UNIT B
Structures: Form and Function

Unit Overview

Fundamental Concepts

In Science and Technology for grades 7 and 8, six fundamental concepts occur throughout. This unit addresses the following two:

- Structure and Function
- Energy

Big Ideas

As you work through this unit, you will develop a deeper understanding of the following big ideas:

- Structures have a purpose.
- The form of a structure is dependent on its function.
- The interactions between structures and forces is predictable.

Overall Expectations

By the end of this unit, you will be expected to:

1. analyse personal, social, economic, and environmental factors that need to be considered in designing and building structures and devices
2. design and construct a variety of structures, and investigate the relationship between the design and function of these structures and the forces that act on them
3. demonstrate an understanding of the relationship between structural forms and the forces that act on them and within them

These homes were designed and built to conserve energy.

Exploring

All the objects in this collage are structures.

The Garden City Skyway Bridge (in the background) crosses the Welland Canal at St. Catharines, Ontario. It is high enough for ships to sail underneath. The ship has just sailed between the two halves of a lift bridge.

Almost everything you can see and touch is a structure: the chair you sit on, the pen you use, the book you are reading, the boulder in the park, the tree you climbed. Even you are a structure, made up of several other structures: skeleton, heart, brain, and so on. A **structure** is something made up of parts that are together in a particular way for a specific purpose or purposes.

Every structure has a form and a function. The **form** is the basic shape of the structure; the **function** is the job that the structure does.

Some structures are natural (trees, rocks, flowers, you), and some are manufactured (airplanes, vases, picture frames, bridges). Manufactured structures are designed with their forms and functions in mind. Designers choose the materials to make each structure and decide how to construct it.

In this unit, you will study the forms and functions of many different structures. You will also study the forces that can act on structures. A **force** is any push or pull that can make an object change shape, speed, or direction. Forces act on all structures. You will learn how different structures react to these forces. You will learn how to predict the action of forces on structures. Forces and structures are constantly interacting. When we understand these interactions, we can build better structures.

Many products that you buy can have an impact on the environment. It is important to consider these impacts when you make buying decisions. Making good decisions will ensure the sustainability of life on Earth.

Ergonomic Design

Some structures are designed to be "ergonomic." This means that the designers understand scientific information about the human body. Ergonomic design can help prevent people from getting hurt while performing repetitive tasks. Many ergonomic designs assist people who have physical challenges. Choosing ergonomically designed structures can improve quality of life.

Think about how you interact with structures when you are doing your schoolwork. You probably sit on a chair with your papers on a desk. Many office workers spend long periods of time working at desks. All of this sitting can be very hard on the human body if it is not supported properly.

As you know, chairs come in a wide variety of forms, but they all perform similar functions. Think of the differences between a stool in the science lab and the chair you sit on to watch television. Several furniture manufacturers make chairs that are ergonomically designed with the office worker in mind.

Before designing these chairs, the manufacturers observed how people sat in chairs when they went about their daily tasks, such as working on a computer, talking on the phone, reaching for work materials, and working at their desks. This research helped the designers.

Compare the form and function of this chair with the one you are sitting on right now.

...MORE TO EXPLORE

B1 *Quick Lab*

Design a Better Desk

As you read this, you are probably sitting on a chair at a desk. Think about the jobs (functions) your desk needs to do. How does its form help it perform its functions? Could you improve its form in order to improve its functions?

Purpose

To suggest improvements to the form of a school desk so it can perform its functions better

Materials & Equipment

- paper
- pen

Procedure

1. List the functions of your school desk.
2. Consider how well it performs each function the way it is now.
3. Make suggestions that you think will improve the way it performs each function.
4. Compare your list with that of a classmate.

Questions

5. What do you consider the most important function of your desk? Why?
6. If you could make one of the changes you suggested, which one would it be? Why?

B2 *Thinking about Science, Technology, Society, and the Environment*

S T S E

Considering Form and Function

Think about the structures in your classroom: chairs, desks, shelves, pens, containers, and many other large and small structures. Each structure has a form and performs a function.

What to Do

1. Use a chart like the one below to list at least six structures you see in your classroom.

Structure	Description of Form	Description of Function

2. Describe each structure's form.
3. Describe each structure's function.

Consider This

With a classmate or as a whole class, discuss the following questions.

4. What structures have the most complex forms?
5. What structures serve more than one function?
6. How might form and function influence each other?

UNIT B

Contents

Unit Task

In your life, you will use many structures that others design. You might also modify an existing structure, and you may design your own structures. For your unit task, you will design something to improve the energy efficiency of an existing structure.

Essential Question

What can be done to older buildings to make them more energy efficient?

Getting Ready to Read

Thinking Literacy

Open Word Sort

Before you begin this unit, work with a partner to write each of the key terms from each chapter on a card. Look for possible ways to categorize the words. Arrange the cards in groups with category labels. Share your categories with the class.

4.0 Designers consider the form and the function of a structure and the forces that act on it.

A tent is a structure you can sleep in.

What You Will Learn

In this chapter, you will:

- explore structures and their functions
- classify structures as solid, frame, or shell
- describe the forces that can affect structures

Skills You Will Use

In this chapter, you will:

- use scientific language when describing structures
- investigate how structures are designed for safety

Why This Is Important

Every object you encounter is a structure. Each structure has specific purposes, called functions. All structures must be designed and built to withstand the forces they will face. By classifying structures and seeing how they are affected by different forces, you will begin to understand what makes a good structure.

Before Reading

Thinking Literacy

Structure Mind Map

You can use a mind map to record what you learn about structures. Take a blank sheet of paper and write the word "Structure" in the centre. When you discover ways to classify structures, add them to your mind map using words and/or pictures. Draw connecting lines to show relationships. Continue with other information you learn about structures.

Key Terms

- solid structure
- frame structure
- shell structure
- load
- tension
- compression
- shear
- torsion

Designers consider the form and the function of a structure and the forces that act on it.

4.0 Getting Started

Figure 4.1 People live in a wide variety of structures.

Just about everything you see is a structure: buildings, cars, trees, bicycles, baskets, your body, your pop can, and so on. And each of those structures has at least one function. A house or an apartment building is a structure that provides shelter, keeps us warm, and gives us a place to keep our other structures (Figure 4.1). Some animals build structures — nests, lodges, and honey combs — also to provide shelter (Figure 4.2).

