the same volume, they contain the same number of gas particles. The mass of the particles is very different, however.

The mass of each helium particle is 4 units, the mass of each air particle is about 30 units, and the mass of each carbon dioxide particle is 44 units. The difference in mass accounts for the difference in density.

USING THE WHAT YOU WILL LEARN / WHY IT IS IMPORTANT / SKILLS YOU WILL USE

Use this opportunity to have students express what they mean by the terms "mass," "volume," and "density." Ask students to prepare a table of three columns, and to write their current understanding of the terms "mass," "volume," and "density." When about half the class is finished with this task, have students form pairs and share their ideas with each other.

Measurement of density requires that students be skillful in measuring solid dimensions, liquid volumes, and mass. Have three measuring instruments available: a metre stick, a large graduated cylinder, and a balance. Ask students to identify the measuring instruments and to demonstrate how to use them.

USING THE FOLDABLES™ FEATURE

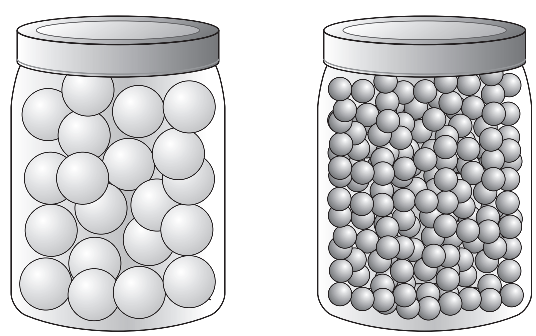
See the Foldables section of this resource. Creating this Foldable should help students integrate what they learned about the three states of matter in Chapter 7 with what they will learn in this chapter.

8.1 DEFINING DENSITY

BACKGROUND INFORMATION

It is important to keep reinforcing the particle theory of matter. Density is related to the mass of each particle, the volume of each particle, and the packing of the particles.

You can model this theory by obtaining two plastic jars, and filling one with large plastic balls or glass marbles; and the other with small steel balls, like slingshot pellets. Ask students, "What might make the jars have different densities?"



- Fewer larger particles will fit into the volume of the jar, there will be more space between them, and the density of the jar will be greater. More smaller particles will fit into the volume of the jar, and the density of the jar will be greater.

- The more massive each particle is, the greater the density of the jar is; the smaller the mass of each particle is, the lesser the density of the jar is.

All of the other factors that affect density, such as temperature, state of matter, and concentration in solution are all related back to the particle theory of matter.

Another very important distinction to make is the difference between "mass" and "weight." The mass of an apple is the amount of matter in the apple. The mass is the total collection of atoms in the apple. Weight is a very different idea. If you hold the apple in your hand so that it is not moving, gravity pulls all of those atoms downward. The *weight* of the apple is equal to *the pull of gravity* that you feel on the matter in the apple.

COMMON MISCONCEPTIONS

- The use of the word "heavy" is confusing for some students. The terms "mass," "volume," and "density" are not intuitively obvious to people. Our muscles, bones, and nerves do not discriminate among "mass," "volume," and "density," but rather group them together, as one bodily experience. Anything with a small volume or a large mass or a large density is often described simply as "heavy." Teachers must take great care to model and require the use of the precise terms "mass," "volume," and "density," and to avoid the confusing word "heavy."
- Students might confuse the terms "mass" and "weight." The *mass* of a book is *the amount of matter* in the book. The mass of the book does not change, no matter where the book is located. The *weight* of the book can change. If the book is in the air and not moving, then the *weight* of the book is equal to *the force of gravity* on the book. If gravity changes, for example if the book is moved to the moon, then the weight of the book will also change.
- Some students might have difficulty with division. The formal operation of division is perhaps the most difficult mathematical operation that young people learn in elementary school. Small wonder, then, that any kind of ratio is not easily grasped by students. Density is a ratio, or a division, of mass by volume. Take care to express density as "1.25 grams *per* millilitre." To help students further, you might explain, "that is 1.25 g in every millilitre," so as to avoid the intellectual difficulty that many students face when confronted with a ratio.
- On page 303 of the student textbook, students will read that attractive forces between particles of a solid are stronger than those between particles of a liquid. Some students may be confused because they remember that when solid sugar is placed in liquid water it comes apart (dissolves). Point out that the description on page 303 is an accurate way to describe solids and fluids, but that some solids will dissolve in certain fluids due to their unique combinations of properties.

ADVANCE PREPARATION

- Film canisters are required, but they are becoming harder to find. Check some photo shops. If you get them, hold on to them! Alternatively, you can purchase small plastic vials or bottles from a pharmacy or a bulk store.
- A lava lamp is useful in Section 8.3, but you could set it up now and have it operating throughout the time that you are teaching this chapter. It will serve as a constant example of the effects of changing densities caused by changing temperature.
- Consult the Unit front matter for a list of BLMs that can be used when teaching this section.

INTRODUCING THE SECTION, p. 302

Using the Text

On page 302, students will read the following line: "Density describes how closely packed together the particles are in a material."

Ask students to contribute examples of "particles that are closely packed" as opposed to "particles that are spaced apart." Any kind of particle can be used: corn flakes, people, houses, trees. Accept all students' responses and write them on the board. Emphasize the best examples. Ask students to consider changing or adding to any examples.

Using the Key Terms and Section Summary

At the beginning of each section in the student textbook are the Key Terms and section summary. Both can be used as a pre-reading strategy and a review tool. Before reading the text in the section, students should be able to define the Key Terms by scanning the text and using the Glossary. The Key Terms include terms from the curriculum outcomes and additional terms that are important for students to know and understand.

The section summary provides an overview of the key concepts being covered in the section. Students may not know all the concepts and terms described in the summary, but they can use this information to help guide them through their reading.

After reading the section, students can go back to the Key Terms and section summary to consolidate their understanding and identify areas that require clarification. At the end of the chapter or unit, students can use the Key Terms and section summary for review. BLM 3-2, Unit 3 Key Terms, and BLM 3-4, Chapter 8 Key Terms, can be used to assist students.

Using a Demonstration

Have two fluids of very different densities available. Many organic substances, like vegetable oil or some alcohols, have a density around 0.90 g/mL. Molasses has a density of 1.4 g/mL, about double that of oil. Prepare two identical empty and cleaned out cardboard cream or milk containers by filling one with vegetable oil and the other with molasses. Students should be able to perceive the difference in mass. Alternatively, prepare two different containers with identical masses of liquid. A small container of molasses will have the same mass as a much larger volume of vegetable oil. Once again, the difference in volume can be perceived directly by students.
Ask questions:

- Which container has the particles with the least mass? (oil, alcohol)
- Which container has the particles that are packed closest together? (molasses)
- Which container has the greatest mass? etc.

TEACHING THE SECTION, pp. 302–306

Using Reading

Pre-reading—Predict-Read-Verify

Instruct students to organize themselves into small groups, with their books closed, and three blank sheets of note paper. One student opens a textbook to pages 302 and 303, and reads *only* the headings: "Defining Density," "Density and the Particle Theory," and "Density of Solids, Liquids, and Gases." The other students write the headings at the top of each page.

Instruct students to work silently and alone for two minutes, writing what they predict the text will present under each heading at the top of each page.

Have students discuss their predictions for three minutes, so that each can add to and modify their own predictions.

During Reading—Note Taking

Have students read and write silently for 10 minutes, jotting down the main ideas under each heading at the bottom of each page.

Supporting Diverse Student Needs

- Have students draw a line down their notebook page so that $\frac{1}{3}$ of the page is to the left of the line and $\frac{2}{3}$ of the page is to the right of the line. For each topic in this section (density of solids, density of liquids, and density of gases), have them make written notes on the right side of the page, and draw a helpful diagram on the left side. Diagrams based on the particle theory will do the best job of illustrating the concepts. Diagrams will be especially helpful to visual learners, and to students with written output difficulties.

After Reading—Reflect, Verify, and Evaluate

Instruct students to discuss any similarities and differences between their predictions and their notes. Have them make corrections as needed. Students can use the last page for answers to the Reading Check questions.

Reading Check Answers, p. 306

1. Students' answers will vary but should show that students understand that when particles are more closely packed together, density is greater.
2. Students' answers will vary. Their explanations should include the following:
   - Particles in solids have fewer empty spaces between them than most fluids.
   - The attractive forces between the particles in solids prevent the particles from coming apart. An object that moves through a fluid actually pushes the particles of the fluid apart because the attractive forces between the particles are not as strong as in most solids.
3. The only way in which the density of a pure substance can change is if the substance undergoes a change of temperature or a change of state. For example, the density of water decreases when the water warms, and then changes from a liquid state to water vapour.
4. Whenever a liquid has a greater density than a solid, the solid will float on top of the liquid. The force of gravity upon one unit volume of that liquid will be greater than the force of gravity on the solid. Gravity will pull the more massive particles of the liquid to a lower level than the less massive particles of the solid. This process forces the solid to float on the top. You might ask students, "Will a cork float on water in the zero gravity of space orbit?" (No, if the environment is truly zero gravity.)

USING THE ACTIVITY

- Activity 8-1A on page 305 of the student textbook could easily be used before the reading assignment,

as a concrete experience of density. It could also be used after the reading to confirm the concepts.
- Detailed notes on doing the activities follow.

Find Out Activity 8-1A

Differing Densities, p. 305

Purpose

- Students discover that substances that have the same volume can have different masses, and students infer that if the volume is the same, but the mass is different, then the density of the substances must be different.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
2 weeks before	Ask students, colleagues, and photo shop employees for empty film canisters.	For each group: – one set of film canisters – granular and liquid materials to put in the containers (e.g., plastic beads, metal ball bearings, paper clips, modelling clay, feathers, air, water, sand, salt, sugar, flour, water, vinegar, gravel, pennies (or other coins), crumpled paper, tissue paper, cotton balls, molasses, vegetable oil, or fabric softener)
1 week before	Gather granular and liquid materials for the containers. (See suggestions below.) Prepare your master list of container numbers and contents.	
1 day before	Make copies of BLM 3-20, Differing Densities (optional).	

Time Required

- 10 min if students use the table on BLM 3-20, Differing Densities; 20 min if students make their own table as found in the student textbook

Safety Precautions

- Students should wear lab coats and safety goggles.
- Students should not open the containers.
- Remind students not to taste any samples if the containers happen to spill, leak, or open.
- Students should wash their hands after the activity.

Science Background

With the containers completely filled, the volumes are identical. The density of each substance is directly proportional to the mass of each container. Controlling the volume in this way reduces the complexity of the lab.

Activity Notes

- Try to obtain enough film canisters so that there are five in each set.
- You may be able to obtain large quantities of film containers from a photograph development lab. If this option is not available in your area, you might want to substitute empty prescription bottles for the film containers. Ensure that the containers are all the same size, and block out the contents so that students cannot see what is inside.
- Fill each container with exactly the same volume of material.
- Fill the containers as full as possible so that students cannot guess the contents by shaking the container and listening to how it sounds.
- Possible materials for filling the containers include plastic beads, metal ball bearings, paper clips, modelling clay, feathers, air, water, sand, salt, sugar, flour, water, vinegar, gravel, pennies (or other coins), crumpled paper, tissue paper, cotton balls, molasses, vegetable oil, or fabric softener.
- If you use liquids, you may want to tape around the lids for extra spill-proofing.
- You might consider using granular materials of a very similar size: glass or plastic beads, steel or copper shot, small marshmallows, rice, etc. These materials can be used to reinforce the particle explanation for density.

Supporting Diverse Student Needs

- Arrange the groups so one fluent speaker of English is working with each English language learner. Ask English language learners to participate fully in recording and analyzing data.
- BLM 3-20, Differing Densities includes a prepared table for recording results. This table will be helpful to students who have difficulty transferring the table from the student textbook.
- Allow students who have trouble expressing their ideas in writing to answer What Did You Find Out? question 2 orally.
- Pose this question as enrichment: "How could we find the volume of one film canister? How many ways can you think of?" Provide this question as a problem to be solved. There are several approaches.

What Did You Find Out? Answers

1. Students' answers will vary, depending on the materials in the containers.
2. It is important to keep all the volumes equal in this activity so that the same amount of material is being compared each time. The volume is a controlled variable. (When the volume is the same, but the mass is different for each material, then students can compare the densities of the various materials. If the volumes were different, the observer could not compare

the densities of the materials.) The containers are opaque, so the observer cannot see the materials inside them.

USING THE FEATURES

www Science: The Mercury Barometer, p. 307

This feature can best be used *after* students have acquired a dependable qualitative concept of density, preferably after Activity 8-1A. A mathematical description of density is not required. This feature also relates strongly to Section 9.2: Pressure, Hydraulics, and Pneumatics. Make a note to return to this feature when you are discussing atmospheric pressure on page 355.

The mercury barometer is a fascinating device, for two main reasons: First, the mercury itself is an exotic substance, a metal that is liquid at room temperature. Furthermore, mercury is almost twice as dense as iron, 13.55 times more dense than water, and about 10 000 times more dense than air. Second, students find the barometer quite mysterious in its workings. What causes the mercury to go up the tube?

Obtain 3 m of clear plastic tubing from a hardware store or a wine-making shop. It should have stout walls, but can be any diameter. Obtain several clean, unused disposable plastic droppers from a pharmacy or a science supplier. Cut the very top of the bulb off the droppers, so that you have what resembles a very small, thin funnel.

Prepare a container of cold water with some food colouring in it. Dangle the plastic tubing down into the container from a landing above the container. Push one of the droppers into the top end of the plastic tube, to serve as a mouthpiece. Now ask students if it is possible to suck the water up the tube. This question should generate quite a discussion, with some clear predictions of different outcomes. Invite a volunteer to try it. Usually, the water rises easily for the first few centimetres. As the water rises, however, it becomes increasingly difficult to draw the water up the tube. At some point, the volunteer will have to give up! Change droppers, and allow another student to try.

The experience may convince students that the height of the water column is limited by something. In fact, the water column is being pushed up the tube by the outside atmospheric pressure. No amount of suction, and no vacuum, can "suck" water up the tube past about 10 m. Once the water reaches that height, the mass of the column of water in the tube is equal to the mass of the column of all the air above the tube, all the way up to space.

The mercury in a mercury barometer is 13.55 times more dense than water. A column of mercury 760 mm tall has the same mass as a column of air with the same diameter that goes all the way up into space. As soon as the atmosphere has pushed the mercury up 760 mm, the air can push the mercury no farther, no matter how much taller the vacuum is above the mercury.

Science Watch: Icebergs, p. 308

How much of an iceberg floats? Fill a large measuring cup (1.0 L) with ice cubes. Add cold water precisely to the 1.0 L line. Most of the ice will be below the water line, but some will be above it. Where will the water line be when the ice melts?

Have students predict the level of the water after melting. Let the ice melt over the course of the afternoon. (Students may be surprised that the water level stays in precisely the same place!)

Here is something that you can do to show students how this activity works. The density of liquid water is 1.00 g/mL. Measure and record the mass of an empty plastic bag and twist-tie. Using a graduated cylinder, measure exactly 100 mL of water into the plastic bag. Inflate the bag, twist it shut, and tie it with a twist-tie. Measure and record the mass of the bag plus water plus twist-tie. When you subtract the mass of the bag and twist-tie, you should have put exactly 100 g of water into the bag.

Now put the bag of water into a freezer, being careful to turn the twist-tie to the top. The water will freeze and expand. The mass of ice is still 100 g, but the volume is now 109 cm^3. The density of ice is 0.917 g/cm^3.

If you take that lump of ice out of the bag, and put it into a measuring cup of water, the 100 g of ice will sink until it has displaced exactly 100 g of liquid water (Archimedes' principle). It only has to sink until 100 mL of water are displaced, which leaves 9 cm^3 of ice sticking out above the water level. That little bit of ice sticking up is the iceberg that you see above the ocean!

Measure the level of the water carefully. As the ice melts, it shrinks in volume. The 100 g of ice becomes 100 g of water, which is 100 mL of water. The volume of the melt-water is precisely the same as the volume of water that the ice block displaced. The water level in the measuring cup stays the same!

You might challenge students to use the information given and the scale on a map to estimate the speed of icebergs in the Labrador current, in kilometres per hour.

SECTION 8.1 ASSESSMENT, p. 309

Check Your Understanding Answers

Checking Concepts

1. Gold is red hot in the liquid state. At that temperature, its particles are moving quickly, are far apart, and are less attracted to each other than in the solid state. A number of gold particles in a liquid state occupies a larger volume than the same number of gold particles in a solid state! Liquid gold is slightly less dense than solid gold. Most substances are like this.
2. Water particles are far apart, and air particles are very far apart, and they move easily out of the way as the dolphin passes through them.
3. Various answers are possible. Students' tables should be neat, well organized, and labelled. Items denser than water will sink.
4. Many answers are possible. All answers should include the cause, the density change, and perhaps the observable effect of the density change. Warm air expands, becomes less dense, and rises; cool air contracts, becomes more dense, and descends.
5. The attractive forces between particles are similar to magnetic forces: the closer the particles are, the stronger the force is. In solids, the particles are very close, so the attractive forces are very strong. In gases, the particles are very far apart, and the attractive forces are very weak. Gas particles can move freely. In liquids, the attractive forces are strong enough to hold the particles together, but not strong enough to fix them in one place. In solids, the attractive forces hold all the particles together in one place.

Understanding Key Ideas

6. "Empty space" has no matter in it at all. Empty space is a complete vacuum. "Air" is mostly empty space, but it does have air particles flying around in it.
7. The particles in water are closer, and more strongly attracted to each other. It is harder to move through the particles in a liquid like water.

Pause and Reflect Answer

Oil is less dense than water, and floats on the surface. The floating oil can be gathered up in a boom as it lies on the surface of the water.

Other Assessment Opportunities

- Consult the Unit front matter for a list of applicable Assessment BLMs.

8.2 DETERMINING DENSITY

BACKGROUND INFORMATION

All of the measurements suggested in this section involve two distinct measurements, and a calculation. The student must measure the volume of the matter, and its mass. Then the student must calculate the density as a ratio of $\frac{\text{mass}}{\text{volume}}$.

These measurements require several skills:

- measuring volume of a rectangular solid using V = (length) × (width) × (height)
- measuring volume of a liquid using a graduated cylinder
- measurement of the volume of an irregular solid by displacing a volume of water
- use of a balance
- competency in simple algebra and arithmetic
- competency in rounding, and choosing appropriate units.

It is important that students have these skills as they begin to work with density. Most of these skills have previously been learned in the mathematics curriculum, but are likely to need some review and practice.

Students can find a review of these topics in Science Skill 7, in the Science Skills Guide on page 488. Reviews of Measuring Length, Measuring Area, Measuring Volume, and Measuring Mass will help students recall the concepts and practise the skills. Review of these skills will be enhanced if students have graduated cylinders and balances to work with.

COMMON MISCONCEPTIONS

- Students are likely to confuse the general term "weight" with size, volume, mass, and density. A student who uses the term "weight" may switch among these confused meanings in the same sentence. Avoid the use of the word "weight" as much as you possibly can. To reinforce the use of the precise terms, ask students to rephrase their sentences to use the correct term.

ADVANCE PREPARATION

- Grade 8 Mathematics Section D: Shape and Space (Measurement) should be covered in mathematics class prior to this section to give students the background they will need in measurement of mass and volume. Ideally, it would be completed just before this section is started.

- Each lab group will need one balance. Triple beam balances might be the most available, but they require careful training. Double pan balances are most time-consuming to use, but students appear to learn the concept of mass most readily from them. Electronic balances are very easy to use, but do not help students differentiate between "mass" and "weight."
- Volume-measuring equipment is necessary. Large plastic graduated cylinders, 100 mL or larger, are most useful. Overflow cans can be used, but are not very accurate.
- Sample fluids and solids are needed. Liquids: water, vegetable oil, glycerine, and molasses are most readily available. Solids: wood, steel, and aluminum blocks can be obtained from local small manufacturers. Steel and aluminum scrap is valuable, and you may have to pay for these materials.
- If you decide to build a "density tower" of different substances, you will need a tall, clear container. Add to it, very gently, and in this order: corn syrup, water, one grape, oil, one "super ball," and a bit of foam plastic packing material. In activity 9-1C, students can build a simpler density tower of their own.
- Consult the Unit front matter for a list of BLMs that can be used when teaching this section.

INTRODUCING THE SECTION, p. 310

Using the Text

This section will probably require significant teacher intervention. You may need to review the concepts *volume* and *mass* from Grade 8 Mathematics Section D: Shape and Space (Measurement) before beginning this section. Invite volunteers to teach the class (using real materials) how to find the mass of an object, the volume of a cube, the volume of an amount of water, and the volume of an irregularly shaped solid. Then invite students to look at pages 310, 489, and 490 to compare the methods shown in the text to the methods they have just used.

Using the Key Terms and Section Summary

At the beginning of each section in the student textbook are the Key Terms and section summary. Both can be used as a pre-reading strategy and a review tool. Before reading the text in the section, students should be able to define the Key Terms by scanning the text and using the Glossary. The Key Terms include terms from the curriculum outcomes and additional terms that are important for students to know and understand.

The section summary provides an overview of the key concepts being covered in the section. Students may not know all the concepts and terms described in the summary, but they can use this information to help guide them through their reading.

After reading the section, students can go back to the Key Terms and section summary to consolidate their understanding and identify areas that require clarification. At the end of the chapter or unit, students can use the Key Terms and section summary for review. BLM 8-2, Unit 3 Key Terms, and BLM 3-4, Chapter 8 Key Terms, can be used to assist students.

TEACHING THE SECTION, pp. 311–315

Using Reading

Before beginning this section, students will need a thorough understanding of mass and volume—their meanings, and how to measure them (Grade 8 Mathematics Section D: Shape and Space, Measurement).

Pre-reading—K-W-L (Know-Want to Know-Learned)

Organize students into small groups. Have students prepare four pages with headings that relate to the following:

Measuring Mass
Measuring Volume
Calculating Density
Using Density to Find Mass and Volume.

Instruct students to skim the text silently and alone, jotting down all key terms, highlighted words, subtitles, formulas or any other key ideas that catch their attention on the appropriate pages.

Then, in their groups, have students discuss each noted term. What do they know about it? Can they do the measurement? Have students share this information. They will need about 5 to 10 minutes to go through each section of text.

As a class, compile a list of "Want to Knows."

During Reading—Note Taking

In each group, have one student read one page of text, skipping tables and practice problems. The other students write notes as the reading progresses. When the reader comes to a sample problem, he or she should write the steps on a piece of paper for the others to follow.

If students do not understand the material on the page, they should ask the members of their group for help. If they do not understand within three minutes, they are to note what they do understand, and what they do not understand.

Each group can choose another student to read the next page of text, and continue in this manner until the whole block has been done, about 15 minutes.

Solutions to the practice problems are found below under Practice Problem Answers.

Supporting Diverse Student Needs

- Students without strong mathematics skills may benefit from making one of the triangles that appear in the margin of the student textbook and using it to decide which equation to use to solve each problem.
- After students have read this section in groups and solved the sample problems together, gather any students who are not able to solve the first few practice problems independently into a small group and work with them to solve a few problems. Help them decide what equation to use, then work through each step with them. Complete just the first steps, allowing them to complete the solution in pairs or individually.

After Reading—Reflect and Evaluate

Clarify students' understanding as a class. Ask a student to share one thing that he or she does not understand. Provide the missing information or invite volunteers to provide it. Continue discussing the material until all students' questions have been answered.

Review the "Want to Know" list the class developed before reading. Which questions have been answered?

BLM 3-21, Calculating Density Practice Problems, and BLM 3-22, Working with Density Measurements, provide additional practice calculating density. BLM 3-23, Densities Calculations, provides practice calculating mass and volume, when density is given. BLM 3-24, What is the Density of a Tennis Ball?, provides students with an opportunity to apply all they have learned about measuring volume and mass and calculating density.

Reading Check Answers, p. 315

1. You need to measure both the volume of the substance and its mass.
2. $D = \frac{m}{V}$
3. Put a volume of water into a graduated cylinder, and measure the volume accurately. Place the small object into the water, causing the water level to rise in the graduated cylinder. Read the new volume of the water. The difference between the first volume and the second volume must be the volume of the irregularly shaped object.
4. If the mass of the pure substance increases, then there must be more of it. Therefore, the volume must also increase.

Practice Problems Answers pp. 312–313

Students should provide a complete solution, as described in the student textbook.

1. $D = \frac{m}{V}$
   $= \frac{(8.1\ \text{g})}{(3.0\ \text{cm}^3)}$
   $= 2.7\ \text{g/cm}^3$
   The density of the metal is 2.7 g/cm^3. It is aluminum.
2. $D = \frac{m}{V}$
   $= \frac{(3.15\ \text{g})}{(2.5\ \text{mL})}$
   $= 1.26\ \text{g/mL}$
   The density is 1.26 g/mL. It is not water because the density of water is 1.0 g/mL.
3. $D = \frac{m}{V}$
   $= \frac{(2.0\ \text{g})}{(1000\ \text{mL})}$
   $= 0.0020\ \text{g/mL}$
   The density of the gas is 0.002 g/mL, and the gas is probably carbon dioxide.

Practice Problems Answers p. 313

1. $V = \frac{m}{D}$
   $= \frac{(9.66\ \text{g})}{(19.32\ \text{g/cm}^3)}$
   $= 0.50\ \text{cm}^3$
   Its volume is 0.50 cm^3.
2. $V = \frac{m}{D}$
   $= \frac{(15\ \text{g})}{(0.0002\ \text{g/mL})}$
   $= 75\ 000\ \text{mL}$
   The helium would occupy 75 L.
3. $V = \frac{m}{D}$
   $= \frac{(250\ \text{g})}{(1.03\ \text{g/mL})}$
   $= 243\ \text{mL}$
   The sea water would occupy 243 mL.

Practice Problems Answers p. 314

1. $m = V \times D$
   $= (20\ 000\ \text{mL}) \times (0.0014\ \text{g/mL})$
   $= 28\ \text{g}$
   Its mass is 28 g.

2. $m = V \times D$
$= (6.5\ cm^3) \times (8.92\ g/cm^3)$
$= 57.98\ g$
The copper has a mass of 58 g.
3. $m = V \times D$
$= (7.0\ mL) \times (0.90\ g/mL)$
$= 6.3\ g$
The machine oil has a mass of 6.3 g.

USING THE ACTIVITIES

- Activity 8-2A on page 315 of the student textbook is best completed just before students complete the reading. The activity is quick and simple, and provides good examples of all of the concepts. It also provides a hands-on introduction to density, helping students internalize the concepts so that they can draw on them as they perform the calculations in the reading.
- Activity 8-2B on pages 316 to 319 of the student textbook is the core lab in this section. Some understanding of mass, volume, and density are required to begin, so it should follow the reading. The activity provides many opportunities to experience and practise the main concepts.
- Activity 8-2C on page 320 of the student textbook is best used as an enrichment activity, after Activity 8-2B.
- Detailed notes on doing the activities follow.

Find Out Activity 8-2A

What is the Density of a Pencil? p. 315

Purpose

- Students will use the formula D = m ÷ V to calculate the density of a pencil.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather the balances and graduated cylinders.	For each group: – 1 balance – 1 graduated cylinder – 1 long pencil

Time Required

- 20 min

Safety Precautions

- Protective eyewear is always required.
- Ensure students wipe up spills immediately.

Science Background

This activity provides a very rough measurement of the density of a pencil. Most pencils have a density of about 1 g/cm^3, so they will be very near the sinking/floating point in water.

Activity Notes

- Review the meaning of density and the formula for density.
- Put students into groups and distribute the apparatus and materials.
- Demonstrate how to submerge the pencil.

Supporting Diverse Student Needs

- The instructions for this activity include no illustrations or diagrams. Work directly in a small-group setting with students who have reading difficulties and students who have trouble following written instructions to be sure they understand what to do.
- Students with weak fine-motor skills will find this activity easier to do if you use a larger cylinder and object, such as an oversize souvenir pencil.
- As an extension, ask, "How could you revise this activity to measure the density of small pencils?"

What Did You Find Out? Answers

1. The pencil will either sink (greater density than water) or float (lesser density than water).
2. Students should explain that to determine the density of an object with a regular shape, they could find the mass, use a formula to calculate the volume, then divide the mass by the volume. For an irregularly shaped object like the pencil, they can't use a formula to calculate volume, so they have to measure the volume of water the object displaces.

Extension Answers

Students could use a variety of small objects, so their measurements will vary. Students should be able to describe how they obtained their measurements.

Core Lab Conduct an Investigation 8-2B

Determining Density, pp. 316–319

Purpose

- In this investigation, students measure the mass and volume of various substances in order to calculate their densities. Students present the results in a graph. They will discover that the mass-to-volume ratio (i.e., density) of a substance remains constant.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
2 weeks before	Obtain 4 L each of water, oil, glycerol, molasses, and sand.	For each group: – balance – 2 large graduated beakers – 500 mL of fluid or sand
1 day before	Remind students to bring five different-coloured markers to the next class. Make copies of BLM 3-25, Determining Density (optional).	

Time Required

This exercise is lengthy. You may wish to schedule it over two days.

- 75 min for Part 1
- 25 minutes for Part 2

Safety Precautions

- Give students detailed instructions for careful handling of balances.
- Remind students to avoid spilling liquids and sand on the balances.
- Give students instructions for appropriate disposal of materials.

Science Background

It is important for students to understand that the *mass* of a substance is the *amount of matter that the substance contains*. The mass of a specific volume of a substance does not change, regardless of who is observing it or where it is being observed.

Density is the mass-to-volume ratio (g/mL) of a substance. Density is an *intrinsic* property: the density of gold is always 19.3 g/cm^3 no matter where or when it is measured.

Students will want to use the everyday term "weight." However, the meaning of the word "weight" is very vague, and can mean very different things at different times and places. When students use the everyday word "weight," they often mean density. Students might say "lead is heavy," when what they mean is "lead is dense." If students are permitted to use the word "weight" in the lab, sometimes they will mean "mass," and sometimes they will mean "density." Try to avoid the word "weight" if possible. Discourage the use of the words "heavy" and "light" as they, too, can be misunderstood.

Activity Notes

- This investigation is lengthy. You may want to carry it out over two days.
- Check the maximum mass that your balance can measure. A volume of 500 mL of water has a mass of 500 g. If your beaker has a mass of 100 g, your balance needs to measure at least 600 g. If the investigation calls for greater masses than your balance can handle, adjust the amounts of the liquids you use, so that students measure the mass and calculate the density for volumes of 50 mL, 100 mL, 150 mL, 200 mL, and 250 mL.
- Conducting a trial run can help you identify possible difficulties students may have with the procedure.
- If necessary, review how to measure volume and how to use the balance. Accurate measurement of mass and volume is essential in this investigation.
- Larger student groups will reduce the amount of material required in this investigation.
- Students may need to review graphing skills, calculating averages, and ratios. Watch the groups as they work, and pause the class or a group for a brief review, if needed.
- Students may find the following mnemonic useful. Construct a graph with a "water" density line plotted on it as in the graph on the right. All other lines (for other substances) plotted on the same graph will be "steeper" if they are denser than water and "flatter" if they are less dense than water. With this set-up, you can then tell students that all substances with steeper slopes will sink in water, and all substances with flatter slopes will float. Note: Avoid using scales with the same-sized interval, as doing so produces a water line that looks like a perfect diagonal. This result misleads students into thinking that the water line always bisects a graph, regardless of scale.
- Students can record their results on BLM 3-25, Determining Density.

Supporting Diverse Student Needs

- It may be helpful to demonstrate each step so that English language learners and students with reading difficulties can follow your example.
- Use as many labels as possible for the apparatus and materials. It can also be helpful to post a large chart with definitions, explanations, and units of measure to help build vocabulary.
- This activity is math-intensive. Pair stronger math students with weaker math students. You may wish to hand out a graph template with pre-labelled axes to help students with recording difficulties and insufficient graphing experience.
- The cooperative nature of the data-gathering phase of this activity builds students' interpersonal learning styles. Cooperating to gather enough data

to draw conclusions is an approach commonly used in science.

- This activity requires both a high level of activity and a high level of self control. Place students who are easily distracted in groups small enough that each student has a role to play at all times.
- To build intrapersonal as well as interpersonal skills, have students answer Analyze question 4 on their own, then discuss their ideas with a partner. Pairs can then share their ideas with the whole class.

Analyze Answers

1. The lines on the graph will be straight. They have different slopes. Some pairs of lines are closer together than others.
2. The mass-to-volume ratio remains constant for each substance. Students' explanations for this result might vary. The mass-to-volume ratio stays the same because the same volume is added each time in the trial. The same volume of the same substance has the same mass, so the increase in volume causes a proportional increase in the mass.
3. Students' answers will vary. The activity results should support the hypothesis that dividing the mass of a substance by its volume will result in density.
4. (a), (b), and (c) Students' answers will vary. Their answers should be very specific.

Conclude and Apply Answers

5. Similar lines occur on the graph because the mass-to-volume ratios for some of the substances are similar. This result means that those substances have similar densities.
6. The steeper the slope of the line on the graph is, the higher the mass-to-volume ratio is. Oil has the lowest slope, so it is least dense. Sand has the steepest line, so its mass-to-volume ratio, or its density, is the highest.
7. As the mass-to-volume ratio increases, the slope of the line becomes steeper.
8. Students' results will vary. Any straight line that passes through (0, 0) and lies between the line for sand and the line for water on the graph is acceptable.
9. The greater the number of particles is, the greater the mass is. Dense substances, like lead or gold, would have larger number of particles, and more massive particles, packed more closely into a smaller volume.

Extend Your Skills Answers

10. Students' answers will vary. Students might conclude that the more viscous a substance is, the greater its density is. However, this conclusion is not the rule. Oil, wax, and grease are all more viscous than water, and less dense.
11. Increasing the temperature of a substance will not change the nature of the particles themselves. It will, however, increase the space between the particles. Because the particles become more loosely packed, the substance becomes less dense.

Think About It Activity 8-2C

Comparing Densities, p. 320

Purpose

- In this activity, students use a table of density values for different substances to consider how density and the states of matter are related.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Make copies of BLM 3-26, Comparing Densities (optional).	None

Time Required

- 20 min

Science Background

Density is not an everyday term for students. They may confuse the term "density" with hardness, or with weight. Do students understand the meaning of the word "density" when they read density values in a table, or see the word in print?

Activity Notes

- Students can work independently or with a partner.
- Discuss the answers to the What to Do questions before students answer the questions in the Analyze and Extension sections.
- Additional practice comparing densities is provided on BLM 3-26, Comparing Densities.

Supporting Diverse Student Needs

- For English language learners and visual-spatial learners, the diagrams of the balances on page 320 could be very helpful as you discuss the meanings of the words "mass," "volume," and "density." Inviting students to draw these diagrams themselves can help you assess students' understanding of these terms.

- Have students with conceptual difficulties work with a partner and two copies of the student textbook. They can leave one copy open at page 320, and the other open to the table on page 312.
- Many students can provide better responses when they can manipulate a real example. Consider providing a double pan balance with two measuring cups and two very different substances such as foam plastic packing material, and metal hardware such as nuts or bolts.
- As a possible enrichment exercise, have some students make up additional review quiz questions plus answers.

What to Do Answers

1. Gold is most dense. It is a solid at room temperature.
2. Hydrogen is least dense. It is a gas at room temperature.
3. Solids tend to be most dense.
4. Gold is denser than mercury.

Analyze Answers

1. Students' answers will vary. Any liquid or solid with a density less than 1.00 g/cm^3 will float on water.
2. Students' answers will vary. Liquids or solids with a density greater than 1.00 g/cm^3 will sink in water.

Extension

1. The feathers will have a much larger volume.
2. The measuring cup of gold will have a much greater mass.

USING THE FEATURES

www Science: The Galileo Thermometer, p. 321

This feature must be done *after* activity 8-2B, and *after* thorough discussion of differing densities. Make a note to return to this feature once again when students have completed Section 8.3 and Activity 8-3A, Lava Lamps.

Students are not as familiar with *density* as they are with *sinking and floating* behaviour. Teachers can use the more familiar sinking and floating experiences as a starting point, and move into the topic of relative density.

The best starting point for discussion of the Galileo thermometer is to ask students questions such as the following:

- Why do some glass balls sink to the bottom of the fluid?
- Why do some of the glass balls float to the top of the fluid?
- What makes some of the glass balls just stay in the middle of the fluid, without either sinking or floating?
- Does the fluid in the column make a difference? If we changed the fluid to alcohol, for example, would the glass balls behave in the same way?
- Does the density of a fluid affect whether objects sink or float in it?

Students' answers to these questions are likely to vary. If students use the term "heavy" in their answers, encourage them to use the terms "mass," "volume," and "density" as they discuss the Galileo thermometer.

One fruitful approach to a discussion of the Galileo thermometer is to follow students' lead: if students cannot arrive at a consensus about how it works, then just leave the issue undecided. Print students' conjectures on large poster paper, and come back to them from time to time as students become acquainted with new ideas. Section 8.3 discusses the effects of temperature on density. Section 9.1 presents a discussion of buoyancy and density. Students should be able to arrive at good explanations as they gain more knowledge.

A Galileo thermometer is a colourful addition to any classroom. Consider purchasing one from a toy store, science museum, or science supplier. Students can monitor the temperature in the room, and wonder all year long about how the thermometer works!

Science Math Connect: Working With Density Measurements, p. 322

This activity offers the greatest learning opportunity if students record their work as they go.

Science Math Connect Answers

Practice Problems

1. $D = \frac{m}{V} = \frac{(1780\text{ g})}{(200\text{ cm}^3)} = 8.9\text{ g/cm}^3$ Nickel
2. $D = \frac{m}{V} = \frac{(972\text{ g})}{(360\text{ cm}^3)} = 2.7\text{ g/cm}^3$ Aluminum
3. $D = \frac{m}{V} = \frac{(132.79\text{ g})}{(9.8\text{ mL})} = 13.6\text{ g/mL}$ Mercury

4. $D = \frac{m}{V}$
$= \frac{(1404\ g)}{(650\ cm^3)}$
$= 2.2\ g/cm^3$ Salt

5. $D = \frac{m}{V}$
$= \frac{(1422\ g)}{(1800\ mL)}$
$= 0.79\ g/mL$ Ethyl Alcohol

SECTION 8.2 ASSESSMENT, p. 323

Check Your Understanding Answers

Checking Concepts

1. 1.59 g/cm^3
2. Lead has the greater density.
3.

SUBSTANCE	MASS (g)	VOLUME (cm^3)	DENSITY (g/cm^3) (MASS-TO-VOLUME RATIO)
aluminum	5.40	**2.00**	**2.70**
salt	6.48	3.0	**2.16**
copper	**44.6**	5.0	8.92
oak	0.33	**0.47**	**0.70**
salt	**8.64**	4.0	**2.16**

4. The density of water is 1.00 g/mL. The regular soft drink must have a density greater than 1, and the diet soft drink must have a density less than 1.
5. The density of a pure substance is always the same (at the same temperature and pressure). The mass of the pure substance must be directly proportional to the volume. Adding one more millilitre of liquid always adds precisely the same mass.

Understanding Key Ideas

6. The volume of a liquid is measured using a graduated cylinder.
   The volume of any solid can be measured by submerging the solid in a liquid and measuring the displaced liquid. If the solid has a regular shape, its volume can be determined by measuring its dimensions, and calculating the volume.
   Gases always completely fill the volume of their containers, so the volume of a gas is the volume of its container.
7. The mass-to-volume ratio of a substance is the density of that substance.
8. Displacement of water can be used to measure the volume of any solid, liquid, or gas, as long as the substance is not soluble in the water, because the water displaced will have the same volume as the item displacing it.
9. The copper is solid. The particles of copper are very close together, and strongly attracted to each other. The mercury atoms will not be able to flow between the copper atoms. (The mercury will eventually diffuse into the copper, making a silvery copper/mercury amalgam. The process takes a long time.)