Figure 4.2 Animals live in a wide variety of structures too.

The various forces in the world affect structures. For example, when a strong wind blows, the trees sway. If you step on a marshmallow, it squashes. The wind and the weight of your foot are forces affecting the trees and the marshmallow, respectively.

Sometimes, you can predict the interactions between forces and structures. You know that the marshmallow has no chance of staying fluffy under your foot. However, it is harder to predict when a branch will snap instead of sway.

Throughout your life, you will make choices when you buy structures such as clothing, electronic items, cars, and homes. In order to make good choices, you need to understand key ideas about structures. In this chapter, you will study several types of structures, looking at their forms and functions (Figure 4.3). You will find out what forces, such as the wind, can act on them. You will also see how structures are designed to sense and withstand those forces.

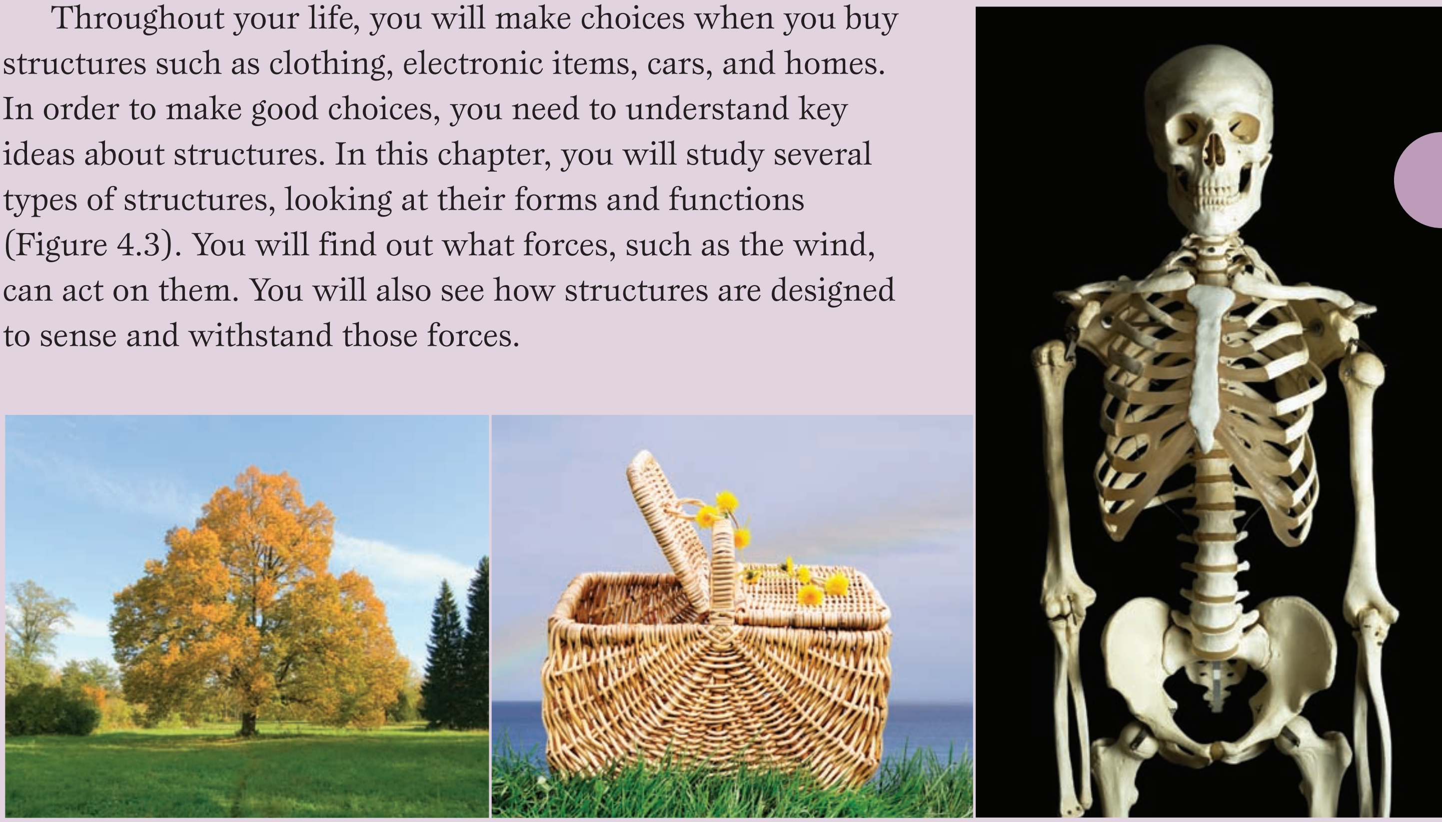


Figure 4.3 All of these things are structures.

B3 Quick Lab

Wind Effects

Depending on where they grow, some plants are stronger than others. In this investigation, you will investigate how the wind can affect different plants.

Purpose

To observe the effects of wind on various structures

Materials & Equipment

- cardboard to wave as a fan
- 3 or 4 different potted plants

Procedure

1. Examine the structure of each plant.
2. Predict what might happen if wind blew on each plant.
3. Wave the cardboard like a fan in front of each plant, first gently and then more forcefully. Record your observations.

Questions

4. Describe how the wind affected each plant.
5. Which plants behaved similarly? Why?
6. What might happen in each case if the wind were even stronger?

4.1 Classification of Structures

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

- A structure can be classified by its function.
- A structure can be classified by its construction.
- A structure can be classified as a solid, frame, or shell structure.

When people think about structures, they often think about towers and bridges. While these structures are impressive, the truth is that every object you encounter is a structure. If you pack snow to make a snowball, you have made a structure. If you combine ingredients and bake a loaf of bread, you have also made a structure.

If you look carefully at a wide variety of structures, you will notice that many of them have similarities. Different structures might serve the same function, like the structures in Figures 4.4 and 4.5. In this section, you will explore ways to classify structures.

Figure 4.4 A rock can serve as a seat.

Figure 4.5 A car seat has a specific function.

B4 *Starting Point* Skills A C

Have a Seat

Think about at least six different structures that you can use as a seat. Make a list of them. Some can be indoors, some can be outdoors.