Pause and Reflect Answer

The salt water contains both water and salt in the same volume. The density of salt is greater than the density of water, so the density of salt water should be between the densities of water and salt. The mass of the salt water is greater, even though the volume is the same.

Demonstration: Fill a glass with water just barely to the brim, but not heaping over. Add one tablespoon of pickling salt, a few crystals at a time, stirring with a very thin stir stick. With care, you can dissolve the entire spoonful of salt without causing the glass to overflow. The particles that make up the salt can fit into the spaces between the water particles, so the overall volume of the mixture does not increase.

Other Assessment Opportunities

- Consult the Unit front matter for a list of applicable Assessment BLMs.

8.3 CHANGES IN DENSITY

BACKGROUND INFORMATION

Two distinct causes of changes in density are presented in this section: evaporation and temperature changes.

Evaporation is the simplest case. Damp sand, for example, contains a certain percentage of water. Imagine a bucket containing tightly packed damp sand. If the sand is allowed to dry, the water particles evaporate into the air and diffuse away. The resulting dry sand is less dense than it was. Many substances become less dense as they dry up.

Density changes caused by temperature are more complex. When a substance is heated, its particles are given more kinetic energy. The particles move apart, and the whole substance expands. Since the mass of each particle remains unchanged, the overall result is a constant mass occupying a larger volume. Raising the temperature causes a lower density. When a substance is cooled, its particles are slowed and are attracted more closely together. Since the volume is less, and the mass of the particles remains unchanged, the density of a substance is greater when it is colder. This result is true for almost all of the millions of substances known to science.

There is a very small number of exceptions to this general behaviour. All of the exceptions occur around a change of state. Water, one of the most common substances, is one such exception. When water changes state from liquid to solid, its particles are actually farther apart as a solid than they were as a liquid. The frozen water particles become fixed into a pattern that contains more empty spaces, so the ice is actually less dense than the liquid water was. It is more accurate to say "water becomes less dense during the process of solidification" than to say "water becomes less dense as it cools."

COMMON MISCONCEPTIONS

- "Hot air rises" is a commonplace notion, but it is not, by itself, correct. Hot air is less dense, and cool air is more dense. Cooler, denser air is more strongly attracted by gravity. As the colder, denser air sinks due to a larger attraction by gravity, it forces the warmer, less dense air upward.
- "density = weight"; Students who hold this notion are inclined to speak of cold air as being "heavier." Once again, the imprecise and often inaccurate words "weight," "heavy," and "light" should be avoided. Students should use the terms "mass," "volume," and "density" instead.

ADVANCE PREPARATION

- Obtain a lava lamp for Activity 8-3A. Have the lamp operating throughout this chapter, so you can refer to it at any time. Students will be able to see, perhaps 100 times a day, behaviour caused by the changing densities of wax and water as they are heated and cooled.
- Try to find a "Galileo thermometer," a tall tube of water containing a dozen or more small floating glass spheres. As the temperature of the water increases, the water becomes less dense. One by one, the little glass spheres sink as the water warms up.
- Activity 8-3B requires sources of hot water and cold water. If hot and cold running water are not available in your classroom, you will need an alternative source of hot water, and some ice. Also needed are 250 mL beakers, stirring rods, thermal mitts, and food colouring.
- Consult the Unit front matter for a list of BLMs that can be used when teaching this section.

INTRODUCING THE SECTION, p. 324

Using the Text

It may be helpful for students to make an opening page for their notes with two columns titled *Higher Density* and *Lower Density*. Within those two columns, students can write parallel but contrasting entries, to make a table of comparisons. For example, students might write "larger spaces between particles" and "smaller spaces between particles" side by side under the two columns. In this way, students build up pairs of "compare and contrast" factors that contribute to changes of density. Some students may already have a good understanding of these ideas; to other students, these concepts will be completely new. Instruct students to record any ideas that they have before reading.

Using the Key Terms and Section Summary

At the beginning of each section in the student textbook are the Key Terms and section summary. Both can be used as a pre-reading strategy and a review tool. Before reading the text in the section, students should be able to define the Key Terms by scanning the text and using the Glossary. The Key Terms include terms from the curriculum outcomes and additional terms that are important for students to know and understand.

The section summary provides an overview of the key concepts being covered in the section. Students may not know all the concepts and terms described in the summary, but they can use this information to help guide them through their reading.

After reading the section, students can go back to the Key Terms and section summary to consolidate their understanding and identify areas that require clarification. At the end of the chapter or unit, students can use the Key Terms and section summary for review. BLM 8-3, Unit 3 Key Terms, and BLM 8-4, Chapter 8 Key Terms, can be used to assist students.

TEACHING THE SECTION, pp. 324–326

Using Reading

Pre-reading—Predict-Read-Verify

Have students use a pencil to lightly number the paragraphs in the text. Paragraph 1 begins "As you know..."; paragraph 6 ends with "easier to burn." Ask students to skim the headings, the captions in the illustrations, and the first sentence in every paragraph. As they skim, have them jot down their prediction of the content of each paragraph in their notebooks (2 min).

During Reading—GIST

The purpose of this strategy is to produce a short summary of the reading that preserves the meaning of the reading. Instruct students to read each paragraph and summarize the contents of each paragraph in one sentence.

After students have completed reading and summarizing each paragraph, have them summarize the sentences they wrote to condense the gist of the reading into no more than 20 words.

Supporting Diverse Student Needs

- Students can work in groups to create a visual representation of density changes. Have them work together to create a cycle map to show the density changes in a hot air balloon as it rises and falls, a car tire over the course of a year, or a lava lamp. Science Skill 10, on pages 496 and 497 of the textbook includes information about creating cycle maps and other graphic organizers.

After Reading—Reflect and Evaluate

Instruct students to compare their predictions (prereading) with their paragraph summaries (during reading). To what extent were their predictions correct?

As an extension, BLM 3-27, Bone Density, provides information about changes in bone density.

USING THE ACTIVITIES

- Activity 8-3A on page 325 of the student textbook is best used before students have read the section, as an introduction to changing densities.
- Activity 8-3B on page 328 of the student textbook is best used after the reading to verify students' understanding of the reading.
- Detailed notes on doing the activity follow.

Think About It Activity 8-3A

Lava Lamps, p. 325

Purpose

- Students will relate changes of temperature to observable evidence of changes of density, using the particle theory.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 week before	Begin to search for at least one lava lamp in working order. Ask students and colleagues. Purchase one if necessary.	– Distribute lava lamps around the room (if you have more than one).
1 hour before	Turn on the lava lamp, so that the wax can melt and circulate.	

Time Required

- 15 min

Safety Precautions

- Be sure the lava lamps are safely plugged in, away from water or other hazards.
- Lava lamps can become warm. Caution students not to touch the lamps.
- Lava lamps are fragile. Keep them safely back from the edges of tables and benches.

Science Background

The slow, hypnotic motion of the wax in the lava lamp is evidence of changes of density due to heating and cooling. As the blobs of coloured wax near the top of the lamp are cooled, they become more dense than the surrounding water. Because the wax is more dense, gravity pulls it down more strongly than the water, and the blob of wax sinks. At the bottom of the lamp, the wax is heated by the bulb. It becomes less dense than the water. The water sinks downward because of gravity, forcing the blobs of wax upward. Two other factors contribute to the motion. The first hidden factors in the process is the difference in heat capacity of the water and the wax. If you add the same amount of thermal energy to wax and to water, the temperature of the wax increases almost four times as much as the temperature of the water. For that reason, the density of the wax also changes much more than that of the water.

The second factor is the fact that the water is transparent and the wax is opaque. Light energy passes right through the water, leaving no energy behind. Light energy is absorbed by the opaque wax, and is changed to heat energy. Light energy then heats the wax more that it heats the water. This process also makes the wax change density more than the water.

Activity Notes

- Instruct students to read the activity and observe the lamp.

- Have students draw a large, full-page diagram of the lava lamp.
- Have students answer the questions together, writing at least one sentence for each answer on their diagram. The particles called for in question 4 can be drawn right on the diagram.

Supporting Diverse Student Needs

- This activity is particularly appealing to visual-spatial learners. Such students may benefit from being paired with students who can read aloud the instructions and the questions in the activity.
- A real, operating lava lamp can provide useful visual cues for students who have never seen one.
- To build visual-spatial skills, challenge students to include a diagram in their answer to question 4.
- Enrichment task: Challenge students to compare and contrast the behaviour of the wax and the water particles.

What Did You Find Out? Answers

1. As it is heated, the wax becomes less dense than the water.
2. As the warm wax becomes less dense, it floats in the water.
3. At the top of the lamp, the wax cools, becomes more dense than the water, and begins to sink.
4. Students' answers will vary. Each answer should consider the role of the kinetic energy of the particles and the space between the particles. An example: "As the wax is heated, the wax particles increase in kinetic energy. Because they are moving faster, they move a little farther apart. With larger spaces between the particles, the wax occupies more space. The mass of the particles remains unchanged, so the overall density of the wax decreases. Because it is less dense, the warm wax floats upward in the water." Students should explain the cooling process in a similar way. The cooling wax particles move more slowly and become more closely packed. The wax becomes more dense than the water, and sinks in the water.

Find Out Activity 8-3B

Layers of Water, p. 328

Purpose

- Students will verify that water has two different densities at two different temperatures.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather the beakers, stirring rods, thermal mitts, spoons, and food colouring. Ensure you have a source of hot and cold water.	For each group: – two 250 mL beakers – 1 stirring rod, 1 spoon – food colouring – 1 pair of thermal mitts
1 hour before	Prepare the source of hot and cold water.	

Time Required

- 20 min

Safety Precautions

- Remind students to be careful handling hot water. Use the safety mitts. You might have them practise the pouring position with no water in the beaker before they begin.
- All students should wear eye protection.

Science Background

Because the water particles move more quickly when they are hot, the water will be less dense at higher temperatures. It should be possible to float a layer of hot water on top of a layer of cold water without mixing. To make this happen, students must pour the water very carefully.

The stirring rod should be held across the top of the beaker as shown in the diagram. The water will cling to the stirring rod, and flow smoothly to the spoon. The bowl of the spoon should be held level with the water. Sometimes it is possible to bend the handle of the plastic spoon, so that the spoon is level with the water.

Activity Notes

- Instruct students to obtain the hot and cold water, and to colour the hot water with the food colouring.
- Gently and slowly pour the hot water, using the stirring rod to direct the flow onto the spoon.
- The hot water should float on top of the cold water with minimal mixing.
- The layered water can be left for a few minutes, to observe the rate of mixing.

Supporting Diverse Student Needs

- The procedure for introducing the hot water is crucial for success and for safety. Have students who have trouble following written instructions refer to the diagram as you read What To Do point 1, or demonstrate for the class what to do.

- This experience requires dexterity and steady hands, as well as verbal-linguistic explanations. Its varied nature should appeal to body-kinesthetic learners, logical-mathematical learners, and verbal-linguistic learners. Distribute the reading, writing, and other roles in the activity so that students who struggle with one skill might find success in another area.
- To build intrapersonal and interpersonal skills, have students answer the What Did You Find Out? questions on their own, then discuss answers as a class. Remind students to practise good listening and speaking skills.
- For enrichment, repeat the experiment, having students pour the cold water onto the hot water. Have students predict the results before attempting this part of the experiment.

What Did You Find Out? Answers

1. Hot water is less dense than cold water.
2. The tiny particles sometimes diffuse across the boundary, mixing the hot and cold water.
3. The kinetic energy is greater among the particles of hot water, causing larger spaces between the particles. In cold water, the kinetic energy is lower and the spaces are smaller.
4. Students' answers may vary. Some students will predict that the liquids will simply mix. Others might predict that the cold water will sink and form a layer on the bottom.

USING THE FEATURE

www Science: Iridium—The Densest Substance on Earth, p. 327

Organize students into small groups to read the selection. Instruct students to generate some questions based on this reading. For example, "What is the density of iridium?" "What are the colours iridium compounds?" "How is iridium used in radiation therapy?" and so on. Each group should produce more questions than the number of students in the group.

Have each student assume responsibility for one question, and at home, or in the classroom, do an Internet search to answer the question.

On the following day, have each student do a 30-s mini-presentation to share what they learned in their research.

SECTION 8.3 ASSESSMENT, p. 329

Check Your Understanding Answers

Checking Concepts

1. From least to greatest density the substances are Styrofoam®, oil, plastic, water, a grape, and corn syrup.
2. When the balloon expands, the density of the helium decreases. The same mass of helium is distributed over a larger volume.
3. In cold temperatures, the volume of a liquid decreases, increasing the density of the liquid and making the column shorter. If the temperature is increased, the volume of the liquid increases, the density decreases, and the column becomes taller.

Understanding Key Ideas

4. Temperature is the kinetic energy of the particles of a substance. Increasing the temperature increases the kinetic energy of the particles, increasing the spaces between particles. Doing so decreases the density of the particles. Cooling the substance reduces the kinetic energy, reducing the spaces between particles, and increasing the density of the substance.
5. As water in a pond cools, its particles get closer together, and its density increases. The cold water sinks to the bottom of the pond. In the solid form, however, the water particles are organized into fixed positions with larger spaces than liquid water. When the water begins to freeze, the density of the ice is less than the density of the liquid water, so the ice floats and forms a layer on top of the pond. This layer of ice forms an insulating layer that keeps the rest of the pond from freezing and allows living organisms to survive the winter.

Pause and Reflect Answer

The latex can stretch. As the balloon rises, it encounters lower air pressure.

The helium expands in the low pressure, and the balloon expands with it.

Other Assessment Opportunities

- Consult the Unit front matter for a list of applicable Assessment BLMs.

CHAPTER 8 ASSESSMENT, pp. 330–331

PREPARE YOUR OWN SUMMARY

Students' summaries should incorporate the following main ideas:

1. Densities of Solids, Liquids, and Gases
   - The density of pure substances depends on the state of matter.
   - In the gas state, particles are far apart and density is low.
   - In the liquid state, particles are close, and density is high.
   - In the solid state, particles are very close, and density is usually highest.
2. Calculating Density
   - Density is the mass-to-volume ratio, or $D = m \div V$.
   - Students should be able to provide an example.
3. Effect of Temperature on Density
   - Density is related to how close the particles of matter are packed.
   - Increasing temperature causes more motion, larger spaces, and lower densities.
   - Decreasing temperature causes slower motion, smaller spaces, and higher densities.
4. Temperature and Density in Everyday Life
   - Students should describe examples of the effects of density that they see in everyday life.

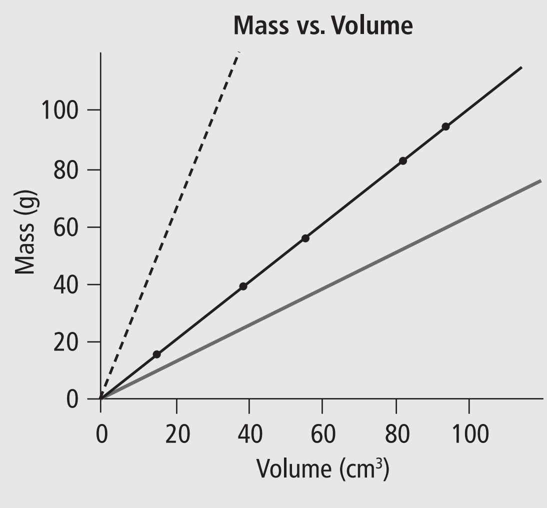
CHAPTER REVIEW ANSWERS

Checking Concepts

1. Density is the ratio of mass to unit volume.
2. The more closely the particles of a pure substance are packed, the more dense that substance will be. The more massive each particle is, the denser the substance will be.
3. The particles are packed much more closely in the liquid water than they are in the vapour state. (At room temperature, the liquid is almost 2000 times denser!)
4. A lump of solid can push aside the particles in the liquid or the gas, so the solid lump can move through the liquid or the gas.
5. For example, the liquid state of water is denser than the solid state of wax.
6. The volume of irregularly shaped objects can be measured only by displacement of water because you could never take all the measurements you would need to calculate the volume with a formula.
7. *Mass* is the *total quantity of matter* in an object. *Density* is the *amount of mass in a given volume of the substance.*
8. Temperature and pressure must remain the same.
9. Students' answers may vary. For each example of changes in density, students should include observed behaviour and an explanation of why the temperature change affects the density. For example, "As warm air near a window cools down, its particles move less and get closer together, increasing the density, and causing a draft of cold air near the window." or "A fire increases the temperature of the gases in the air, which makes the gases take up more space, decreasing the density of the gases. The less dense gases float upward on the cooler surrounding air."

Understanding Key Ideas

10. Students' answers should be accompanied with an explanation.
    (a) Material 1 has the largest mass. 50 cm^3 has a mass of 570 g.
    (b) Material 3 takes up the most space. 100 g occupies 40 cm^3.
    (c) Material 1 $D = 11$ g/cm^3; Material 2 $D = 8.0$ g/cm^3; Material 3 $D = 2.6$ g/cm^3
11. (a) Students' graphs will vary. A sample graph is below. Each graph should have a title, labelled axes, units, clear data points, and a "best fit" line through the data points.



    (b) The mass-to-volume ratio for each measurement is 1.000 g/cm^3.
    (c) water

(d) A line for a higher density substance will lie above and to the left of water; a line for a lower density substance will lie below and to the right of water.

12. All four methods use a graduated cylinder as the measuring instrument.
    - Water: Pour the water into a graduated cylinder to measure volume.
    - Ice: Half-fill a graduated cylinder. Add ice cubes to the water, and measure the change in the volume of water. The difference is the volume of the ice. (displacement)
    - Fill the bottle to the brim with water. Pour the water into a graduated cylinder to measure its volume.
    - Put the water vapour into a container of known volume, like the water bottle above.
13. The density of the gold is much greater than that of feathers. The gold particles must be much more densely packed than the feathers. 1 kg of gold will occupy much less space than 1 kg of feathers.
14. Density and viscosity of a fluid are not directly related. They can vary independently of each other. The density of oil is less than that of water, but oil's viscosity is greater than that of water. The density of molasses is more than that of water, and molasses' viscosity is also greater than that of water. Density depends on the mass and the size of each particle. Viscosity depends on the "stickiness" of the particles, and their ability to tangle or otherwise interfere with the motion of other particles.

Pause and Reflect Answer

- Gases can be expelled into a bag. The volume and mass of the gas can be measured, and the density of the gas found.
- Liquids like blood or lymph can be drawn off into a graduated cylinder, their volume and mass measured, and their density calculated.
- Solids like bones or teeth would have to be taken out of the body (ouch!). Mass can be measured using a balance, and the volume of the solid can be found by displacement. Then density can be calculated.

CHAPTER 9 OPENER, pp. 332–333

USING THE PHOTO AND TEXT

Ask students to read the introductory text and examine the photograph. Have students identify and list items that are likely to sink if they are separated from either the diver or the sea bottom (e.g., camera, diving weights, scuba tanks, etc.). Then ask them to identify and list items that are likely to float if they are detached (e.g., air bubbles, suit). Finally, have them identify items that are likely to remain where they are, neither sinking downward, nor floating upward (e.g., anemones, tube worms, etc.).

Ask students what might cause these three behaviours.

USING THE WHAT YOU WILL LEARN / WHY IT IS IMPORTANT / SKILLS YOU WILL USE

Encourage students to read the Why It Is Important section. Discuss some devices in which fluids are used to support, and to move, other things. Ask students to add to the list. Ask, “What other commonly used devices require an understanding of forces, fluids, and pressure?” (e.g., heating and cooling systems, municipal water systems, any device that has an engine, etc.) Use students’ suggestions to extend the discussion to why an understanding of fluids, forces, and pressure is so important in many areas.

USING THE FOLDABLES™ FEATURE

See the Foldables section of this resource.

9.1 FORCES AND BUOYANCY

BACKGROUND INFORMATION

This section introduces dynamics—the study of why objects move. The short answer is that objects move in response to forces. But what exactly is a force? Simply put, a force is any type of push or pull. Most commonly, force is applied by direct contact, as when you push on your car, or your grocery bag pulls on your hand. Force can also be applied by distant influences such as gravity. Every particle of your body is pulled downward by Earth’s gravity, and so is the moon!

Very often we observe the case of “balanced” forces. Gravity pulls the grocery bag down, our hand pulls the grocery bag up. Balanced forces are always from two different sources (in this case, gravity and your hand), and they always act upon the same body (the grocery bag).

It seems obvious that if an object is stationary, then the forces acting on that object are balanced. This concept is true, but it is not the whole truth. When any object is moving at a constant speed, the forces on that object must be balanced. Newton’s first law of motion states: A body continues to maintain its state of rest or of uniform motion unless acted upon by an external unbalanced force. Think about a skater gliding on smooth ice. There is almost no friction. Once the skater has accelerated to a certain speed, he or she can glide at that same, constant speed, applying no additional force. Forces are balanced (zero force forward, zero friction backward). If there is friction on the ice, the skater cannot maintain a constant speed unless he or she applies an additional force to balance the friction.

Perhaps you have noticed that you have to push extra hard to get your car moving in the first place. You have to balance the force of friction, plus you must exert an extra amount of unbalanced force to get your car moving. Unbalanced forces cause changes in speed, or acceleration. You must always apply an unbalanced force to accelerate an object, or to bring it to rest. As soon as the forces are balanced again, the object just remains at a constant speed (which can be zero).

In this unit, the objects tend to be at rest, or moving slowly at a constant speed. We do not need to worry very much about unbalanced forces. For example, a boat floating in the water is being acted upon by balanced forces. The boat is neither speeding up, nor slowing down, so there cannot be any unbalanced forces.

COMMON MISCONCEPTIONS

- Students often assume that a continued force is necessary for an object to continue moving. In a frictionless environment, an object will continue moving forever without any added force. Added forces are necessary to change motion, but are not needed to maintain the same motion.
- Another common misconception is that an applied force will always cause a motion. This belief is not the case if there is an equal and opposite force to the applied force. In this situation, the forces effectively cancel, resulting in zero net force, and therefore no change in motion of the object. An example is the force you apply to hold a heavy object in your arms out in front of you. The object is not moving, but you can feel that you are exerting a force.
- Similar to the confusion students may have shown in previous chapters, floating and sinking behaviour is often confused with ideas like “weight,” “heavy,” and “light,” as mentioned in previous sections. However, “heavy” objects can float (ships)

and "light" objects can sink (thumbtack). Avoid the use of the terms "weight," "heavy," and "light." Do use the terms "force," "density," "mass," and "volume," as these can be used to explain floating and sinking behaviour.

- Force is measured in Newtons. Near the Earth, the force of gravity on a 1.0 kg mass is very nearly 10 Newtons (N). When students hold a 1.0 kg mass in their hands, they are experiencing a force of about 10 N. (The force of gravity on a 1.0 kg mass is actually 9.8 N. Using 10 N instead of 9.8 N introduces a small error, about 2%. This error is smaller than most of the errors in student experiments.)

ADVANCE PREPARATION

- Activity 9-1A on page 338 requires one fresh egg for each group, and plenty of salt. Pickling salt has nice large crystals, and results in a clear solution. Water softener salt is a good alternative. Table salt contains starch and silica to prevent clumping, so it always produces a slightly cloudy mixture.
- Activity 9-1B on page 342 requires clear water bottles with lids, or clear soft drink bottles. In addition, you will need either glass eye droppers with rubber bulbs, or plastic disposable droppers wrapped with a small amount of copper wire.
- Activity 9-1C on page 344 requires tall, closed containers. You can use test tubes and stoppers to make miniature density towers. For a full sized tower you could use clear, 2 L soft drink bottles with lids.
- Activity 9-1D on page 345 requires Newton force gauges that are capable of recording forces from 0.5 N to 20 N. Electronic force sensors are preferable for this activity and can be used for other activities in this section. (Note that an interface is also necessary to use electronic sensors.)
- Consult the Unit front matter for a list of BLMs that can be used when teaching this section.

INTRODUCING THE SECTION, p. 334

Using the Text

Use just one permanent diagram, poster, or bulletin board display to reinforce the concepts in this section. The diagram should represent a 1.0 kg object in the centre. There should be two arrows of equal length, one directed up, the other directed down. Mark the downward arrow "force of gravity" and the upward arrow "supporting forces." Refer to this diagram frequently to reinforce the concept of balanced forces.

To introduce the section, draw students' attention to the diagram and ask them for examples of what the supporting forces might be. Encourage a variety of responses, for example, wind, muscles, buoyancy.

Using the Key Terms and Section Summary

At the beginning of each section in the student textbook are the Key Terms and section summary. Both can be used as a pre-reading strategy and a review tool. Before reading the text in the section, students should be able to define the terms listed in the Key Terms by scanning the text and using the Glossary. The Key Terms include terms from the curriculum outcomes and additional terms that are important for students to know and understand.

The section summary provides an overview of the key concepts being covered in the section. Students may not know all the concepts and terms described in the summary, but they can use this information to help guide them through their reading.

After reading the section, students can go back to the Key Terms and section summary to consolidate their understanding and identify areas that require clarification. At the end of the chapter or unit, students can use the Key Terms and section summary for review. BLM 3-2, Unit 3 Key Terms, and BLM 3-5, Chapter 9 Key Terms, can be used to assist students.

Using a Demonstration

Obtain a 1.0 kg mass, and two Newton force scales. Construct an arrow, about 50 cm long, labelled "Force of Gravity 10 N." Tape the tail of the arrow to the mass so that the head of the arrow points down. Then attach two force scales to the mass with light string, so that the mass is supported by two strings and two scales. As students adjust the relative tension on one of the scales, the other one compensates so that the total of the two upward forces is always close to 10 N. You may need to give the scales a tiny vibration with your hand to overcome any sticking. When the mass is moving at a constant speed of zero, the downward and upward forces are balanced.

The actual force of gravity on a 1 kg mass is actually 9.8 N, but a 2% error is not going to be noticeable in a demonstration like this one.

TEACHING THE SECTION, pp. 334–343

Using Reading

Break the reading up into three distinct parts: Forces (pp. 334–336); Buoyancy (pp. 336–339); and Density (pp. 339–343). The subject matter in each of these three sections is sufficiently challenging and distinct that students will probably find it helpful to treat them one at a time. To help students deal with the material, the same reading strategies should be followed in all three parts.

Pre-reading—Predict-Read-Verify

Break this section up into chunks that follow the headings. For the first part, the headings would be the following:

- Forces
- Balanced and Unbalanced Forces
- Mass vs. Weight

Use the chunks as topics for discussion. Ask students what they think the headings refer to. Direct them to re-write the headings in their notebooks as questions, leaving one half page for each heading. Have them make predictions about what they will learn, and write their predictions under each heading. Then, have them read the section and compare their predictions to what they have learned.

During Reading—Note Taking

Direct students to make brief, summarizing notes under each heading as they read. Their notes should be written to answer the question posed by the heading, or to support that answer.

Supporting Diverse Student Needs

- Visual-spatial and verbal-linguistic learners may benefit from explaining buoyancy using BLM 3-29, Buoyancy Diagram, and showing how buoyancy can be controlled using BLM 3-30, Swim Bladder and Submarine. These BLMs could be made into overhead transparencies to facilitate class discussion. During these discussions, encourage students who have had trouble understanding the text to ask questions. Have one student explain the concept, then invite questions, and ask other students to respond to each question using the transparencies as a reference.
- Body-kinesthetic learners will understand the section about measuring liquid density much more readily if a hydrometer and a variety of liquids are available for students to use to test the densities of several liquids.

After Reading—Semantic Mapping

When students have finished taking notes, have them compare and contrast their notes with their predictions. Students should create a simple table to show the major similarities and differences between their predictions and their notes.

To apply what they have learned about mass and weight, students can complete the calculations of their own mass and weight on different planets, using BLM 3-31, Mass vs. Weight Calculations. To apply what they have learned about buoyancy, they can complete BLM 3-32, Identifying Buoyancy. To extend what they have learned, they can use BLM 3-33, Zebra Mussels.

Reading Check Answers, p. 336

1. a push or a pull
2. Two forces are balanced if they are equal, and opposite, and acting upon the same object. Balanced forces add up to zero net force. An unbalanced force is a force that is not opposed. Unbalanced forces cause a change in the speed or direction of a moving object
3. Mass: the amount of matter in an object. Weight: the force of gravity that acts on an object.
4. The amount of matter in a body will be the same, wherever that body may be. The force of gravity on the same object will change, depending on the object's location.

Reading Check Answers, p. 339

1. Buoyancy is the upward force on objects that are submerged in, or floating on, a fluid.
2. Gravity pulls downward on an object. The buoyant force pushes upward on the same object.
3. Neutral buoyancy is a state in which the force of gravity is exactly balanced by the buoyant force, so the object neither rises nor sinks.
4. The buoyant force on an object is equal to the mass of the fluid that was displaced by the object.
5. You will sink in the water until your body has displaced the same mass of water as your body mass. (If you exhale and hold your breath, you will sink until only the top of your head sticks out above the water.)

Reading Check Answers, p. 343

1. Average density is the total mass of an object divided by the total volume of that object.
2. The metal of the ship is distributed over a large volume. The average density of the ship, including air spaces, is less than that of water. After it sinks just enough into the water to displace a mass of water equal to its own total mass, the ship reaches neutral buoyancy.
3. The greater the density of the fluid, the smaller the volume of fluid a ship has to displace in order to float. Dense fluids provide a greater buoyant force.
4. The hydrometer has a certain mass. The hydrometer sinks in the fluid until it has displaced a mass of water equal to its own mass. A scale shows how far it has sunk in the fluid. The greater the fluid's density, the less the hydrometer has to sink.

USING THE ACTIVITIES

- Activity 9-1A on page 338 of the student textbook is best used to illustrate Archimedes' principle. Students could profitably use this activity as a chapter opener, before studying buoyancy and Archimedes' principle. It could also be used afterward, to reinforce the concepts.
- Activity 9-1B on page 342 of the student textbook would be best used to illustrate the concept of average density. The model could be quickly built before the reading, and then referred to throughout the lesson, to reinforce the concepts.
- Activity 9-1C on page 344 of the student textbook is a conversation starter. It builds upon the concepts in Chapter 8, and anticipates the ideas in Chapter 9. It could serve as a chapter opener, or could be held until after the reading linking buoyancy and density. Once the towers are built, they can be referred to throughout this chapter.
- Activity 9-1D on page 345 of the student textbook must follow the section "How Buoyancy and Density Are Related." Students need to be aware of fluid density and Archimedes' principle before they do this investigation. This activity is best done at the end of the section.
- Detailed notes on doing the activities follow.

Find Out Activity 9-1A

The Amazing Floating Egg, p. 338

Purpose

- In this activity, students will discover that adding salt to tap water changes the density and buoyant force of the tap water.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather materials.	– 1 fresh egg per group – 75 g salt per group – clear drinking glasses (may be plastic) – sugar (optional)

Time Required

- 30 min

Safety Precautions

- Remind students not to taste anything in the science lab.
- Eggs may carry Salmonella bacteria. Make sure that any broken eggs are wiped up and that the area is cleaned with warm, soapy water. Students should wash their hands after handling or cleaning up broken eggs.

Science Background

- A drinking glass containing 250 mL of water can dissolve about 90 g of salt, although the rate of dissolving slows as the solution becomes more concentrated. It should take only 35 to 50 g of salt dissolved in 250 mL of water to reach the density that will float an egg.
- Heating the water will not increase the amount of salt that can dissolve, although warm water will dissolve the salt more quickly.
- A fresh egg placed in tap water will sink to the bottom. As salt is added, and slowly stirred, the egg will gradually lift from the bottom, and eventually float near the top of the glass.
- When more tap water is added very gently to the glass, for example, by pouring against the inside of the glass, the tap water will form a layer floating on the denser salt water. The egg will remain between the two layers, sinking in the fresh layer, and floating in the salty layer.

Activity Notes

- Do this activity before students read the subsection "How Buoyancy and Density Are Related."
- Ask students to name a variety of things that they know will float in water. Discuss what these items are made of and how they are designed and constructed. What factors are probably involved in their ability to float? (density, average density, shape)
- Next, ask if students think a fresh, raw egg in the shell will float. Students' opinions might vary. Ask for explanations. Then introduce the activity.

Supporting Diverse Student Needs

- This activity will appeal to students who prefer kinesthetic experiences. For those who are challenged by having to draw a labelled diagram, suggest these labels: glass, salt water, fresh water, egg. Visual-spatial learners can use these diagrams as part of their answers to What Did You Find Out? questions 1 and 2.
- Make sure that students realize that the density of the water increased when the salt was added. The change in density affected the buoyant force exerted on the egg.
- As enrichment, ask students, "Will sugar work instead of salt? Why or why not? Try it."

What Did You Find Out? Answers

1. The egg floats because the dissolved salt increases the density of the tap water. When enough salt has been added, the density of the solution becomes greater than the density of the egg, and the egg floats.

2. Students' sketches and explanations should show that when more water is carefully added to the solution, the egg floats in the middle of the glass. The dense salt water sinks to the bottom, the egg floats on that, and the tap water is the least dense so it floats above all.

Find Out Activity 9-1B

Cartesian Diver, p. 342

Purpose

- In this activity, students will investigate the effects of changing the average density of a "diver."

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
3 weeks before	Start collecting 1 L plastic pop bottles with caps; ask students and colleagues to bring them as well.	For each group: – one 1 L plastic transparent pop bottle – 1 medicine dropper – water
1 week before	Obtain medicine droppers for groups.	

Time Required

- 20 min

Science Background

- Whales and fish do it; scuba divers do it; submarines do it. They change their average density by changing the volume of air that they contain. The greater the volume of air is, the smaller the overall density is, and the more likely it is that the animal will float upward. Reducing the volume of air reduces the average density, increasing the animal's tendency to sink.
- This activity depends upon the fact that liquid water is nearly incompressible, while a gas like air is highly compressible. When the student squeezes the bottle, its volume is reduced. Any air at the top of the bottle is compressed. The water is not compressed, but it exerts pressure on the tiny volume of air inside the diver. This pressure causes the tiny volume of air inside the diver to become even smaller. As the volume of air in the diver decreases, the amount of water in the diver increases, the overall density of the diver increases, and the diver sinks.

Activity Notes

- If glass medicine droppers are not available, try using disposable droppers. Add a paper clip or bit of wire to the tip of the dropper, and adjust the amount of water in the dropper so that it just floats. You may even substitute the clear body of a ball point pen, sealed at the top with a little bit of modelling clay.
- Try the activity yourself first, so you can troubleshoot students' questions or problems.
- Introduce the activity by talking about underwater diving. Then direct students' attention to the diver in this activity.
- Ask students to predict what they think will happen when they squeeze the bottle.
- Fill the bottle right to the brim with water, so that it contains no air bubbles at all. The bottle will contain very little gas to compress, so students do not have to do work to compress the extra air. Students will have much greater success getting the diver to go up and down.
- Pop bottles should be transparent.
- Make sure students have the medicine dropper half-filled with water and that they hold the bottles upright.
- The bottles may be hard to squeeze. Tell students to secure the cap tightly and squeeze "hard."

Supporting Diverse Student Needs

- Every student in the class should make one of these models, to ensure that students have first-hand experience. To build vocabulary for English language learners and others, emphasize words like "pressure," "volume," and so on as you discuss answers to What Did You Find Out? questions 1 and 2.
- For those who have trouble following instructions, demonstrate the What To Do steps to the end of step 3. You could also have bottles and divers ready so students can begin with step 4.
- This activity will appeal to students who prefer kinesthetic experiences. Others can be challenged by having to draw the apparatus. Suggest that students make two sketches (one for a squeezed bottle, and one for a released bottle), and use these labels: bottle, bottle cap, medicine dropper, water, air, compressed air.
- As an extension, put two divers inside one bottle. Ask, "Do they behave in the same way? Why or why not?"

What Did You Find Out? Answers

1. When the bottle is squeezed, the amount of water in the "diver" increases.
2. When the bottle is suddenly released, the amount of water in the "diver" decreases.

Extension Answers

3. Squeezing the bottle both decreases the amount of low density air, and increases the volume of high density water, inside the diver. The diver's average density increases, and the diver sinks. Releasing the bottle causes the volume of air to increase and the volume of water to decrease, and the diver floats again.

Conduct an Investigation 9-1C

Build a Density Tower, p. 344

Purpose

- In this investigation, students will build a density tower and discover that different liquids exert different buoyant forces on different materials.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 week before	Gather apparatus and materials.	– Tall, clear plastic jars with lids, or other transparent containers. Soft drink bottles with caps can be used if the solids are small enough to fit into the mouth of the bottle. – cork, wood chips, or toothpicks – paper clips – other small objects (for Extend Your Skills) – rubber gloves – water with food colouring – vegetable oil
2 days before	Prepare kits of apparatus and materials.	
1 day before	Mix water and food colouring in sealable containers for transport. Make copies of BLM 3-34, Build a Density Tower (optional).	

Time Required

- 60 min

Safety Precautions

- Students should wear lab coats and goggles for this investigation.
- Students should not taste the samples.
- Students should not pour substances down the drain. Give them specific instructions for disposal of materials.

Science Background

The water and vegetable oil will separate reliably into two layers, as the density of water is 1.0 g/mL, and the density of oil is about 0.9 g/mL. The other objects should be chosen as follows:

- To float on oil, the density must be less than 0.9 g/cm^3. Possibilities include cork and plastic foam.
- To sink in oil and float on water, the density must be between 0.9 g/cm^3 and 1.0 g/cm^3. Possibilities include a grape, superball^{TM}, polyethylene toy, and polypropylene rope. These are the most interesting materials, so try to find as many examples as you can.
- To sink in water, the density must be greater than 1.0 g/cm^3. Possibilities include a plastic building block, marble, stone, and metal object.

Activity Notes

- Students can work in pairs or groups of up to four.
- Make sure that the lids of the containers have a good seal. Soft drink bottles have caps made for the purpose. If you are in doubt, use duct tape or clear packing tape to seal the lids tightly.
- The materials used to create a density tower have different densities. After you have shaken the tower, the materials should settle in layers. The more dense the fluid is, the lower its position is in the density tower.
- Using a wide variety of objects in the density tower provides an opportunity for students to observe the buoyancy caused by different combinations of densities.
- Before students shake their density towers, check the seal on the containers. Tape the seals if necessary.
- Advise students that shaking the containers too vigorously will increase the time required for the substances to settle.
- Students can use BLM 3-34, Build a Density Tower, to record their results.

Supporting Diverse Student Needs

- Pair English language learners with verbal-linguistic learners. Together, they should discuss the procedure, apparatus, and materials used. This partnership provides the English language learner with an opportunity for one-on-one conversation and practice with new vocabulary in a real setting.
- Some students may approach Conclude and Apply question 4 mathematically and others visually, by referring to the tower. Validate both responses, and ensure the class has the opportunity to hear both explained, as well as other approaches used.
- Seeing the substances in clear layers should help visual-spatial learners internalize the concept of relative density and how it affects buoyancy.
- For enrichment, provide the density of the oil and the water, and have students estimate the densities of the other objects.

Analyze Answers

1. Students' answers will vary, depending on what items were placed in the density tower. A sample table is shown below.

OBJECT	RANKING
cork	1
oil	2
superball	3
water	4
penny	5

2. Substances that are denser than water will sink (e.g., paper clip, penny). Substances that are less dense will float (e.g., cork, toothpick, pencil).

Conclude and Apply Answers

3. A solid can be less dense than a liquid. Cork is a solid that is less dense than many liquids. The particles that make up cork are held together as a solid but they have spaces between them. Many liquids have particles that are closer together than the particles in cork, but the liquids' particles move more freely. The liquid is thus more dense than cork and can support it.
4. Volume does not determine the density of the object. As long as the temperature and pressure stay the same, the density of a substance remains constant. The density of an object is its mass-to-volume ratio. The mass of an object increases proportionally as the volume of the object is increased; therefore, the density of the object remains the same.