What are the advantages and disadvantages of each one in its function as a seat? Share your ideas with a classmate.

B5 During Reading

Thinking Literacy

Making Connections

Good readers activate their prior knowledge by making connections between what they read and themselves, the world, and/or other texts. As you read about classifying structures in this section, think about connections you can make to the information presented.

Classifying Structures

We often classify structures by looking at their functions. Some structures are made to contain something, some structures support something on top, and some span a space. For example, if you notice soil running out of your school garden when it rains, you may decide to build a retaining wall to hold the soil in. If you have trouble reaching a high shelf, you may use a step or stool to lift yourself up. If workers are building a wall, they build scaffolding first, and walk around safely (Figure 4.6).

A bridge is a structure designed to span a gap. Sometimes the gap is a stream or river (Figures 4.7 and 4.8). Other bridges span another roadway; if so, we call the bridge an overpass. Early bridges consisted of a log felled over a stream; modern bridges are designed in many different forms. Look at the bridges in your community. No matter how simple or complicated the form of each bridge, its function is still to span a gap safely.

Another way to sort structures is to examine how they are built and what they are built from. We will look at this in Chapter 5. A third way to classify structures is to divide them by their forms, into solid structures, frame structures, and shell structures.

Figure 4.6 Construction workers erect a scaffold so that they can work on high walls.

Figure 4.7 Three bridges in Vancouver. The modern bridge in front is the SkyTrain Bridge, the middle one is a road bridge, and the lowest is a railway bridge. The railway bridge has a "swing" section that opens to let ships through.

Figure 4.8 Covered bridges were designed and built many years ago. The roof allowed the snow to slide off so that its weight would not damage the bridge. This covered bridge in Guelph was built recently by volunteers.

B6 Learning Checkpoint

Classifying Structures

Draw a table with four columns and six rows. In the first column, write the names of six structures you can see in your classroom. As you work through the chapter, write the function of each structure in Column 2. If you are unsure of the function, put a question mark. In Column 3, list the materials each is made of. In Column 4, write whether you think it is a solid structure, a frame structure, or a shell structure.

Compare your table with that of a classmate. Discuss the items you put question marks beside. Compile a class list for discussion. What types of structures come up the most often?

Solid Structures

Do you know what mountains, dams, sand castles, wax candles, and apples have in common? All are considered **solid structures** (Figure 4.9). Most solid structures are solid all the way through, although a mountain might contain caves, a dam might have rooms to hold electrical generators, and an apple may have a worm hole. A solid structure weighs more than a hollow structure of the same size and made of the same material.

Suggested Activity
B7 Quick Lab on page 105

Figure 4.9 Packing the material together is important when constructing solid structures.

Frame Structures

Frame structures are made of parts fastened together. The parts are often called structural components. For example, your skeleton is a frame structure. Its structural components — your bones, ligaments, and tendons — are joined together. A bicycle frame is another example of a frame structure (see Figure 4.10).

Frame structures can exist as just the frame or as a frame covered by a coating. For example, a tennis racket, dish-drying rack, and spider's web are structures that are only frames. Umbrellas, cars, and bats' wings consist of a frame covered by some sort of material.

Figure 4.10 A delicate spider's web and a sturdy car frame are both frame structures because they are built like a skeleton.

Shell Structures

Most strong, hollow structures are **shell structures**. Have you ever been inside an igloo or looked up into a domed roof? Have you poured milk out of a carton into a glass or blown up a balloon? If so, you have seen a shell structure (Figure 4.11).

Since shell structures have space inside them, they often make good containers. They also use very little material in their construction. This means that they are quite light for their size. Clothing can even be considered shell structures.

Take It **Further**

Some very famous structures from around the world include the Eiffel Tower, the Great Wall of China, and Mount Everest. Can you think of a famous solid structure, shell structure, and frame structure? Begin your search at ScienceSource.

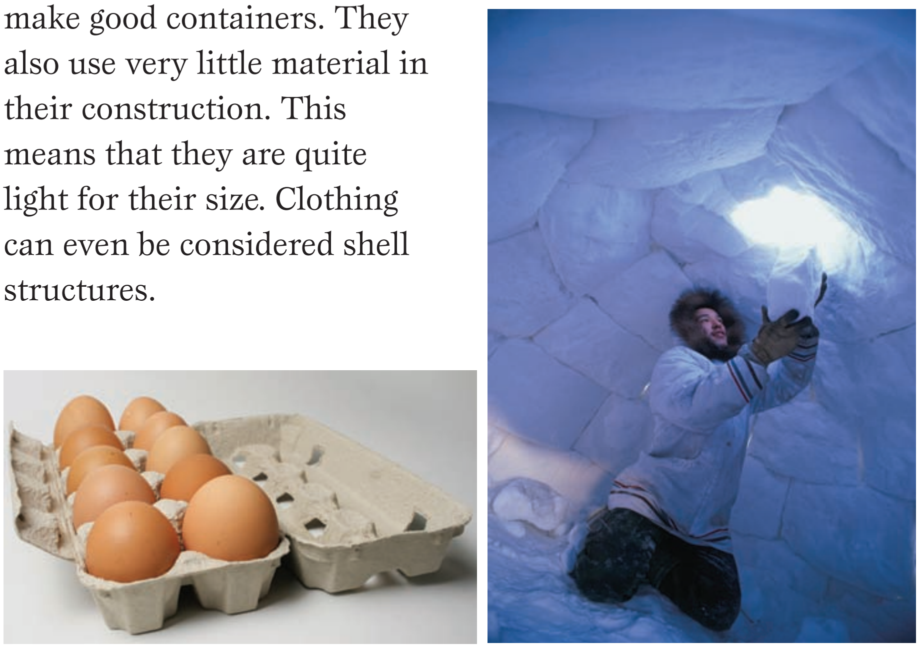


Figure 4.11 The igloo, the egg carton, and the egg shells themselves are shell structures.

Combination Structures

Many structures are **combination structures** because they are combinations of shell, frame, and solid structures. For example, Figure 4.12 shows how a house is built from solid structures — bricks, nails, and pieces of wood called boards. The boards are nailed together into a frame that gives the building strength. **Strength** is the ability of an object to withstand forces. Both the walls and the roof are now frame structures.