Extend Your Skills Answer

5. Students will choose very different kinds of materials, so variation should be expected.

Think About It Activity 9-1D

Measuring Buoyancy, p. 345

Purpose

- In this investigation, students analyze photographs and data to determine whether or not various liquids exert the same buoyant force.

Time Required

- 30 min

Science Background

Students will have to take a second or third look at each photograph, as the observations do require care. Accurate readings of the measuring instruments are the most important part of students' observations.

It is not obvious in the photographs, but the metal mass is displacing a volume of water equal to its own volume. The force of gravity on the displaced water is equal to the buoyant force on the mass in every case. Because the three liquids have different densities, the buoyant force of each is slightly different, and each is able to balance a different portion of the force of gravity. This fact results in different weights for the same mass when it is suspended in different liquids.

Activity Notes

- Remind students that mass and weight are not the same thing.
- This investigation offers an excellent opportunity for parents to help students work through the What to Do and Analyze questions at home.
- You may want to demonstrate how a spring scale works so that students understand what is being shown in the photographs.
- Students need to have read the section "How Buoyancy and Density Are Related" before they do this investigation.

Supporting Diverse Student Needs

- Few students will have experience using a hydrometer. If one is available, bring it in and demonstrate how it behaves in different liquids.
- The general principle of this activity is easy to demonstrate. Use a bucket of water and a large elastic band. The "weight" can be made of a water bottle containing about one third sand and then filled with water. Loop the elastic around the neck of the bottle. Hold the bottle by the elastic, and lower the bottle into the water. Students who might have difficulty interpreting and comparing diagrams may prefer to experience the changing "weight" of the bottle as it is lowered into the bucket of water, and then fished out again.
- Logical-mathematical learners can be partnered with students who require assistance. Have partners explain the values in the investigation to each other.
- Some students may not know which values to use in the given formula. You can demonstrate, using liquid 1 as an example.
  F = weight in air – weight in liquid
  = 1.0 N – 0.85 N
  = 0.15
- This activity will be very challenging to English language learners and students who have trouble following written instructions. There are no activities to cue students. You may need to work with these students in a small, separate group.

What to Do Answers

1. Listed in order from greatest to least, the buoyant force in the three cases are:
   Green: 0.30 N; Red: 0.15 N;Blue: 0.10 N
2. Listed in order from greatest to least, the densities of the three liquids are: Green 2.0 g/mL; Red 1.0 g/mL; Blue 0.67 g/mL. Both lists are in the same order.

Analyze Answers

1. The weight of the 100 g mass submerged in the liquids decreases as the density of the liquid increases. When the 100 g mass is submerged, it displaces its volume of the fluid. The force of gravity on the displaced fluid provides a force that pushes upward on the mass, called the buoyancy force. The greater the density of the surrounding fluid is, the greater the mass of the fluid displaced is. The greater the mass of fluid is, the greater the force of gravity on that fluid is, and the greater the buoyancy force is.
2. The hydrometer in set 2 shows a different reading for each liquid. In liquid 3, the hydrometer extends halfway out of the liquid. In liquid 2, the hydrometer is almost entirely submerged. In liquid 1, the top of the hydrometer's scale is slightly below the surface of the liquid. The greater the density of the liquid is, the less the hydrometer has to sink to displace a mass of liquid equal to its own mass.
3. Archimedes' principle states that the mass of the displaced volume of liquid equals the buoyant force. The 100 g mass displaces the same volume of liquid every time. However, the density of the fluid is different. The greater the density of the fluid is, the greater the mass of the displaced fluid is, and the greater the force of gravity upon the displaced fluid is. Therefore the buoyant force exerted by each liquid must be different. The greater the density of the liquid is, the greater the buoyant force is that it exerts.

USING THE FEATURE

Science Watch: Brace Yourself for the Force, p. 346

After students have read the section, ask them, "Are the forces acting on the tooth balanced or unbalanced?" (The teeth are moving extremely slowly, at constant speed. The forces on the teeth must be balanced.) Ask students, "How can balanced forces cause something to change?" (Unbalanced forces are necessary to cause acceleration, or change in speed. Unbalanced forces must have been used to get the teeth moving in the first place. Once the tooth is moving (even slowly) as long as the speed is constant, the forces are balanced.)

SECTION 9.1 ASSESSMENT, p. 347

Check Your Understanding Answers

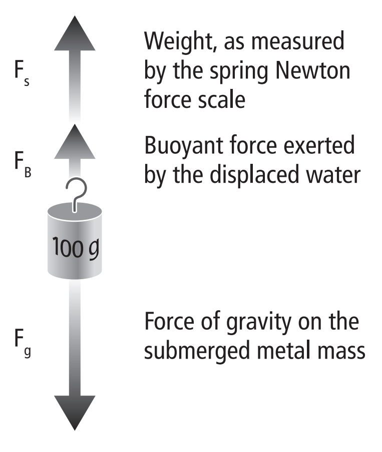
Checking Concepts

1. The motion of the soccer ball was changed. The goalie must have applied a force to stop the ball.
2. Peter's mass would still be 84 kg. The amount of matter in Peter does not change.
3. A bathroom scale measures the force that gravity exerts upon your body. On the moon, the force of gravity is one sixth as much, so your weight would also be one sixth as much. Bathroom scales are built to operate on Earth only, so they will incorrectly translate your weight into a mass, and display a mass that is only one sixth of your real mass, which has remained unchanged.
4. The boat would sink. Its volume is so small that it only displaces 260 g of water. It would have to displace at least 320 g of water to float.
5. If you change the shape of the substance, you could change the average density of the material.
   (a) Compressing foam plastic beads can increase their density by squeezing out air to cause them to sink.
   (b) Shaping foil into a boat with a much larger volume will make the average density of the metal object much less, making it able to float.

Understanding Key Ideas

6. Students' answers will vary, but should contain the following points:
   (a) The diagram must show a car with equal forces pushing in opposite directions. These forces should be labelled as balanced. The answer should explain that the car remains at its current speed, zero.
   (b) The diagram should show the force of both people pushing in the same direction. There should be a third force, friction, pointing in the opposite direction. If the student explains that the forces are unbalanced, then the car is accelerating. If the student claims that the forces are balanced, then the car must be travelling at a constant speed.

7. Students' answers will vary. One sophisticated student answer can be seen in this diagram.



8. The blimp is filled with helium. Together with the tonnes of fabric, frame, motor, TV cameras, batteries, gondola, and people, the helium and the other objects have an average density very close to the density of air. The blimp's neutral buoyancy allows it to float without rising or sinking.
9. Submarines have ballast tanks which can be filled with sea water, or with air. If the ballast tanks are filled with water, the average density of the submarine is greater than sea water and the submarine sinks. If the water is pumped out of the ballast tanks, and air is allowed in, then the average density of the submarine is less, and the ship rises.
10. (a) The wooden boat has a smaller average density. It will float, and the waterlogged stick will sink.
    (b) The metal block has a greater average density. It will sink. The metal boat has a smaller average density. It will float.
    (c) The sealed, empty plastic bottle has a lower average density. It will float, while the water-filled bottle might sink.

Pause and Reflect Answer

Students' answers may vary a great deal. Students may mention mass, particles, spaces, attractive forces, friction, density, viscosity, temperature, and speed. Free-falling 4 km from an airplane will take about 2 min. Air particles are very far apart, so they can easily move out of the way. Water particles are close together, and strongly attracted to each other, so they do not move out of the way as easily. The air is much less dense, and much less viscous, than cold sea water. The submersible would travel through the air at a much greater speed, because the air's resistance to flow is so much less. Also, because air is so much less dense, it would exert a much smaller buoyant force. The force of gravity would be much stronger than the buoyant force, and the submersible would accelerate quickly.

Other Assessment Opportunities

- Consult the Unit front matter for a list of applicable Assessment BLMs.

9.2 PRESSURE, HYDRAULICS, AND PNEUMATICS

BACKGROUND INFORMATION

The concept of pressure in liquids and gases is presented using two approaches. The first approach appeals to students' experiences of pressure. Students will probably have a strongly intuitive understanding of pressure. They should be presented with as many opportunities for new experiences as possible. For example, pump up a volleyball, bring in a sports bicycle with shock absorbers, let students measure their blood pressure. There are many opportunities available. This approach is most likely to be intuitively understood. The second approach provides a mathematical description of pressure. Students are likely to find this part much more difficult, and will need support. Scientists' use of algebraic equations can be intimidating to students who are not confident in their math skills. Use a well structured approach to the math, and encourage students to write down all of their thinking. Students will need as many examples of everyday pressures as possible. The unit used to measure pressure is the Pascal, a very small pressure of only 1 N distributed over 1 m^2.

Three distinct topics are addressed in this section:

- The first topic introduces the concept of pressure as a force distributed over an area, or "force per unit area." The experience of pressure is likely something most students will be able to relate to.
- The second topic provides a description of the behaviour of solids, liquids, and gases under pressure.
- The third topic deals with mechanical systems that use fluids under pressure. Pascal's law states that "pressure applied to an enclosed fluid is transmitted equally throughout the container." The particles of a fluid are free to move. When pressure is applied to a fluid, the particles are slightly pressed together. They collide more frequently with their neighbours. The neighbouring particles respond by moving slightly away, and colliding more often with their neighbours. The pressure is transmitted throughout the container very quickly.

COMMON MISCONCEPTIONS

- Students may confuse the concepts of "pressure" with the concept of "force." They have thousands of experiences in which increasing pressure correlates to increasing force, and vice versa. Students will likely use the two ideas interchangeably, as people often do in day-to-day speech. However, pressure and force each have their own specific meaning. It is very important to point out that pressure is the area over which the force is distributed as often as possible, or $P = \frac{F}{A}$.
- Many students do not understand the concept of the vacuum. A vacuum is a space containing no matter, such as the space between the Earth and the moon that contains almost no particles. Such a space has zero pressure. Instead, students are likely to think of a vacuum as suction. For example, students will almost always speak of "sucking" a soft drink up a straw. Challenge this idea as often as possible. Point out that they live at the bottom of an ocean of air. If they decrease the pressure inside their mouth, the pressure of the atmosphere pushes the water up the straw.

ADVANCE PREPARATION

- Activity 9-2A on page 349 requires two small balloons and one straight pin for each student.
- Activity 9-2B on page 357 requires two different-sized modified syringes for each pair of students. (Modified syringes are syringes without needles.) You may wish to purchase a can of silicone spray to lubricate the syringes so that they move and respond more easily.
- Activity 9-2C on page 359 requires the same sets of syringes.
- Activity 9-2D on page 360 requires three empty plastic pop or water bottles (500 mL), with their caps.
- Consult the Unit front matter for a list of BLMs that can be used when teaching this section.

INTRODUCING THE SECTION, pp. 348–349

Using the Text

In this section, students will explore the effects of pressure in fluids and some practical applications of fluid pressure. Some examples are given on page 344. See what other examples students can think of. Most students will likely be familiar with the effects of pressure, but they may not have considered what pressure is and how it works.

Conduct a brainstorming activity focussing on examples of pressure in fires and fire fighting.

- Students will probably identify the pressure associated with the hoses that deliver the water or foam used to fight the fire. Students may not realize that the water (or foam) shot from the hoses is under very high pressure. This high pressure is apparent in the photo on page 348. In addition, the water is moving at extremely high speeds. It takes considerable strength on the part of the firefighters to direct the water. The pressure in the hoses can cause a kickback effect that can knock a person off his or her feet.
- Some students may be able to identify the role played by varying air pressure in determining the direction a fire takes. Gases produced when materials burn can expand as they become hotter. When they expand too much, the doors and windows of the burning building may blow out, allowing in fire-feeding oxygen.
- Some students may know that the Jaws of Life are operated by hydraulic pressure.

What is Pressure? on page 349 will provide students with a working definition of pressure, which they will need to complete Think About It Activity 9-2A.

Using the Key Terms and Section Summary

At the beginning of each section in the student textbook are the Key Terms and section summary. Both can be used as a pre-reading strategy and a review tool. Before reading the text in the section, students should be able to define the Key Terms by scanning the text and using the Glossary. The Key Terms include terms from the curriculum outcomes and additional terms that are important for students to know and understand.

The section summary provides an overview of the key concepts being covered in the section. Students may not know all the concepts and terms described in the summary, but they can use this information to help guide them through their reading.

After reading the section, students can go back to the Key Terms and section summary to consolidate their understanding and identify areas that require clarification. At the end of the chapter or unit, students can use the Key Terms and section summary for review. BLM 3-2, Unit 3 Key Terms, and BLM 3-5, Chapter 9 Key Terms, can be used to assist students.

Using the Activity

Think About It Activity 9-2A

Pop 'em Quick!, p. 349

Purpose

- Students will observe first-hand the connection between surface area, force, and pressure.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
3 days before	Gather balloons and straight pins.	For each group: – 2 small balloons – 1 straight pin
1 day before	Ask students about latex allergies.	

Time Required

- 15 min

Safety Precautions

- Ask students about latex allergies before distributing balloons.
- Goggles should be worn.
- Remind students to be careful with the straight pins. Quilters' pins have coloured heads and are easier to locate if they are dropped. They are also longer and may be easier to handle.
- Rinse puncture wounds immediately and apply an antiseptic. Bandage if necessary.
- Allow only one person to blow up each balloon to avoid spreading germs.
- Advise students not to chew on the balloon fragments, which can be hazardous if swallowed.

Science Background

The balloons will resist popping with a finger, but will pop readily with a pin, since the force is distributed over a larger area by the finger and a smaller area by the pin. The pressure (force per unit area) is greater when a pin is used.

Activity Notes

- Make certain that each pair of students gets two balloons that are the same size or shape (for example, both round, or both oblong, and both with the same diameter and capacity).
- Show students the approximate inflation size they should use.
- Students should not overinflate their balloons. Overinflated balloons will pop on almost any sharp corner or object.
- Give students a few minutes to discuss their ideas for fast balloon-popping methods before they proceed with the activity.

Supporting Diverse Student Needs

- Students with allergies, etc., may not be able to inflate balloons. Pair these students with others who can.
- The direct evidence in this activity will be appealing to students oriented to sensory, body-kinesthetic learning. Other students more oriented to linguistic, spatial, or logical-mathematical intelligence may not find this activity engaging.

  Challenge these students to note the area of the flat part of the balloon in contact with the desk, and correlate it to the overall force exerted. Is it the same or different in the two cases? (The area should be greater when more force is used, i.e., when the balloon is pressed with a finger.)
- As an extension, ask students to predict the results for, then test, a third method, such as using a ball point pen or a dull pencil.

What Did You Find Out? Answers

1. It took less force and less time to pop the balloon with the pin.
2. The straight pin had the smaller surface area.
3. The same amount of pressure is needed to pop the balloon either way. Because the force is applied to such a small area with the pin, less force creates the same amount of pressure. (This concept should become clearer to students as they work through this section.)
4. The greater the area is, the more force that is required to provide the same pressure.

TEACHING THE SECTION, pp. 350–359

Using Reading

Break the reading up into three distinct parts: Relationship Among Force, Area, and Pressure (pp. 350–353); Pressure and Liquids in Nature (pp. 354–355); and Pascal's Law (pp. 356–359). The subject matter in each of these three sections is sufficiently distinct that students will probably find it helpful to read and discuss them one at a time.

Part 1: Relationships Among Force, Area, and Pressure (pp. 350–353)

The algebra in particular is likely to be challenging. Spend time becoming familiar with the equations and the methods of solving a problem. Some preparation will be necessary.

Pre-reading—K-W-L (Know, Want to Know, Learned)

Arrange students into pairs. Have students fold one sheet of paper in half horizontally to make four sections. Write these headings on the sections:

How is force different from pressure?
How are pressure and area related?
Calculating Pressure from Force and Area
Calculating Force from Pressure and Area

Direct them to skim the text, examining headings, illustrations, and captions (3 min).

Write these questions on the board: "What is pressure? What is force? Are pressure and force the same thing, or different things? What is area? What is the relationship among force, area, and pressure?" Probe students' current understanding by having each pair discuss their thoughts. Have students write the things that they currently believe they know under the headings above. Alone, have each student write two or three "want to knows" under each heading (2 min). Then, have them share ideas with their partner. Together, students should compile a larger list of "Want to Knows" under each heading (3 min).

During Reading—Think, Pair, Share

Ask students to read pages 350 and 351 (to the sample problem) quietly and alone, and record their notes and thoughts under the headings they set up earlier. Then lead the whole class through the solution of the sample problem on page 351. Write the formula for pressure on the board. As you record the solution, draw students' attention to these conventions:

- Equal signs align one below the other.
- The formula is written with a horizontal line between the numerator and the denominator.
- Substitute for F and A using brackets and including the units.
- Round your answer to as many digits as you were given.

Then have students continue to use Think-Pair-Share to solve the practice problems in the student textbook. They should try each solution on their own, then compare solutions in pairs. They can solve the other two sets of practice problems the same way (one finding force, and the other finding area). Remind students of the conventions for solving problems (see above) to help them structure their solutions in the conventional way.

When finished, instruct pairs of students to share their notes and thoughts on the text, and to review their lists of things they want to know. As students go through their lists, have them identify ideas with which they need more help. Tell them to list those "want to knows" on the board.

Supporting Diverse Student Needs

- Have students without strong mathematics skills work with a classmate to check answers to the practice problems and revise them as necessary. Emphasize that to be complete, answers must include units and a statement of the solution.

After Reading—Semantic Mapping

Have students draw a diagram that will help them remember the relationship among force, area, and pressure.

BLM 3-35, Calculating Pressure, and BLM 3-36, Pressure Problems, provide further practice calculating pressure, force, and area.

Practice Problem Answers p. 351

Students should provide a complete solution, as described in the text.

1. $$\begin{aligned} P &= \frac{F}{A} \\ &= \frac{(0.80\ \text{N})}{(0.016\ \text{m}^2)} \\ &= 50\ \text{N/m}^2 \end{aligned}$$
The pressure on your hand is 50 Pa.

2. $$\begin{aligned} P &= \frac{F}{A} \\ &= \frac{(14\ \text{N})}{(0.60\ \text{m}^2)} \\ &= 23.333\ \text{N/m}^2 \end{aligned}$$
The book exerts 23 Pa pressure.

3. $$\begin{aligned} P &= \frac{F}{A} \\ &= \frac{(185\ \text{N})}{(0.12\ \text{m}^2)} \\ &= 1541.667\ \text{N/m}^2 \end{aligned}$$
The pressure at the bottom of the tub is 1542 Pa.

Practice Problem Answers p. 352

1. $$\begin{aligned} F &= P \times A \\ &= (2500\ \text{Pa}) \times (0.15\ \text{m}^2) \\ &= 375\ \text{N} \end{aligned}$$
Water exerts 380 N. (Round to the nearest 10.)

2. $$\begin{aligned} F &= P \times A \\ &= (517\,000\ \text{Pa}) \times (0.0005\ \text{m}^2) \\ &= 258.5\ \text{N} \end{aligned}$$
The force on the piston is 260 N.

3. $$\begin{aligned} F &= P \times A \\ &= (241\,000\ \text{Pa}) \times (1\ \text{m}^2) \\ &= 241\,000\ \text{N} \end{aligned}$$
Force on 1m^2 of tire is 241 kN. (240 000 Newtons).

Practice Problem Answers p. 353

1. $$\begin{aligned} A &= \frac{F}{P} \\ &= \frac{(102\,000\ \text{N})}{(153\,000\ \text{Pa})} \\ &= 0.67\ \text{m}^2 \end{aligned}$$
The area must be $0.67\ \text{m}^2$.

2. $$\begin{aligned} A &= \frac{F}{P} \\ &= \frac{(24\,525\,000\ \text{N})}{(19\,620\ \text{Pa})} \\ &= 1250\ \text{m}^2. \end{aligned}$$
The area must be $1250\ \text{m}^2$.

3. $A = \frac{F}{P}$

$= \frac{(50\ 662.5\ \text{N})}{(101\ 325\ \text{Pa})}$

$= 0.5\ \text{m}^2$

The area must be 0.500000 m^2.

Reading Check Answers, p. 353

1. Pressure is the force acting on a certain area of a surface.
2. The greater the force is (on the same area), the greater the pressure is. The smaller the area is (if the force stays the same), the greater the pressure is.
3. $P = \frac{F}{A}$
4. The Pascal. One Pascal is the pressure exerted by one Newton force distributed over one square metre. 1 Pa = 1 N/m^2
5. For large pressures, we often use the kiloPascal, kPa.

Part 2: Pressure and Liquids in Nature (pp. 354–355) and Pascal's Law (pp. 356–359)

Pre-reading—Predict-Read-Verify

Have students skim the two sections, paying careful attention to the pictures, captions, and headings. Tell students to break each part up into chunks that represent their skimming, and to provide a heading for each chunk. Some headings for Pressure and Liquids in Nature might be the following:

- Pressure and Water
- Solids, Liquids, and Gases
- Pressure and the Atmosphere

Use the chunks as topics for discussion. Ask students what they think the headings mean. Direct them to re-write the headings in their notebooks as questions, leaving one half page for each heading. Have them make predictions about what they will learn, and write their predictions under each heading. Have them read the section, and compare their predictions to what they have learned.

During Reading—Note Taking

Direct students to make brief, summarizing notes under each heading as they read. Their notes should be written to answer the question posed by the heading, or to support that answer.

Supporting Diverse Student Needs

- Encourage students to include fully labelled diagrams in their notes, especially for hydraulic and pneumatic systems. Creating and referring to these diagrams will be especially helpful to visual-spatial learners. Working with a classmate to create the diagrams will be helpful to interpersonal learners and those with reading difficulties.

After Reading—Reflect and Evaluate

When students have finished taking notes, have them quietly write statements to compare and contrast their notes with their predictions. Have them write three pieces of interesting new information and suggest when or where each one might be useful to know. If students do not have a clear idea of how a pneumatic system works, refer to the diagram on page 359 of the student textbook as you talk about where the force is applied, where the gas is under pressure, how the pressure is released, and what happens when the pressure is released.

Reading Check Answers, p. 355

1. The deeper you swim, the greater the weight is of the water above you.
2. Compressibility is the ability to be squeezed into a smaller volume or space.
3. The space between particles in a gas is very large. The particles can be squeezed into a smaller volume.
4. The particles in both the solid state and the liquid state are touching each other. It is not possible to squeeze them together much closer than they are already.
5. The atmospheric pressure is less at higher altitudes. As students saw on page 276, as you go up farther and farther in the atmosphere, the pressure gets less and less. Air trapped inside your ears is released in little "burps" from the inside of your eardrum to the outside. You experience your ears popping.

Reading Check Answers, p. 359

1. Pascal's law: The pressure applied to an enclosed fluid is transmitted equally throughout the container.
2. A hydraulic system transmits forces through a liquid.
3. A pneumatic system transmits forces through a gas.
4. The brake system in a car is hydraulic. The shock absorbers on a bicycle are pneumatic.
5. A small force acting on a small area in one part of an enclosed fluid can become a large force acting on a large area in the same system.

USING THE ACTIVITIES

- Activity 9-2A on page 349 of the student textbook is best used as an introductory activity. Detailed information about this activity can be found in Introducing the Section.

- Activity 9-2B on page 357 and Activity 9-2C on page 359 of the student textbook are best completed together, as they use the same equipment, and the methods are similar. Use them after students have read about Pascal's law, so students come to the experience equipped to observe the surprising difference in forces.
- Activity 9-2D on page 360 of the student textbook is best used when discussing the compressibility of solids, liquids, and gases.
- Detailed notes on doing the activities follow.

Find Out Activity 9-2B

Simple Hydraulics, p. 357

Purpose

- Students use modified syringes and plastic tubing to create and investigate simple hydraulic systems and how they function.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
2 weeks before	Obtain syringes, and plastic tubing to fit.	For each group: – 2 modified syringes (syringes with no needle) – 15 cm plastic tube

Time Required

- 20 min

Safety Precautions

- Warn students not to squirt water at anyone. A high speed jet of water can injure the eyes.
- Students should wear safety glasses at all times.

Science Background

The volume of water transferred out of one syringe will be equal to the water transferred into the other syringe. Students can check this result using the graduations on the barrel of the syringe.

Water is incompressible. It is not possible to store energy in compressed water, so hydraulic systems are more easily controlled. Hydraulic systems can be used for pushing, pulling, lifting, prying apart, ramming, or cutting. Hydraulic systems can exert much more force than a single person. Unlike the simple modified-syringe hydraulic systems that students made, the hydraulic systems in construction machinery require powerful pumps to move the liquids in the systems. Hydraulic oil under high pressure can exert a huge amount of force on a large piston inside a hydraulic cylinder.

Activity Notes

- The piston in each syringe is designed not to leak. Sometimes, they are so tight that a dry syringe sticks or is difficult to operate. If you just touch your finger in a little mineral oil, and then rub that onto the rubber piston, the plunger will operate much more smoothly. Work the piston in and out of the syringe before adding water.
- Plastic tubing is readily available at some pet shops, hardware stores, and wine-supply stores. It comes in various diameters, so make certain the size you buy fits snugly over the ends of the syringes.
- You may want to consider informing parents that modified syringes are part of the classroom materials used in this unit of the science/technology program.
- The modified syringes are brand new and have never been used with a needle. Explain the difference between a modified syringe and a syringe-and-needle combination to students.
- Save the modified syringes and tubing from this activity for reuse in Activity 9-2C: Exploring Pneumatics, on page 359 of the student textbook. Consider doing both activities at the same time.

Supporting Diverse Student Needs

- To help students who have difficulty following written instructions, demonstrate the first 3 steps of What To Do. Alternatively, you could have a few preassembled hydraulic systems available for these students to use.
- Many students think of syringes as "needles." Work with all students to help them use new terms appropriately. New terms include modified syringes (no needles!), pistons, plungers, main cylinder, and reacting cylinder. To consolidate these new terms, have students draw a diagram and label each of these components.
- Students with written output challenges may find this activity easy to do, but difficult to explain. Pair these students with classmates who can assist them in understanding and writing up this work, using the new terms.
- To promote body-kinesthetic learning, ensure that all students have a chance to operate the system and feel the pressure themselves.
- Groups including students with a variety of dominant learning styles are at an advantage here, as there are many types of reasoning and learning needed to complete this activity. Encourage students to cooperate and assign tasks so that everyone has a chance to contribute in a meaningful way.

- As an extension, as the experiment is proceeding, ask some students to record the change in volume and the distance moved by each plunger. Is there a pattern?

What Did You Find Out? Answers

1. When a force is applied to the "main cylinder" in the hydraulic system, the plunger in the "reacting cylinder" moves out.
2. The setup is an example of a hydraulic system since the transmission of the applied force is done through the liquid. (The force is exerted on an enclosed liquid.)

Find Out Activity 9-2C

Exploring Pneumatics, p. 359

Purpose

- Students observe how pressure is transmitted in a simple pneumatic device.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
2 weeks before	Obtain syringes, plastic tubing to fit.	For each group: – 2 modified syringes (various sizes) – 15 cm plastic tube

Time Required

- 30 min

Safety Precautions

- Warn students not to force the plungers at either end of the pneumatic system as the system might burst.
- Students should wear safety glasses.

Science Background

Because gases are compressible, it is possible to store up energy in compressed gas. Pneumatic systems can release very quickly, as gas has low viscosity. Therefore, a compressed gas can release its energy rapidly. The speed and stored energy of pneumatic systems sometimes makes them dangerous to work with. In this system, it is possible to make the plunger pop right out of the syringe at high speed, propelled by compressed gas.

If the pressure of the gas remains constant, the volume of gas squeezed out of syringe A should be identical to the volume of gas entering syringe B.

Activity Notes

- The piston in each syringe is designed not to leak. Sometimes, they are so tight that a dry syringe sticks or is difficult to operate. If you just touch your finger in a little mineral oil, and then rub that onto the rubber piston, the plunger will operate much more smoothly.
- Fit the plastic tubing closely to the nipple on each syringe. If the plastic tubing has been used before, trim off the little stretched bit at the end. Do not lubricate the plastic tubing to make it easier to get on, as it will also slip off more easily.
- Students might start with syringes the same size, and then switch to two syringes of different sizes. They should experiment with a number of configurations. Reverse the direction, so that the action syringe in one test becomes the reaction syringe in the next test.

Supporting Diverse Student Needs

- To help students who have difficulty following written instructions, demonstrate the first 3 steps of What To Do. Alternatively, you could have a few preassembled pneumatic systems available for these students to use.
- Groups including students with a variety of dominant learning styles are at an advantage here, as there are many types of reasoning and learning needed to complete this activity. Encourage students to cooperate and assign tasks so that everyone has a chance to contribute in a meaningful way.
- To promote body-kinesthetic learning, ensure that all students have a chance to operate the system and feel the pressure themselves.
- For enrichment, as the experiment is proceeding, ask some students to record the change in volume and the distance moved by each plunger. Ask, "Is there a pattern?"

What Did You Find Out? Answers

1. The force at B varies, depending on the relative sizes of the syringes.
2. This system can be used to make work easier. The syringes can be arranged so that a small inward force on piston A results in a larger outward force at piston B. Piston A must move a greater distance than piston B in order for piston B to move.

Conduct an Investigation 9-2D

Bottle Squeeze, pp. 360–361

Purpose

- Students do a hands-on investigation to compare the compressibility of solids, liquids, and gases.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
2 weeks before	Collect 500 mL pop bottles, with twist off caps.	For each group: – 500 mL beaker, or measuring cup – 3 empty plastic pop bottles with twist-off caps, 500 mL each – water – sand
1 week before	Obtain a quantity of clean, dry sand.	

Time Required

- 40–50 min

Safety Precautions

- Remind students to wear their safety goggles, lab coats, and rubber gloves.
- Wipe up any spills immediately.
- The "empty" pop bottle may crack after several squeezes.

Science Background

As the particle theory explains, the spaces between gas particles are large, and it is relatively easy to squeeze the bottle to force the particles closer together. In solids and liquids, the spaces between the particles are much smaller, so it is difficult to squeeze them together.

Activity Notes

- Review the particle theory with students.
- Preview the investigation with students.
- Ask students to make predictions about the compressibility in each of the trials. They should then be able to record and compare the actual results with their predictions.
- Explain why it is important for the bottles to be completely full in steps 5 and 6. Allow the sand to settle into the bottle before screwing the cap into place. Shaking the bottle gently, or tapping it lightly on the counter, will help to ensure there are no trapped air pockets in the sand.
- Discuss why there is a 5 min waiting period before adding more water in step 5.
- Have students prepare a table with two columns. Have them title the first column "Substance" and the second column "Particle Theory."
- Have students name and rank the substances in the first column, and then use the particle theory to explain the behaviour of each substance in the second column.

Supporting Diverse Student Needs

- Body-kinesthetic learners will do well at this activity. You may wish to pair them with visual-spatial learners for the analysis.
- Students have experienced the "cause and effect." A "cause and effect" diagram will support students who prefer visual and/or kinesthetic experiences. Ask student to draw two diagrams: one with the diver floating, and one with the diver sinking. Instruct students to write label headings such as "pressure," "extra pressure," "volume of air," "density," etc., to cue students to fill in the missing details, and to provide an explanation of causes and effects in this activity.
- The design challenge in Extend Your Knowledge provides extension. For further extension, have students design and conduct an experiment to test compressibility using the devices they find or build.

Analyze Answers

1. (a) As the amount of water in the bottle increased, it became more difficult to compress the bottle.
   (b) As the amount of sand in the bottle increased, it became more difficult to compress the bottle.

Conclude and Apply Answers

2. (a) A gas is more compressible than a solid.
   (b) A gas is more compressible than a liquid.
3. A liquid is slightly more compressible than a solid.
4. Answers will vary. The water would probably compress a bit, then the bottle would burst. Liquids can only compress a little bit. Most of the force of the car's weight would be transferred to the bottle itself.

Extend Your Knowledge Answers

5. Students' answers may vary. Some students may recall that solids are compressed deep within the Earth. Others may believe that water can be compressed, but only under higher pressure. Ideally, a controlled force would be applied equally to all parts of the bottle.
   Students might construct a lever or a press that could provide greater pressure. Caution: have students stand clear of the bottle cap as it might pop off with considerable force.

USING THE FEATURE

Science Watch: Body Hydraulics, p. 362

After students read this section, ask, "How much pressure does your heart exert on the blood?"

Blood pressure is measured in millimetres of mercury, mm Hg. To convert to Pascals, multiply mm Hg by 0.133. A blood pressure of 120 mm Hg × 133 = 16 000 Pa, or 16 kPa.

Some students may have experience with blood pressure. Healthy normal blood pressure varies between 120 mm Hg and 80 mm Hg. According to Pascal's law, the pressure at one point inside your arteries will be the same everywhere in your arteries.

Olympic weight lifters must squeeze their abdominal muscles very tightly in order to support hundreds of kilograms. Ask students to hypothesize whether squeezing abdominal muscles increases the blood pressure in the arteries in their brains. (It does.)

You can use BLM 3-37, How the Heart Works, as an overhead transparency to help students understand the path of the blood, and the effects of pressure in a human heart.

SECTION 9.2 ASSESSMENT, p. 363

Check Your Understanding Answers

Checking Concepts

1. $P = F \div A$ 2 cm = 0.02 m
   $A = \pi r^2$
   $= 3.14 \times 0.02 \text{ m} \times 0.02 \text{ m}$
   $= 0.001 \text{ m}^2$
   $P = (500 \text{ N}) \div (0.001 \text{ m}^2)$
   $P = 500\ 000 \text{ N/m}^2$
   The pressure of her head on the floor is 500 kPa, or 500 000 Pa.
2. As they rise, they encounter lower and lower atmospheric pressure outside the balloon. The helium in the balloon expands as the pressure decreases, eventually bursting the balloon.
3. The heart is like the pump, and the blood is like the hydraulic fluid. The blood circulates inside the closed system.
4. The pressure is greater at the bottom of the barrel, because there is a greater weight of water above it. The water squirts farther if it leaks from the bottom, as long as the holes are the same size.
5. The air inside the plane is at higher pressure than the air outside the plane. If the door opens, air will move rapidly out of the plane, taking people with it if they are not belted in.

Understanding Key Ideas

6. The space between gas particles is large, so gases can be compressed. Liquids cannot be compressed because there is little space between the particles.
7. In the atmosphere, the air inside and outside your body can equalize pressure as you breathe and move. When you are holding your breath, the extra 30 kPa of water pressure cannot be equalized, so you feel it. The air is still up there over the pool, so the pressure underwater is actually 130 kPa.
8. (a) Pneumatic systems are based on the compressibility of gases. Compressed gas stores energy that can be released quickly. (For example, a paint ball gun stores a measured amount of compressed gas. When you pull the trigger, the expanding gas propels the paintball out at high speed.)
   (b) This property helps pneumatic systems do work by storing energy. You can exert a force on the system, and the system will store the energy as compressed gas, then it can be released at a time, or in a place where work is to be done.
9. Pumps move the fluid around and provide pressure. The valves control the flow of the fluid, and the movement of the pistons.

Pause and Reflect Answer

Expect a wide variety of answers. Here are some examples.
Desirable = D
Undesirable = UD

HOME	SCHOOL	GROCERY STORE	HOSPITAL
– soda pop (D)	– soda pop (D)	– cans being dented (UD)	– gases in containers (D)
– sealed food containers (D)	– vacuum cleaner (D)	– forklifts for lifting (D)	– sphygmomanometer (D)
– vacuum cleaner (D)	– brakes in bus (D)	– garbage crushing (D)	– heart attack (UD)
– brakes in car (D)	– drinking fountains (D)	– automatic door openers (D)	– CPR (D)
– natural gas range (D)	– plumbing systems (D)	– ripped chip/ snack bags (UD)	–compression/ decompression chambers (D)
– natural gas leak (UD)			
– plumbing systems (D)			

Other Assessment Opportunities

- Consult the Unit front matter for a list of applicable Assessment BLMs.

9.3 RELATIONSHIPS AMONG PRESSURE, VOLUME, AND TEMPERATURE OF GASES

BACKGROUND INFORMATION

The key to understanding this section is the particle theory. At every opportunity, draw simple particle diagrams.

- Pressure inside a balloon, for example, is caused by particles of air colliding with the wall of the balloon.
- The greater the number of particles is per unit volume, the greater the number of collisions is, and the greater the pressure is. Adding air to your tire increases the number of particles inside the tire, thus increasing pressure.
- The greater the speed of the particles is, the greater the force of each collision is. Increasing the temperature of a gas will increase both the force of each collision and the number of collisions per second, thus increasing the pressure.
- Reducing the volume of a container will cause the particles to be squeezed together. More collisions will occur with the sides of the container. Thus, pressure increases.
- Sometimes a container, like a partially inflated plastic bag, is free to expand at constant pressure. If the gas is heated inside such a container, the particles will move more quickly. As they collide with the bag, they push the container outward. Heating a gas at constant pressure causes the gas to expand in volume.

COMMON MISCONCEPTIONS

- "Pressure causes ... " In general, pressure is a *consequence* of other changes in a gas. The pressure in a cylinder of gas depends on the temperature, the volume, and the number of particles present. Causing a change in temperature, a change in volume, or a change in the number of particles causes a change in pressure. It is not possible to change pressure directly without doing one of these three things.
- "Pressure is an effort or an exertion." Students have a very deep set of experiences of pressure in their own bodies: breathing, sneezing, blowing up balloons, eliminating wastes. Usually, the experience of pressure is accompanied by experiences of effort or exertion. This belief is probably why students are convinced that pressure is the same as exertion or effort.
- Students might forget that gases are made of very small particles with a lot of space between them. Remind students to always think of the behaviour of the particles of gas when they try to understand gas behaviour.

ADVANCE PREPARATION

- Small balloons are needed in Activity 9-3A, one balloon for each student.
- Balloons (or plastic food bags) are needed for Activity 9-3B, as well as drinking straws and elastic bands. Soft chewing gum is optional, but recommended.
- Each lab group performing Activity 9-3D will need a lab stand plus one or two clamps, a syringe, and a set of laboratory masses.
- Have ready a number of things to help demonstrate gas pressure, volume, and temperature relationships: a bicycle pump equipped with a pin; volleyball, football, basketball, etc.; hydraulic jack, or bottle jack; blood pressure apparatus.
- Consult the Unit front matter for a list of BLMs that can be used when teaching this section.

INTRODUCING THE SECTION, pp. 364–365

Using the Text

Ask students to look at the photograph on page 364 and read the caption. Ask students, "Does anyone know someone who uses a breathing apparatus like this?" "How much oxygen is released each time that person breathes?" (A flow rate of 0.20 L per minute is quite common.) "How long does one oxygen tank last?" (about two days)

- Challenge students: "Under normal circumstances, what volume of oxygen would have to be inside the tank to allow 0.2 L of oxygen every minute for two full days?" (about 600 L)
- How did they get 600 L of oxygen into a cylinder only 6 L in size? (The pressure in the container is about 100 times ordinary atmospheric pressure. The oxygen is compressed.)
- Before doing the reading, present students with a bicycle pump with a lever-type connection. Clamp the end of a pencil or pen in the connection, to seal the connection. (Even better, if you have access to a tire pressure gauge, use that to seal the connection.) Invite students to use their weight and strength to squeeze the cylinder as far as they can. Most students can barely reach 500 kilopascals (kPa) (or 70 pounds per square inch).

Using the Key Terms and Section Summary

At the beginning of each section in the student textbook are the Key Terms and section summary. Both can be used as a pre-reading strategy and a review tool. Before reading the text in the section, students should be able to define the Key Terms by scanning the text and using the Glossary. The Key Terms include terms from the curriculum outcomes and additional terms that are important for students to know and understand.

The section summary provides an overview of the key concepts being covered in the section. Students may not know all the concepts and terms described in the summary, but they can use this information to help guide them through their reading.