When the frame is finished, the wall and roof frames are covered with plywood. Windows and doors are placed into holes cut in the plywood.

The builder now covers the outside wall with bricks or siding, and the roof with shingles. These keep the house dry when it rains.

Figure 4.12 A house is built from solid structures that are put together to form a frame. The walls and the roof form a covering around the frame.

B7 *Quick Lab*

Building Solid, Frame, and Shell Structures

Structures that have the same function may have very different forms. For example, every chair is designed to support the weight of a person sitting on it (Figures 4.13, 4.14, and 4.15). In this lab, you will build different forms of chairs and test their strength.

Purpose

To build structures to illustrate solid, frame, and shell structures

Figure 4.13

Figure 4.14

Materials & Equipment

- toothpicks
- modelling clay

Procedure

1. Sketch three chairs: one that can be classified as a solid structure, one as a frame structure, and one as a shell structure.
2. Build a model of each chair with toothpicks and modelling clay. Try to build the chairs approximately the same size.
3. Think of a different structure and repeat steps 1 and 2 for the structure of your choice.
4. As a class, design a way to test the ability of each chair to support weight.

Questions

5. What did you notice about the use of materials when you built solid structures, frame structures, and shell structures?
6. Which type of structure was best able to support weight?
7. What generalizations can you make about solid, frame, and shell structures?

Figure 4.15

B8 *Quick Lab*

Unpacking the Packaging

Packaging is a structure that you encounter every day. It is used to protect other structures during transport. Packaging also displays the product in the store. Something as simple as a bar of soap (a solid structure) may come in a cardboard box (shell structure) that might be wrapped in plastic (another shell structure).

In this activity, you will study packaging as structures. When choosing your packaging, select a wide variety of products, such as food, school supplies, and electronics.

Purpose

To study the structures involved in packaging

Materials & Equipment

- all of the packaging associated with several recent purchases
- pencil and paper
- kitchen or bathroom scale

Procedure

1. You will look at all of the packaging that came with several different products. Keep the sets of packaging separate.
2. Take one set of packaging. What did it contain? Examine the packaging material. Describe the packaging qualitatively, in a chart like the one in Table 4.1. A qualitative description is a description just in words (e.g., describing the colour, the texture, the shape).
3. Describe the amount of packaging quantitatively by weighing it or finding its volume. A quantitative description is one that uses measurements to describe something (e.g., length, weight).

Table 4.1 Unpacking the Packaging Recording Chart

Product	Qualitative Description	Amount of Material	Type(s) of Material

4. Repeat the process for three more different items.

Questions

5. Compare your chart with those of your classmates. Do you agree with the way your classmates described the various packages?
6. What structures came with the most packaging? What structures came with the least? What structures do you buy that have no packaging?
7. Compare the weight or volume of each structure with the weight or volume of the packaging it came in. Do you notice any trends?
8. Do you think the packaging did its job?
9. Do you think each piece of packaging was necessary?

4.1 CHECK and REFLECT

Key Concept Review

1. Define "structure" in your own words. Describe three ways in which you can classify structures.

2. Classify the following structures as a solid structure, a frame structure, or a shell structure.
   (a) a three-ring binder
   (b) a tent
   (c) a backpack
   (d) a basketball net
   (e) an ice skate
   (f) a sand castle

Connect Your Understanding

3. Make a chart with four columns. In the first column, list five structures used in either a soccer or a basketball game.
   (a) In Column 2, classify each structure as solid, frame, or shell.
   (b) In Column 3, describe the form of each structure.
   (c) In Column 4, state the function of each structure.

4. Sometimes transporting structures exposes them to forces that they would not encounter during normal use.
   (a) List different ways that you have seen structures protected for shipping.
   (b) Describe one way that you feel is effective.
   (c) Describe one way that you feel is not.
   (d) What do you do with packaging materials after you unpack a structure?

5. Do you think a designer should begin work with form in mind or with function in mind? Give reasons for your thinking.

Practise Your Skills

6. Think of a structure that can be classified as both a frame structure and a shell structure. Draw a simple diagram to help you explain why the structure can be classified in both ways.

For more questions, go to ScienceSource.

B9 *Thinking about Science and Technology*

Structures in Your Lunchbox

What to Do

1. Think about a packed lunch and the structures used to hold each item. What types of structure are they?

Consider This

With a classmate or as a whole class, discuss the following questions.

2. Are structures used to hold food usually shell structures, frame structures, or solid structures? Why do you think that is?
3. What materials are the structures that hold your lunch made from? Can they be reused or are they disposable?
4. How might the choices of structures we use to hold food affect the environment?
5. Which is more of a challenge to transport: solid food or liquid food? Why?

4.2 Forces That Can Act on Structures

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

- A force is any push or pull.
- Forces act on structures.
- Forces can be classified as external (wind, gravity) or internal.
- The magnitude of forces, their direction, and their point and plane of application influence how they affect structures.
- Shear, tension, compression, and torsion are types of internal forces that can affect structures.

Figure 4.16 It is hard to believe that this barn was once strong and useful.

You may hear news stories about a buckled road, homes destroyed by tornadoes, or the collapse of an old building (Figure 4.16). What do these things have in common? They are the result of forces that acted on a structure but the structure could not resist the force.

A **force** is any push or pull. Forces act on all structures. Whether the structure is small or large, it must be designed and built to withstand the forces it will face. If the structure is not strong enough, it may experience structural failure. If it is too strong, time and resources might be wasted. Understanding forces helps you to design and build better structures.

All structures experience forces at all times. Sometimes the effects of those forces are not apparent until time has passed. That is why it is important to design a structure carefully, build it skilfully, and monitor it diligently throughout its useful life.

B10 Starting Point

Skills A C

Gravity Is a Force

When you were younger, building towers of blocks and knocking them down may have fascinated you. You were experimenting with gravity. Use some things from your pencil case and around your desk to make a tall and stable structure on your desk. Keep going until your structure fails. What caused your structure to fail?

Build another structure and wave a piece of paper at it to simulate wind, or build it on a desk and then jiggle the desk to simulate an earthquake.

Describe what happens.

Discuss with a classmate why your structures failed. What do you think you could have done to delay the failure of your structures?

B11 *During Reading* Thinking Literacy

Note Taking

Scan through this chapter looking for the topic headings. As you find each one, rewrite each topic heading in the form of a How? What? or Why? sentence. Write the questions in a chart like the one in Table 4.2. As you read the chapter, record your notes in the appropriate column. When you record your notes, remember that you are trying to record the main ideas. Instead of using sentences, use key words and phrases.

Table 4.2 Chart for Note Taking

Topic Heading in the Form of a Question	Point-form Notes

Internal and External Forces

Structures should be designed to withstand the forces that can act on them. Some of those forces come from outside the structure. These are external forces. An **external force** acts on an object from outside the object. Gravity is an external force that acts on all structures all the time. **Gravity** is the natural force of attraction between two objects. Gravity constantly pulls structures toward Earth's centre. As well, you have probably seen wind blow papers and plastics around. Figure 4.17 shows that wind can even blow people around! Everyday use of a structure can also involve external forces. For example, a ladder is designed to support the weight of the person climbing it. The person is applying a force to the ladder. When you pull out a drawer, you are exerting an external force on the drawer.

Figure 4.17 The wind is an external force acting on these girls and their umbrella.

Other forces are caused by one part of a structure acting on other parts of the structure. This type of force is called an **internal force**. Examples include the tension in a stretched elastic and the compression caused by the weight of a roof pressing down on the walls of a building.

Describing Forces

WORDS MATTER

You may have heard the word "application" used for a form that has to be filled out for a job. With forces it means the placing of a force on a structure. The applied force is the force that pushes or pulls directly on a structure.

Think about the last time you went out in a windstorm. You could feel the strength of the wind, and you noticed when the windspeed increased. You may have noticed the direction in which it was blowing. Sometimes, the wind may have acted on your whole body; at other times, you may have felt it only on your legs.

To describe how any force is acting on a structure, engineers talk about three main things: the force's magnitude, its direction, and the point and plane of its application (see Table 4.3). The **point of application** is the exact location where the force meets the structure. The **plane of application** is the side of the structure affected by the force.

Table 4.3 Describing Forces

Factors Used to Describe a Force	Question to Consider	Example
Magnitude	How big is the force compared to the size and weight of the object?	A gentle breeze causes a flag to flutter. In a very strong wind, the flag appears stiff.
Direction	Where is the force coming from?	If the wind is blowing into your face, it is difficult to walk. If the wind is blowing on your back, you can walk faster, but you might find it difficult to keep your balance.
Point of Application and Plane of Application	Where does the force meet the structure?	Is the wind affecting the entire structure or just a part of it? A strong gust of wind at your feet might be enough to knock you over.

External Forces and Loads

WORDS MATTER

"Dynamic" means changing, and "static" means not changing.

Every structure needs to support a load. The total **load** is the sum of the static and dynamic loads. The **static load** is the effect of gravity on a structure. The **dynamic load** is the forces that move or change while acting on the structure. It is called "dynamic" because these forces change their magnitude, direction, and point and plane of application over time. Figure 4.18 shows the dynamic forces of the truck moving over the bridge and the wind on the bridge.

Think about a bookcase. Its static load consists of the materials that the bookcase is made from. Gravity acts on these materials whether there are books in the bookcase or not. All structures must be able to support their own weight.

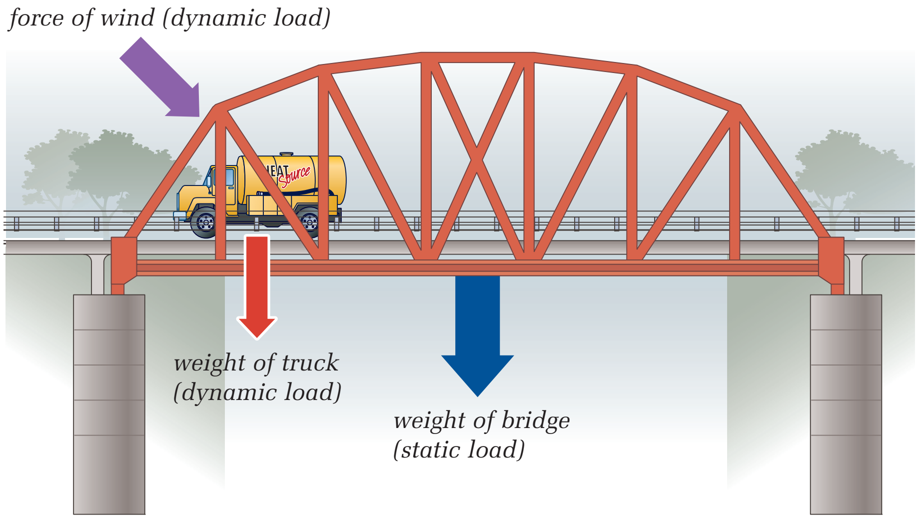


Figure 4.18 Forces acting on this bridge include the weight of the bridge (static load), as well as two dynamic loads: the weight of the truck and the force of the wind.

The dynamic load on the bookcase includes the weight of the books on the shelf. The size of this load changes with the number of books. The effect of this load also depends on where they are placed on the shelf (Figure 4.19).

When you design a structure, you want it to be able to support both its static and dynamic loads. If it is not strong enough, it may fail. If the structure is too strong, it may waste resources.

Take It **Further**

Athletes' bodies experience these forces in many ways. Think of your favourite sport. Investigate the forces experienced by the athletes playing this sport, because of their own movements or because of the equipment they use. Begin your search at ScienceSource.

(a) (b) (c)

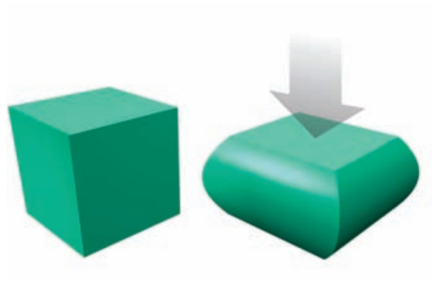
Figure 4.19 When the books are placed in the middle of the shelf (a), the shelf may sag from the unsupported dynamic load. If you place the books nearer the supports ((b) and (c)), the shelf does not sag.