After reading the section, students can go back to the Key Terms and section summary to consolidate their understanding and identify areas that require clarification. At the end of the chapter or unit, students can use the Key Terms and section summary for review. BLM 3-2, Unit 3 Key Terms, and BLM 3-5, Chapter 9 Key Terms, can be used to assist students.

Using the Activity

Find Out Activity 9-3A

Hot and Cold Gases, p. 365

Purpose

- Students investigate in a qualitative way the effect of temperature on the volume of a gas at nearly constant pressure.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
2 weeks before	Collect 500 mL pop bottles, with twist-off caps.	For each group: – one empty 500 mL plastic pop bottle – safety goggles
1 week before	Obtain sufficient balloons and elastic bands.	– 1 balloon – 1 elastic band For the class:
1 hour before	Prepare buckets of ice water and hot water.	– large bowls or buckets – ice water – hot water

Time Required

- 20 min

Safety Precautions

- Ask students about latex allergies.
- The use of goggles is recommended.
- Caution students to use balloons responsibly, and not to pop them, chew them, etc.
- Do not use boiling water. It can scald students if it is spilled. The plastic pop bottle will quickly collapse at that temperature, spoiling the experiment.

Science Background

The balloon is initially nearly collapsed. When it is placed in the hot water bath, the balloon will inflate just a little. For a 500 mL bottle, changing the temperature from room temperature (about 20°C) to the temperature of hot tap water (about 50°C) would cause the volume in the bottle to expand to 550 mL. This small expansion will only half fill a 100 mL balloon with a diameter of 6 cm.

When the heated balloon is placed in the cold water bath, the collapse will be quite noticeable. The temperature falls from about 50°C to 0°C, and the volume of the air will decrease from about 550 mL to about 460 mL. This decrease in air volume may be enough to draw a small balloon right into the bottle.

Activity Notes

- Choose small balloons, with a capacity of about 100 mL. A tempered balloon inflated just to the point where the rubber goes from slack to full would be 6 cm in diameter.
- Before proceeding, have students inflate the balloons first, to stretch or temper the rubber. Let the tempered (stretched) balloon deflate before attaching it to a bottle.
- At room temperature, the balloon should be almost, but not quite, totally collapsed.
- Advise students to moisten the threaded neck of the bottle before attaching a balloon. A little water between the latex and the plastic bottle will both ease the balloon over the neck, and help to make a better seal between them.
- Make the elastic quite tight. Twist it, stretch it, and swing it over the balloon until it is as tight as possible.
- This activity can be repeated as often as time allows.

Supporting Diverse Student Needs

- To build verbal-linguistic skills, encourage students to use the terms "gas," "expand," and "contract" as well as terms for temperature in written and spoken forms.
- To build visual-spatial skills, encourage students to include diagrams in their answers to What Did You Find Out? questions 1, 2, and 3.
- The point of the lab is quite accessible to students of every learning style. Be sure that students who need more practice in language are paired with students who have stronger language skills, to help describe their results.
- As a demonstration, try adding a few drops of a volatile liquid like alcohol to the bottle before attaching the balloon. In addition to expansion due to temperature, students can observe the expansion due to change of state.

What Did You Find Out? Answers

1. Students should observe a small balloon partially inflating.
2. Students should write about the balloon collapsing, perhaps being pushed into the bottle by the atmosphere.
3. When the gas was heated, the air particles in the balloon moved more quickly. They collided with each other both more often and more vigorously. This process caused the particles to move apart, and the gas occupied more space. Cooling the balloon slowed down the particles, they moved together, and occupied less volume. Then the balloon collapsed.

Using a Demonstration

If you have a lot of ice, and 2 or 3 kg of salt, you can try this.

Prepare a bucket of ice. Pour the salt onto the ice, and stir it with a wooden stick. Do not immerse your hands in the mixture, as the temperature can fall to –15ºC very quickly. Bury the bottle in the ice, except the neck. A stopper or a cap will keep the water out. Allow the bottle to chill for 10 min. Put the balloon on the neck of the bottle as was done in the activity, then take the bottle out of the salt mixture and place it in the hot water bath. The balloon could expand from 500 mL at –15ºC to 625 mL at 50ºC. This increase in volume is much more dramatic. The balloon might actually be inflated to its fullness. As a group, have students build an explanation for the dramatic expansion of the balloon. As they describe what happened, encourage them to refer to the particle theory.

TEACHING THE SECTION, pp. 366–370

Using Reading

Pre-reading—Key Word Concept Map

Organize students into groups or pairs. Consider establishing mixed-ability groups, so that students can pool their strengths and offer assistance as well.

Ask students, "What concepts are we learning about? How are these concepts connected?" Have students quickly skim the reading, the headings, the photo captions, and the marginal features to identify key concept words. Direct them to make a list of the key concept words, such as "temperature," "pressure," "volume," "particles," "gas," "liquid," "compress," and "expand." Compile this list on the board.

Instruct students to distribute the key words over a page, and draw a small ellipse around each word. Tell students to draw a single line to connect any pairs of concepts that they think are connected. If they have an idea about the connection, they can describe that connection in writing. If they think there is a connection, but they do not know what it is, they should mark that connection with a "?" If students do not believe there is a connection between two concepts, they should not draw a line between the concepts.

Direct students to read the text, and to look for the relationships between pairs of key concept words that are indicated on their rough concept maps.

During Reading—Note Taking

Students should concentrate on making notes about the connections between concepts that are indicated on their concept maps. Students should also make note of any connections that they had not anticipated.

After Reading—Reflect and Evaluate

Students should compare the connections on the original concept maps, and the notes that they had made previously. Direct students to make corrections and additions to the concept map. Discuss any connections students are still unsure of.

Students can apply what they have learned about pressure using BLM 3-38, Safety with Fluids. BLM 3-39, The Sphygmomanometer, provides additional information about the use of a sphygmomanometer to measure blood pressure.

Supporting Diverse Student Needs

- Dramatic learners may benefit from role-playing molecules in a fluid using BLM 3-40, Particles in Motion Skit.
- Musical-rhythmic learners can write similes to consolidate their understanding of pressure using BLM 3-41, Poetic Pressure.
- Body-kinesthetic learners will enjoy designing and testing a wacky straw using BLM 3-42, Wacky Straw Design.

Reading Check Answers, p. 367

1. If you want to find out how pressure and volume are related, you must not allow any other factor to influence pressure or volume. In other words, control for temperature.
2. If the volume of a gas is forcibly reduced, the pressure of the gas increases.
3. Students' answers may vary. If you hit a bump while riding a bike, the gas in the shock absorbers is squeezed into a smaller volume. The pressure of the gas increases gradually, reducing the amount of shock. If you are holding a straw in your mouth as you increase the volume of air inside your mouth, you can reduce the pressure there. Water can be forced up into your mouth by the greater outside atmospheric pressure.

Reading Check Answers, p. 370

1. Gas will expand if it is heated, as long as the pressure remains constant.
2. You must hold the volume constant.
3. The pressure of a gas will increase as you heat the gas, as long as the volume is held constant.

USING THE ACTIVITIES

- Activity 9-3A on page 365 of the student textbook is best used as a section introduction. The activity is simple, and illustrates the ideas encountered later in this section.
- Activity 9-3B on page 367 of the student textbook is best used after the readings on pressure and volume. The results of the activity should be represented using a particle diagram.
- Activity 9-3C on page 369 of the student textbook can be used either before the reading on Pressure and Temperature (to anticipate the learning) or after the reading to apply the learning.
- Activity 9-3D on page 371 of the student textbook is best used as a section summary lab to tie together the ideas.

Detailed notes on doing the activities follow.

Find Out Activity 9-3B

Lifting with Air, p. 367

Purpose

- Students will use their senses to investigate in a qualitative way the relationships among force, pressure, area, and gas volume.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 week before	Gather straws, balloons, tape, chewing gum, and elastic bands.	For each person: – 1 balloon or large plastic food bag – 1 straw – 1 piece of chewing gum – tape, string, elastic bands – textbooks

Time Required

- 20–30 min

Safety Precautions

- Ask students if they have allergies to latex.

Science Background

Students are actually forcing more gas particles into the balloons at a constant temperature. As the number of gas particles increases, so will both the volume and the pressure. The textbook will apply a force to the balloon. If students observe the balloon from the side, they will perceive that the book exerts the force over the area of contact. The force of gravity divided by the area will be the pressure that is exerted by the book on the balloon.

The stretched latex of the balloon actually exerts a much greater force upon the gas inside the balloon than the book does. If the balloon is very small, or very strong, students will feel the pressure of the latex to such an extent that the pressure of the book becomes almost imperceptible. If you do choose to use a plastic food bag instead of the balloon, the pressure of the air in the bag is easy to understand. When the bag is less than full, the pressure on the bag is atmospheric pressure. Adding a book increases the pressure, but that increased pressure remains constant as long as the bag is not over-filled. It is very obvious to students' senses that adding one more book increases the pressure.

Students might observe this as a case that opposes the general rule "increasing pressure causes a decrease of volume." Emphasize that in this case, more particles are being added to the system, so the rule does not cover this situation. When students stop adding particles (stop blowing more air in), the rule will apply again.

Activity Notes

- Consider using a large food bag, like a large plastic bread loaf bag, instead of the balloon. It will inflate much more easily than a balloon, and students will sense the pressure of the books more directly. Check the bag carefully for holes before beginning.
- Have students chew up some soft-type bubble gum just before the experiment. When the gum is nice and soft, have them form a band of bubble gum around the straw near one end. The soft bubble gum sticks very tightly to plastic. The plastic bag or balloon will make an airtight seal with the gum, especially when the string, tape, or elastic bands are tightened around the gum. Students should dispose of all materials when the experiment is complete.
- Tell students to avoid dropping the books on the balloon or bag. Once a leak occurs, the experiment is ruined.
- Advise students to attempt to balance the books on the balloon or bag. Using your fingers to apply very tiny stabilizing forces to the book will not change the results of the investigation.

Supporting Diverse Student Needs

- The gross concepts of pressure, volume, force, area, and so on are quite accessible, but the subtle relationships among them will be a challenge for some students to explain. Pair these students with verbal-linguistic learners to help build vocabulary.
- This activity is very accessible to body-kinesthetic learners. Encourage visual-spatial learners to watch carefully what happens and process the ideas as well. All students should at least attempt representations that lie outside of their dominant learning style.
- Draw particle diagrams of each situation on the board. An outline of a bag-and-straw apparatus, containing about 30 particles, is probably enough to start a good discussion. The particle diagram can help students make connections between what they did, what they saw, and why it happened. Particle diagrams often help students who are not strong in language skills to bridge the gap between experience and explanation.

What Did You Find Out? Answers

1. The large bulgy part of the balloon inflated first. When the books were on the balloon, the balloon inflated to the sides first.
2. Each additional book applies additional force to the balloon. The force of the books, divided by the area of contact, is the pressure. As the force increases, so does the pressure, so it takes more lung pressure to inflate the balloon.
3. Some students can lift six or more books without bursting the seal.

Think About It Activity 9-3C

The Pressure is Rising, p. 369

Purpose

• Students will construct a graph of pressure vs. temperature, and analyze the graph.

Advance Preparation

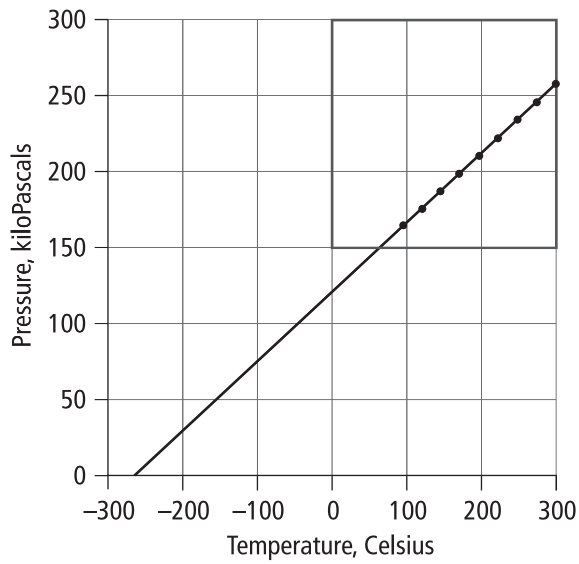
WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Advise students to bring graph paper, and obtain some for students who may not bring their own. Make copies of BLM 3-43, The Pressure is Rising (optional).	– coloured pencils, pens, markers – ruler

Time Required

- 20 min

Science Background

The Pressure vs. Temperature graph should make a straight line, showing that the pressure is proportional to temperature, as long as the volume and the number of particles is held constant. Students' graphs will resemble the top right quarter of the graph as shown at the right.



- If the graph is extended backward and downward to a pressure of zero, you can see that in order to bring the gas to a pressure of zero, the temperature would have to be –273°C, that is, absolute zero. See the Did You Know? section on page 368 for more details.

Activity Notes

- Review Recording Data in Science Skill 6 on page 486 details on graphing.
- Review the details of labelling the axes, including the units, plotting data points as + signs, and drawing the "best fit" line through the data points.

Supporting Diverse Student Needs

- Some students may not have significant experience with scientific graphing. Pair these students with students who are able to conceptualize and draw graphs. Alternatively, provide a template of the graph with axes labelled.
- Students whose difficulties creating graphs will limit their learning can use the prepared graph on BLM 3-43, The Pressure is Rising, to analyze.
- While students with good fine motor skills will find this activity easy, some students will find it more difficult. Provide extra large graph paper to accommodate them.

- Students who like a challenge could construct a graph like that in the Did You Know? feature on page 368.

What Did You Find Out? Answers

1. When the temperature is increased, the pressure increases as well. Since it is a straight line graph, the pressure is proportional to the temperature.
2. Students' answers will vary considerably. Point out to students that both the volume and the number of particles in the container are fixed. As the particles are heated, they speed up. Because they are travelling faster, they collide with the walls of the container with a greater force. This additional force exerts a greater pressure on the walls of the container.

Conduct an Investigation 9-3D

Putting on the Pressure, p. 371

Purpose

- Students will modify and extend the design of an investigation to determine how applied force affects the volume of liquid and the volume of a gas in a syringe.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
2 weeks before	Gather the specialized lab equipment, including the syringes, lab stands, test tube clamps, and masses.	For each group: – plastic syringe with covered tip – lab stand – clamps – set of masses up to 2 kg – 100 mL beaker – water – vegetable oil
1 day before	Make copies of BLM 3-44, Putting on the Pressure (optional).	

Time Required

- 40–60 min

Safety Precautions

- Remind students to clean up any spills immediately.
- Have students check that the apparatus is well constructed and sturdy before they begin. They should tighten any joints and keep the apparatus balanced.

Science Background

The force of gravity on a 1.0 kg mass is 9.8 N. You could say that

"Force of Gravity = 10 × mass" and be very nearly correct. (2% error)

Students' experiments may vary, but students should find the following:

- Air compresses the most. Water and vegetable oil will not compress.
- With more force, air will compress more.
- Water and vegetable oil will not compress any more when more force is applied.

Activity Notes

- Begin the lab with a brief discussion. Show students the assembled apparatus. Draw a graph of Volume vs. Force, with no data on it. Ask students to copy the graph, and draw and label their predictions of some data points. Invite two or three students to share their predictions on the board.
- Have students write their hypotheses before beginning the lab.
- A small diameter syringe will give more dramatic results than a large diameter syringe.
- If the syringes have no caps, then turn a large rubber stopper (number 5 or larger) upside down on the desk (broad end down). Use a nail or other sharp, straight object to push a tiny hole about 1 cm deep in the stopper. When the tip of the syringe is moistened with a drop of water and pushed into the hole, the seal is nearly perfect. The stopper provides additional support for the syringe.
- A droplet of silicone lubricant, such as WD40™ , or mineral oil, will reduce friction and give much better results.
- Instruct students to tap the side of the syringe lightly with a marker each time, to be sure that the piston is not "hung up" by friction.

Supporting Diverse Student Needs

- Some students may not have significant experience with scientific graphing. Pair these students with students who are able to conceptualize and draw graphs. Alternatively, provide a template of the graph with axes labelled.
- This activity will be more successful for all students if you set up groups including students with a variety of dominant learning styles. Different students will excel at different tasks during the lab. If all students agree to help each other, then all students will be more able to complete the lab assignment.
- Provide copies of the data table on BLM 3-44, Putting on the Pressure for students who have trouble recording in writing.

- Invite strong visual-spatial learners to refer to their graph to explain how they developed answers to Conclude and Apply questions 1 a) and 1 b).
- As an extension, have students measure the diameter of the piston and calculate its area. The area of the piston can be used, along with the applied force, to find the pressure exerted on the gas by the weights. Some students may find that this additional challenge will make this lab more connected to the material in the text.

Analyze Answers

1. Independent: the mass used to apply the force; the identity of the fluid
   Dependent: the volume of the fluid
   Controlled: the temperature, and the number of particles of the substance trapped in the syringe
2. Students' answers will vary. In most cases, the exact prediction will not be followed by the experiment. Results should support hypotheses such as the following: More force causes a decrease in the volume of air; air will compress more than water or oil.

Conclude and Apply Answers

1. (a) The volume of the liquids will not change. The volume of the gas will become smaller as greater force is applied.
   (b) The volume of the liquids certainly cannot be reduced to zero. The volume of the gas can be reduced, but the pressure that the gas exerts becomes very large at small volumes, and it becomes extremely hard to compress further. The volume will never become exactly zero.

USING THE FEATURES

Explore More, p. 368

Students should observe that the balloon in the freezer has decreased in volume, the balloon in the sunlight has increased in volume, and the volume of the balloon in a shaded corner has not changed. These observations demonstrate the direct relationship between temperature and volume. (The pressure has only changed slightly due to the balloon—so little that the relationship between temperature and volume can still be seen.) Challenge students to explain what they see using the particle theory.

Did You Know?, p. 368

Ask students what the volume would be at –273°C. Ask, "Is it possible to reach this temperature?" (It is only theoretically possible. The particles themselves have volume. Once the particles are cooled enough that they touch each other, the volume stops shrinking. Scientists have chilled material to close to absolute zero, but not all the way.)

Career Connect: Professional Diver, p. 372

Instruct students to read the passage. Invite students to share any experiences or stories they may have about scuba diving. A scuba tank is pressurized to about 200 to 300 times normal atmospheric pressure!

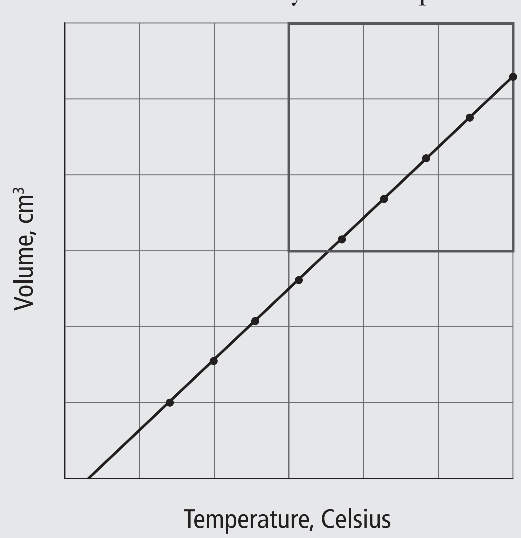
Students can integrate this feature with what they have learned about pressure to create an advertisement for a job using BLM 3-45, Working Underwater Poster.

SECTION 9.3 ASSESSMENT, p. 373

Check Your Understanding Answers

Checking Concepts

1. Apply a force to the container to reduce the volume. The pressure of the gas will increase.
2. Boyle poured mercury into a J-shaped glass tube, sealed at the low end and open at the high end. The mercury trapped a small volume of gas in the low, sealed end of the J-shaped tube. As Boyle poured more mercury into the tube, the height of the mercury column increased. He found that if he doubled the height of the mercury column, the volume of the trapped gas was reduced by half. If he tripled the height of mercury, the volume of the gas became one third its original volume.
3. If the pressure is held constant, the volume of a gas can be reduced by cooling.
4. A typical Volume vs. Temperature graph will be a straight line, like the graph below. Volume increases directly with temperature.