Internal Forces

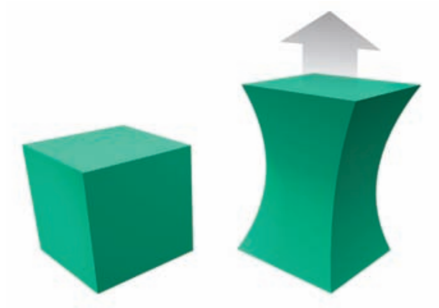
Reach one of your palms up toward the ceiling while reaching the other palm down toward the floor. Does it feel like your body (also a structure) wants to move in two different directions? You have just generated an internal force. This internal force is caused by one part of your body acting on another part. Other structures also experience internal forces.

Suggested Activity
B12 Quick Lab on page 113

Figure 4.20 Internal forces that can affect an object.

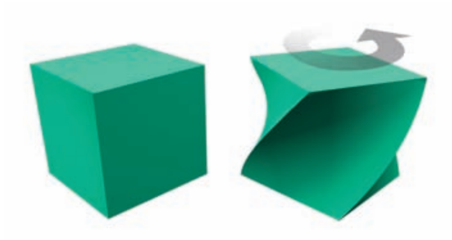


(a) **Compression:** A force that squeezes or presses something together



(b) **Tension:** A force that stretches apart to expand or lengthen

(c) **Shear:** A force that pushes in opposite directions



(d) **Torsion:** A force that twists

Depending on the direction in which they act, internal forces can be classified as **compression**, **tension**, **shear**, or **torsion** (see Figure 4.20 for definitions). The twisting motion of the skater in Figure 4.21 causes torsion inside the skater's body. During other parts of the routine, the skater will experience other internal forces. During a lift, the skater doing the lifting experiences compression. Stretching of the arms to perform gestures may cause tension or shear, depending on the direction of the arms.

Figure 4.21 The twisting motion causes torsion inside this skater.

Designing for Forces

When engineers design structures such as bridges and large buildings, they consider all the forces that could affect it over its lifespan. For example, a bridge in winter has to support snow as well as the cars and trucks. Buildings in areas with a lot of earthquakes must be able to withstand the shaking without losing their windows or falling down.

The engineers often design large structures to withstand what they call a "100-year storm." This is an event that is likely to happen only once in 100 years. Storm damage you see on the television news is often from storms of this size.

B12 *Quick Lab*

What It Feels Like to Be a Structure

Figure 4.22 This person is experiencing compression of the neck muscles. This is similar to what a column might experience in a building.

It can be difficult to imagine how internal forces act on a structure. By using your body to act them out, you will learn more about the different types of forces.

Purpose

To experience compression, tension, shear, and torsion by using your body

Materials & Equipment

- space to move around
- a small textbook

Procedure

1. With a partner, determine how you can act out each of the forces using your bodies. Write down your ideas. For example, to experience compression, you might put the book on your head, as in Figure 4.22.
2. With your teacher's permission, carry out your ideas and record your observations in a chart like the one in Table 4.4.

Table 4.4 What It Feels Like to Be a Structure

Force	Action	Observations
Compression		
Tension		
Shear		
Torsion		

Questions

3. Discuss this activity with your partner. Talk about each action and how it felt. How might structures experience and react to this type of force?
4. Think of an everyday situation in which you experience each type of force (for example, when you reach for something on a high shelf or pitch a baseball). How does your body react to each of these forces?
5. Choose a structure. Suggest ways to minimize compression, tension, shear, and torsion on that structure.

B13 *Quick Lab*

Raise the Flag

Earlier, you observed the effect of wind on various plants. In this activity, you will study in more detail how wind affects structures.

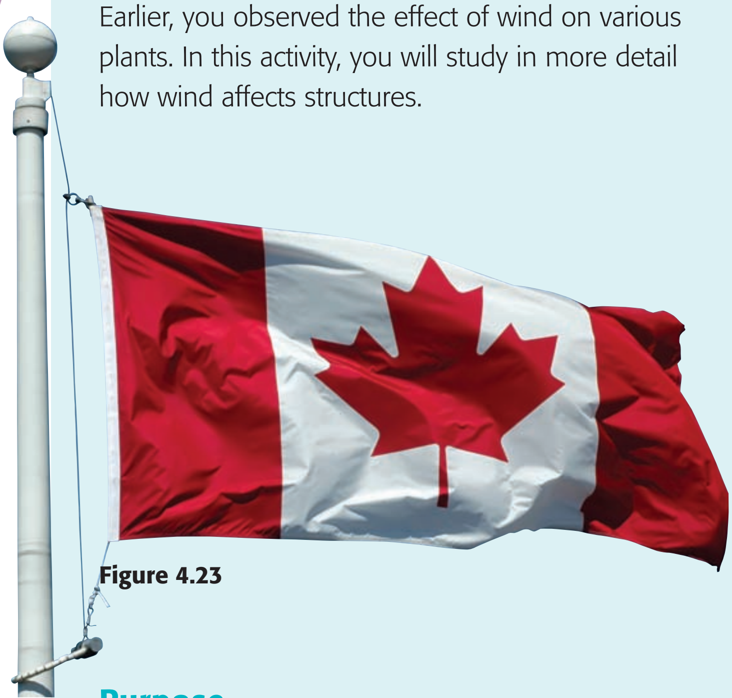


Figure 4.23

Purpose

To investigate the effects of wind on a model flag

Materials & Equipment

- pencil
- piece of tissue paper
- string
- tape
- scissors
- plastic drinking straw
- sheet of note paper

Procedure

1. With a partner, make a model of a flag and flagpole out of the tissue paper, pencil, string, and tape, simulating the dimensions and the connections (see Figure 4.23).

2. Use the sheet of paper to make a fan. Wave the fan to create a wind effect on the flag. Record your observations.

3. Blow through the straw at different parts of the flag. Record your observations.

Questions

4. Describe how the flag moves when you use the fan. How does it change when you wave the fan at different parts of the structure (bottom, middle, and top of the pencil)?

5. Describe how the flag moves when you blow through the straw. How does it change when you blow through the straw at different parts of the structure (bottom, middle, and top of the pencil)?