5. When the volume of a gas is fixed, as in an aerosol can, the pressure of the gas inside increases with increasing temperature. Eventually, the increasing pressure will cause the can to burst, which could easily cause injury.
6. A rigid container will keep the volume of gas constant while temperature and pressure are measured.

Understanding Key Ideas

7. Submerge the entire syringe in a large bucket of water at 50°C.
8. As the temperature falls, the particles of gas move more slowly. The volume of the gas in the tires decreases, so the tires look flat. The weight of the car does not change, so the pressure on the gas in the tires remains relatively constant.
9. Several possibilities exist. Perhaps some of the gas leaked out, so that the number of particles in the syringe is not constant. Perhaps the container changes volume a little, in response to changes in pressure.
10. At the top of the mountain, atmospheric pressure can be quite low. When you seal the bottle, you seal in air at the lower pressure. As you descend, atmospheric pressure increases. The high pressure outside the bottle causes the bottle to collapse. The bottle will collapse until the pressure of the gas inside the bottle more closely matches the pressure outside.

Pause and Reflect Answer

Students' answers may vary. Some possible answers are the following:

- The bag would have to be very strong, i.e., not rip when pressurized.
- The bag would have to resist expansion, in order to stay at the higher pressure.
- The bag must not be porous or leaky.
- The bag must be small enough that it can be inflated quickly.

Other Assessment Opportunities

- Consult the Unit front matter for a list of applicable Assessment BLMs.

CHAPTER 9 ASSESSMENT, pp. 374–375

PREPARE YOUR OWN SUMMARY

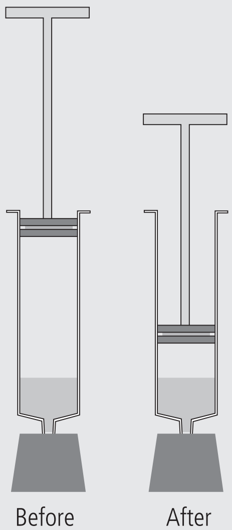
Students' summaries should incorporate the following main ideas:

1. Buoyancy and Fluids
   - When objects are surrounded or partly surrounded by a fluid, the fluid exerts a buoyant force upon the object, in the opposite direction to gravity.
   - The buoyant force upon an object that is immersed in a fluid is equal to the mass of the fluid that was displaced by the object. (Archimedes' principle)
   - The greater the density of a fluid, the greater the buoyant force it exerts.
   - Average density is the total mass divided by the total volume of an object.
2. Pressure and Fluids
   - Pressure is the *force per unit area* exerted by a fluid.
   - The pressure exerted by a fluid increases as the depth of the fluid increases.
   - The atmosphere is a fluid, and exerts pressure.
   - Gaseous fluids are compressible; liquid fluids are incompressible.
   - Pascal's Law: Pressure applied to an enclosed fluid is transmitted with equal force throughout the container.
   - Hydraulics is the study of pressure in liquids.
   - Pneumatics is the study of pressure in gases.
   - Hydraulic and pneumatic systems can multiply force by applying the same fluid pressure to different areas.
3. Relationships among Pressure, Temperature, and Volume of Gas
   - Temperature, pressure, volume, and number of particles are four interrelated variables.
   - When the temperature of a fixed amount of gas is constant, decreasing the volume of the gas increases the pressure.
   - When the pressure of a fixed amount of gas is constant, increasing the temperature causes an increase in volume.
   - When the volume of a fixed amount of gas is constant, increasing the temperature causes an increase in pressure.

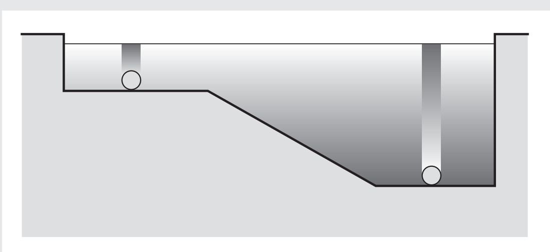
CHAPTER REVIEW ANSWERS

Checking Concepts

1. When the same pressure is exerted on both air and water, the volume of air is reduced, but the volume of water remains the same.



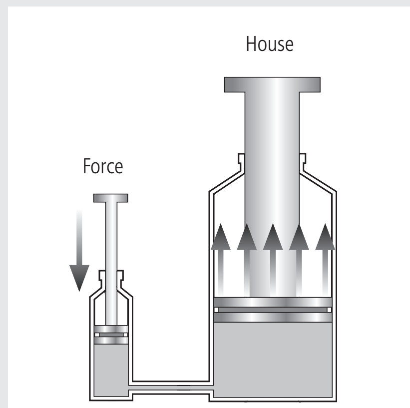
2. The pressure at the shallow end of the pool less, because there is less water above. At the deep end, there is more water above, so the pressure is greater.



3. (a) Hydraulics deals with pressure on liquids; pneumatics deals with pressure on gases.
   (b) Both topics consider pressure on fluids.
4. Hydraulic multiplication is used in life-saving rescue tools. A small force, exerted by a person, is applied to a small area to create a large hydraulic pressure. That pressure is applied to a large area, resulting in a force much larger than the original human force. Forces can be developed that can easily cut steel.
5. Pumps are used to force water into water mains against high pressure.
6. The volume would increase.
7. The number of particles in the system would have to be controlled, as well as the pressure.
8. An increase in temperature would cause an increase in volume, all else being constant. Increasing the pressure would be accompanied by a decrease in volume, all else being constant.

Understanding Key Ideas

9. (a) A piston inside the bicycle pump can be forced downward, reducing the volume of the air and causing an increase in pressure.
   (b) The hole in the basketball needle is so small that the viscosity of air can reduce the flow through the needle.
10. The small force on the small pump acts upon a small area, resulting in a large pressure. The large pressure is transmitted equally throughout the oil. The large pressure acting upon the large area of the big piston provides a large force, capable of lifting the house.



11. (a) You could decrease the pressure on the container, allowing the gas inside to expand.
    (b) To increase the pressure in the altered system, increase the temperature without changing the volume.
12. Energy from the sun could heat the balloon's thin skin, thus heating the air inside. If the balloon is very tight, it cannot increase in volume, so the heated air will increase in pressure. The balloon could burst!

UNIT 3 ASSESSMENT

PROJECT

Emergency Hovercraft, p. 378

Purpose

- Students design and build a hovercraft with a propulsion system that allows it to move from place to place in the classroom.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
2–3 days before	Gather materials. You might ask students to bring cardboard and plastic soft drink bottles with screw caps from home.	For each pair or group: – plastic soft drink bottle with screw cap – square piece of cardboard – pencil – scissors – balloon For the class: – electric drill – hot glue gun or tape

Time Required

- 20–30 min to design the hovercraft
- 30–60 minutes to assemble and test the hovercraft
- additional time for presentations and reporting

Safety Precautions

- You may wish to drill holes for some or all students while they watch. Some students may have experience using power tools safely and may wish to drill holes themselves. Remind those students to be very careful using the power drill, keeping fingers out of the way. Provide a block of wood to drill on in order to protect the surface of the desk.
- The end of the glue gun will be very hot. Caution students not to touch it.

Science Background

A hovercraft uses the energy of air under pressure to stay off land and water, thus reducing friction. Hovercrafts often also use the energy of air under pressure to move forward.

Activity Notes

- Step-by-step instructions are provided to build a hovercraft. Students can follow the given steps, and design the propulsion mechanism on their own, or they create and build an original design for a hovercraft.
- Whether students use the steps provided or design their own, they are required to add their own propulsion mechanism. Students may try altering the direction of the airflow to provide propulsion, adding a small hole in the side of the bottle to direct some air backward and propel the hovercraft, or adding a second balloon from which air will flow backward. Other groups may add an elastic band-powered propeller. Some groups may have trouble coming up with a practical idea. Help them focus their thinking on ideas that will move air backward to propel the hovercraft forward.
- This activity can be done in pairs, resulting in more hands-on experience for each student, or in small groups, minimizing the amount of materials and tools needed.
- The analysis required in Report Out helps students make connections between the functioning of the class' hovercrafts and what they have learned about fluids and pressure in this unit.

Supporting Diverse Student Needs

- Pair English language learners with more fluent English speakers to ensure that instructions are understood by everyone.
- Because construction steps are provided, the activity lends itself to differentiation. Challenge students with strong visual-spatial or logical-mathematical intelligences to design their own hovercraft.

Report Out Answers

2. (b) Students should list effective design elements and explain the science behind what makes them effective.
   (c) Students should explain how each change would affect the functioning of their hovercraft, using scientific principles addressed in this unit.

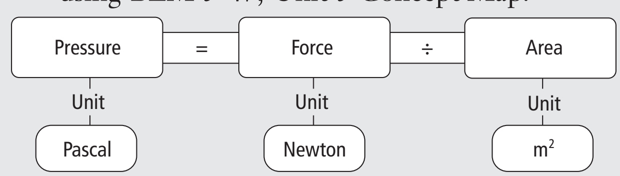
Other Assessment Opportunities

- Consult the Unit front matter for a list of applicable Assessment BLMs.

UNIT 3 REVIEW ANSWERS, pp. 380–383

Visualizing Key Ideas

1. Students can record their answer to question 1 using BLM 3-47, Unit 3 Concept Map.



Using Key Terms

2. True statements are marked T. False statements are marked F and corrected.
   (a) T
   (b) F; The particle theory does apply to all particles (of atomic and molecular size).
   (c) T
   (d) F; The density of a substance changes from solid to liquid to gas states.
   (e) T
   (f) F; Only an unbalanced force can cause a change in the speed of an object.

(g) T
(h) F; Pneumatics uses gases in an enclosed system under pressure. Hydraulics uses liquids.
(i) T
(j) F; The independent variable is the variable you adjust. The controlled variable is held constant.
(k) F; When pressure on a gas is increased, volume decreases OR when pressure is decreased, volume increases.

Checking Concepts

3. The particles of a liquid are free to move around each other. The particles in a liquid will move around each other until they settle in the bottom of the container. The liquid will flow until it touches the sides of the container, whatever the shape of the container.
4. Gas particles are free to move in all directions. Gas particles move in any direction until they hit the sides of the container, thus filling the container completely.
5. Viscosity is a fluid's resistance to flow; flow rate is the speed at which a fluid flows.
6. Increasing temperature decreases the viscosity of a liquid, but increases the viscosity of a gas.
7. Viscosity usually increases as the concentration of sticky particles increases.
8. The space between particles in a gas is large. There are fewer particles of gas enclosed in one unit volume than particles of liquid in the same volume, so the density of the gas is usually much less.
9. Density is calculated using the formula $D = \frac{m}{V}$. Density is mass divided by volume.
10. Mass is the quantity of matter in an object. Volume is the space that is occupied by an object. Density is the ratio of mass to volume for any part of an object.
11. Salt water is denser than fresh water, so it will sink to the bottom. Fresh water will float on the top.
12. Increasing temperature causes the particles to move farther apart. This result decreases density.
13. Air pressure is caused by gravity acting on all of the gas particles above you. The greater your altitude, the fewer gas particles there are above you, and the smaller the air pressure.
14. Buoyant force is an upward force exerted by a fluid upon any object submerged in it.
15. Static pressure is the pressure of an enclosed gas or liquid that is not moving.
16. If a small force is exerted on a small area, a large pressure can result. If that large pressure is exerted on a large area somewhere else, a very great force can be applied there. Hydraulic multiplication thus can transform a small force into a large one.
17. Hydraulic systems use liquids as their working fluid, and pneumatic systems use gases.
18. If temperature is constant, decreasing pressure causes an increased volume.
19. Increasing the temperature of a gas while the pressure is constant will cause the gas to expand in volume.
20. Increasing temperature can cause the pressure to increase.

Understanding Key Ideas

21. (1) All matter is made up of very small particles. (2) All particles in a pure substance are the same; different substances are made of different particles. (3) There is space between the particles. (4) The particles are always moving; as the particles gain energy, they move faster. (5) The particles in a substance are attracted to each other.
22. Solid wax at 40°C will have particles that are moving slowly. They will have small spaces between them, and be strongly attracted to one another, so they will be a solid. Liquid wax at 80°C will have particles that are moving more quickly. They will have larger spaces between them, and be less strongly attracted to one another. This means that the liquid wax will be fluid, and take up more space (or have a lower density) than the solid wax.
23. Pure water consists only of water particles, and 1 L of water has a mass of 1 kg. Pancake syrup contains water, plus more massive sugar particles. The extra mass in the syrup gives 1 L of syrup a mass greater than 1 kg, so its density is greater than the density of water.
24. Mass is the quantity of matter in an object. Weight is caused by the force of gravity on an object.
25. In both cases, the force of your fall would be about the same. Your elbow has a small area, your back has a large area. Pressure is force divided by area. Dividing the force of your fall by area gives a large pressure on your elbow, and a smaller pressure on your back.

26. Viscosity is greater in a substance in which the particles are larger, more readily tangled, or more strongly attracted to one another.
27. Pressure in a gas is generated by decreasing the volume of the gas. The gas must be compressed into a smaller volume in order to generate the pressure to operate the pneumatic device.
28. The force of gravity pulls the object down; the force of buoyancy pushes the object up, exactly opposite in direction to gravity.
29. The buoyant force upon an object is equal to the force of gravity upon the fluid that was displaced by the object.
30. In liquids and solids, the particles are in contact with each other, and cannot be squeezed closer together.
31. The more air particles you force into the tire, the greater the pressure in the tire, even if the temperature is constant. Adding air particles also increases the volume of the tire.
32. Increasing the temperature of the gas increases the speed of the particles. The faster-moving particles move around more, and at constant pressure they spread farther apart from one another and increase the volume occupied by the gas.
33. The label applies to the can whether it is full or not. Even when empty, the can has some gas in it. Heating the gas can cause it to increase in pressure and burst the can. Heating a full can is more hazardous, because the full can will burst at a lower temperature.

Thinking Critically

34. (a) No, sand is a solid.
    (b) Each grain of sand is a solid, and the particles in each grain cannot flow around one another. Each grain, however, acts like a single particle in a fluid. The sand grains can move around one another, much like particles of water can move around one another. Gravity pulls both substances down, and both particles of water and grains of sand move around one another until they take the shape of the container.
35. (a) Deep sea exploration vehicles can operate at great depths. The force of gravity on the water above them can produce enormous pressure. Thick steel is needed to hold up against such pressure.
    (b) If the steel could not withstand the pressure, the whole vehicle would quickly be crushed like a pop can because the outside pressure of the water is so much greater than the inside air pressure.
36. An aerosol spray can has a fixed volume. Heating the gas inside such a container will cause the pressure to increase, possibly causing the can to burst.
37. A hydraulic system would be more appropriate. Hydraulic fluid is incompressible. Hydraulic systems can be controlled precisely, and can be made to operate slowly. Pneumatic systems are filled with compressible gas. The compressed gas stores energy, so pneumatic systems operate very quickly, and with much less control.
38. (a) If the drainage for the eye was blocked, then pressure would build up inside the eyeball, perhaps causing it to expand.
    (b) If the production of fluid was interrupted, the pressure would decrease, perhaps causing the eyeball to collapse.
39. Every time the heart pumped, the blood would flow out away from the heart in all directions, causing increased pressure in the distant blood vessels. As soon as the heartbeat ended, the pressure would cause the blood to flow right back. The blood would not circulate, it would just wash back and forth with each heartbeat, so oxygen and nutrients would not flow to all parts of the body.
40. When we breathe, muscles cause our ribs to go up and our diaphragm to go down, increasing the volume of our lungs. Atmospheric pressure pushes air into our expanded lungs. If we block the air passages, increasing the volume of our lungs would tend to cause lower pressure inside our lungs. Outside atmospheric pressure would still exert force on our chests, squeezing them back, and making it very difficult to expand our lungs.
41. When you pump air into a flat tire, the air cannot leave the tire. More and more air particles are forced into the tire, causing the tire to inflate or expand. This result can lift the car upward, like the lifting airbag rescue device.

Developing Skills

42. (a) Students should provide a complete solution, as described in the student textbook.

$$D = \frac{m}{V} = \frac{(1080\ \text{g})}{(1200\ \text{mL})} = 0.900\ \text{g/mL}$$

The density of the material is 0.900 g/mL.

(b) The material would float on water.

43. Students should provide a complete solution, as described in the student textbook.

$$D = \frac{m}{V} = \frac{(3620\ \text{g})}{(460\ \text{cm}^3)} = 7.87\ \text{g/cm}^3$$

The density of the material is 7.87 g/cm^3. It is most likely iron.

44. (a) Ranked in order of increasing density are substances C, A, and B.

(b) Student diagrams should show substance B on the bottom, A in the middle, and C floating on the top.

45. Students should provide a complete solution, as described in the student textbook.

$$P = \frac{F}{A} = \frac{(140\ 000\ \text{N})}{(1.17\ \text{m}^2)} = 119\ 658\ \text{N/m}^2$$

The pressure exerted by the elephant's feet is 120 Pa.

46. The pressure is equal to the total force divided by the total area.

$$F = \text{Sum of forces} = (350\ \text{N} + 800\ \text{N}) = 1150\ \text{N}$$

$$A = \text{length} \times \text{width} = (0.75\ \text{m}) \times (0.50\ \text{m}) = 0.375\ \text{m}^2$$

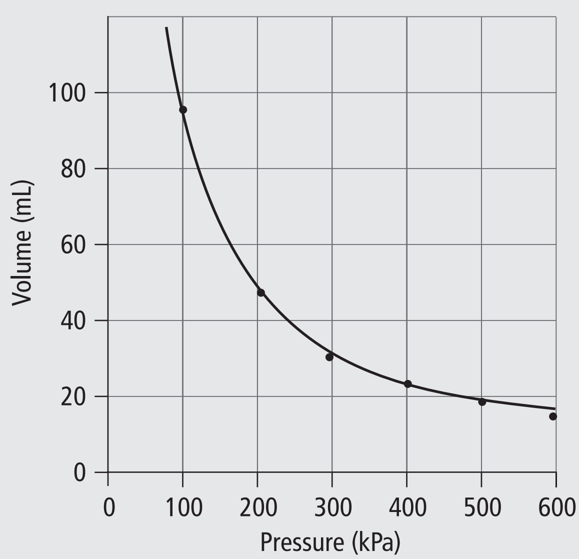
$$P = \frac{F}{A} = \frac{(1150\ \text{N})}{(0.375\ \text{m}^2)} = 3066.66\ \text{N/m}^2$$

The pressure on the floor is 3067 Pa.

47. Students' answers could vary greatly. In each answer there must be a fixed amount of gas, so the number of particles is controlled. The container must be expandable, so the pressure can be controlled. The volume of the gas must be readable, and the temperature of the trapped gas must be variable. An example could be a volume of 20 mL of air trapped in a syringe. Immerse the syringe in water baths of known temperature, and measure how the volume of trapped gas responds. Another example could be 50 mL of air trapped under a graduated cylinder inverted in some ice water. Gradually replace the ice water with hot water, measuring the temperature of the slowly changing water bath and the volume of the trapped gas.

48. Students' graphs may vary on such details as the scale, the numbers on the axes, and the exact position of the curve. All graphs should pass through the points (100, 96), (200, 48), (300, 32), (400, 24), (500, 19), and (600, 16). The curve indicates that whenever the pressure is doubled, (e.g., from 100 kPa to 200 kPa) the volume is decreased by one half (e.g., from 96 mL to 48 mL.)

Volume vs. Pressure Graph



Pause and Reflect

At first, the steel ball has a small amount of liquid water in it. As the ball is heated past 100°C, the particles of the water move about more quickly. The movement of the water particles becomes greater than the attractive forces can hold, and the water particles begin to fly apart, forming a gas. The number of gas particles increases very quickly during this process, so the pressure inside the ball also increases very quickly. Once the water has completely turned to a gas, further heating makes the particles move even faster. The faster the particles move, the greater the force they exert on the walls of the container. This increased force, spread over the surface area inside the ball, is an increase in pressure. If there was a lot of water in the ball, or the temperature increase was very great, the pressure in the steel ball could be enough to cause the ball to burst, possibly with a big explosion.