6. How does using the paper fan demonstrate "plane of application" of a force?

7. How does using the straw demonstrate "point of application" of a force?

4.2 CHECK and REFLECT

Key Concept Review

1. Define "force" in your own words.
2. What types of forces can act on structures? Give examples of each of these types of forces.
3. Categorize each of the following forces as internal or external.
   (a) gravity
   (b) compression
   (c) a strong wind
   (d) tension
4. A family of beavers builds a dam across a stream. Describe the forces that would act on this dam. Describe the magnitude, direction, and point and plane of application of each force.

Connect Your Understanding

5. Some roads have signs that specify a maximum load for the vehicles that travel on them. Why might this be?
6. Which forces are easier to anticipate and design for, internal or external? Why do you think this is so?
7. Describe the most common types of injuries sustained by players in your favourite sport. What does this tell you about the types of internal forces that affect the players' bodies?

Practise Your Skills

8. Draw a simple diagram of a climbing structure in a schoolyard. Describe the structure and its function, and classify it as frame, solid, or shell. On your diagram, show the internal and external forces it might be subjected to.

For more questions, go to ScienceSource.

B14 *Thinking about Science and Technology*

STSE

Damaged Structures

Every day, structures bear the brunt of external forces. Some are damaged by those forces; others are not.

What to Do

1. Describe a structure that you think was subjected to a large external force. What evidence causes you to think that it was subjected to this force?
2. What steps could have been taken to protect that structure from the force?
3. How might technology be used to prevent further damage to the structure?
4. Share your thoughts with a classmate or the whole class.

4.3 Designing for Safety

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

- The function of a structure dictates how strong it must be.
- A good design takes into account the function of the structure.
- Engineers ensure structural safety by using various design features.

Figure 4.24 Potholes are caused by freezing and thawing of the water in cracks in the road.

Figure 4.25 These trees were damaged by ice in eastern Ontario in 1998.

Every day, you walk along sidewalks and are driven along roads. You may have seen and felt potholes in the roads (Figure 4.24). Occasionally, someone is injured when a roof collapses. Roofs are designed to withstand a certain "snowload." A large amount of snow can collapse a roof if it isn't shovelled off. A bridge spanning the Mississippi River collapsed in Minneapolis, Minnesota, in the U.S.A., killing several people. Natural structures also fail when forces are too strong for them (Figure 4.25).

Sometimes, the failure of a structure is tragic. But no one ever reports about the millions of bridges, buildings, and airplanes that do their jobs! These structures are inspected regularly. Occasionally, however, something fails. Whether the failure is a pothole or a bridge collapse, engineers learn from it and improve their designs to ensure safety.

In this section, you will learn about some of the ways in which designers plan safety into structures and the factors they consider when designing and monitoring them.

B15 *Starting Point* Skills A C

Everyday Failures

Think about your everyday life. Perhaps your pencil broke just as you were finishing a math problem. The wind may have blown over your bicycle and bent a pedal.

As a class, brainstorm a list of structural failures that can happen at any time.

With a partner, pick three of the failures from the class list. Discuss each situation and write at least one possible cause for each failure.

B16 *During Reading*

Thinking Literacy

Making Connections

Making connections to a topic helps readers keep their focus while reading, remember better what they read, and understand the topic more completely. As you read this section, think about the connections you can make to the topic of designing safe structures. Add any new information you learn to your structure mind map.

Preventing Failure

No one can design a structure to be 100 % failure-proof. The materials it is made from wear down over time. A person may use it incorrectly and break it. Unexpected forces might come into play.

Engineers use the techniques of risk management to reduce the risk of failure as much as possible. They deal with known risks in one of three ways: ignore the risk, avoid the risk, or design for the risk.

Some things that could happen to a structure are highly unlikely. For example, an elephant may walk into your room, sit on your chair, and break it. This is a highly unlikely event, so chairs are not designed with this in mind. This risk is ignored.

Most bridges are designed with supports that can withstand the impact of a ship. However, if a bridge is designed with no supports in the water (Figure 4.26), the risk of a ship collision has been avoided.

Designing for risk requires a thorough understanding of the structure and the forces that may affect it. Designers often over-compensate for the various risks, making the structure stronger than it really needs to be. They also build in safety features, such as backup systems and warning systems that may use sensors.

Figure 4.26 Boats cannot collide with the supports of this bridge, because they are not in the water!

B17 *Learning Checkpoint*

Designing for Risks

Pencils are designed to withstand "normal use" — the force of day-to-day writing. They were not designed to withstand the force of a hammer! That risk was ignored by early pencil designers. As well, people do not use pencils underwater, so that risk could be avoided by designers.

Pretend you are the designer of another structure (your choice). What risks would you consider? What risks would you ignore or avoid? Share your ideas with a partner. Then, join with another pair and continue the conversation.

Write a summary of your ideas.

Figure 4.27 Have you ever seen the "maximum load" notice on an elevator?

Designing for Loads

When designing a structure, the designers must calculate the load it will need to support. A chair, for example, must be able to support itself. If the chair is designed for normal use, designers consider the range of people who might use the chair. Occasionally, more than one person might sit on the chair at one time. Thus, they design the chair to support more than itself plus the biggest occasional load. Some structures have warning notices about the maximum load they are designed to support (Figure 4.27).

Designing for Safety

In Ontario, all builders must follow the regulations set out in the Ontario Building Code. The code gives minimum standards for all aspects of a building, including load-bearing design and materials. The Ontario Building Code assures the public of a certain level of safety.

The Ontario Fire Code is a law that states that every home in Ontario must have working smoke alarms on every floor and outside all sleeping areas. A smoke alarm is a device that can detect smoke. Properly installed and working smoke alarms can warn people to get out of a burning building. This reduces the number of fire-related injuries and deaths.

Suggested Activity
B19 Inquiry Activity on page 121

Designing for Efficiency

Something described as "efficient" operates well without a waste of time, effort, or expense. For example, if two students build bridges that can support the same load, the bridge that uses the lesser amount of materials (usually by weight) is considered more efficient.

Sensors

A **sensor** is any device that can detect or measure real-world conditions. Different sensors can detect heat, light, pressure, or sound, as well as changes in the amounts of these things.

Sensors in a home include smoke detectors, carbon monoxide detectors, and thermostats. A thermostat (Figure 4.28) monitors ("senses") the temperature. Different thermostats control the heating and cooling in your home, and the temperature in your oven and your refrigerator. Thermostats respond to temperature changes by activating other equipment. When the furnace thermostat detects that the temperature in the house has gone down, it signals the furnace to turn on.

If a smoke alarm (Figure 4.29) detects smoke, it makes a loud noise. Carbon monoxide detectors sound when they detect a build-up of deadly carbon monoxide gas.

Sensors are also used in entertainment. Perhaps you have played a computer game with a floor pad (Figure 4.30). Sensors in the pad send information to the computer about your dance steps. This results in a score for your performance, which motivates you to try to improve.

You may also have come into contact with motion detectors. In some buildings, lights turn on when someone enters a room. When you hold your hands under the tap in some restaurant washrooms, the water runs. Doors in many stores open as you walk toward them. These types of sensors all detect a change and activate equipment to respond accordingly.

Engineers use many types of sensors to ensure public safety. Sensors that can detect vibrations are frequently installed throughout new commercial buildings. Day-to-day vibrations from traffic are monitored by a computer. After a tornado or an earthquake, the computer can determine if the structure has been damaged and tell if it is safe to go back inside.

Figure 4.28 A thermostat. You set the temperature you want at the top, and the thermometer at the bottom reads the current temperature in the room.

Figure 4.29 Sensors in a smoke alarm can perform their functions properly only when they are in good working order.

Figure 4.30 Sensors are found in many devices from practical ones to entertainment ones.

Take It **Further**

One type of sensor has been given the nickname "smart sensor." This simply means that the information collected by the sensor is processed by a built-in computer. Begin your search for smart sensors at ScienceSource.

B18 *Quick Lab*

Be an Inspector

One method used to ensure the safety of structures is visual inspection. Inspectors examine an existing structure for signs of weakness. These signs include cracks, warping, and rusting or corrosion of metal. Many everyday structures show these signs of weakness long before they fail, so the defects can be repaired. Structures are often modelled, and simulated forces are applied to the structures to test their limitations.

Purpose

To study everyday structures for signs of weakness

Materials & Equipment

- 2 identical, disposable food containers with lids

Procedure

1. Examine the disposable food containers and think about how they are used. Write down how you think the structure might show signs of weakness when it is used over and over again.
2. Put one of your containers aside. With the other container, simulate how you might use it. For example, you might wash it or put items into it. You might put the lid on and take the lid off and pour items out. Continue the simulation for 10 cycles. Record your observations in a chart like the one in Table 4.5.

Table 4.5 Signs of Structural Weakness

Cycle #	Observations	Inferences

3. Compare the unused container with the one you used in the simulation. Record any signs of weakness.
4. Repeat the simulation for another 10 cycles and record observations again.

Questions

5. Did the structure show the signs of weakness you predicted?
6. How might you design the structure so that it lasts longer?
7. This activity simulates what would happen over a period of time. Suggest another situation in which simulations could be used to test a structure.
8. How would you design a sensor that could tell the owner when the food container was going to fail?

B19 *Inquiry Activity*

Toolkit 2

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

Loads to Measure

Figure 4.31

Bridges have to support huge dynamic loads thoughout their length. In this investigation, you will simulate the load at different parts of a bridge by using a spring scale (see Figure 4.31).

Question

What is the effect of the location and the direction of a force acting on a structure?

Materials & Equipment

- straws
- tape
- spring scale

Procedure

1. Using straws and tape, construct a simple bridge to cross a gap of 50 cm. Place the bridge between two desks and tape the ends to the desks.
2. Simulate the load on the bridge by using a spring scale to pull down on the bridge in each of the following ways until the bridge just begins to bend. At that point, read the force on the spring scale, then release the scale.
   (a) Pull straight down from the centre of the bridge.
   (b) Pull straight down from one end of the bridge, close to the support.
   (c) Pull down at a 45° angle from the centre.
   (d) Pull down at a 45° angle from one end.
3. Record your measurement for each situation.

Analyzing and Interpreting

4. What was the difference between pulling straight down from the centre and from one end of the bridge?
5. What was the difference between pulling straight down and pulling at a 45° angle at the centre of the bridge? Was this result the same at the end of the bridge?

Skill Builder

6. How might you modify the procedure to increase the accuracy of your measuring?

Forming Conclusions

7. What do you conclude about the importance of knowing where a force will act on a structure?
8. Determine the weakest point on your bridge. If you were a bridge designer, where would you test your bridges for the maximum dynamic load it can support?

4.3 CHECK and REFLECT

Key Concept Review

1. Describe some ways in which structures can fail. Why is it important to try to prevent these failures?
2. (a) Pick one structure that has to support a large load. Describe how it was designed for this load with safety in mind.
   (b) Repeat for a structure that has to contain something.
   (c) Were sensors incorporated into the designs to increase safety?
3. In your own words, distinguish between "dynamic load" and "static load." Include an example to support your answer.

Connect Your Understanding

4. When engineers consider the forces that can act on a structure, they must think about all parts of the structure. Describe three different places on a bridge that would experience very different forces.
5. Make a list of all of the sensors you can think of in your school building. Describe the function of each sensor.

Practise Your Skills

6. You have been asked to design a desk to use for a laptop. What factors should you determine so that you can decide on the maximum load the desk can support?
7. Design a test to determine if a chair has been properly built to support a load. Choose a type of chair that you would like to test. Describe how you will stress the chair. State the criteria you will use to determine if the chair can support the load.

For more questions, go to ScienceSource.

B20 *Thinking about Science and Technology*

STSE

Safe Activities

What to Do

1. Make a T-chart. On the left side of the chart, list some of the activities you participate in, such as skating, bike riding, etc. Write a title for this column.
2. On the right side of the chart, list some of the structures that keep you safe while you do these activities.

Consider This

With a classmate or as a whole class, discuss the following questions.

1. How does each of the structures keep you safe?
2. What improvements could you make to any of the structures to keep you safer?
3. Why are you required by law to use some structures (such as a helmet when riding a bicycle) that prevent injury? Why is using other structures (such as elbow pads while riding a bicycle) optional?

Confederation Bridge

Figure 4.32 During winter, ice poses a threat to the Confederation Bridge.

Before May 1997, people took a ferry to get to Prince Edward Island. The ferry journey was long and you had to wait in line at each end. The Canadian and P.E.I. governments wanted a better way to make the journey. However, this solution had to be environmentally friendly, safe, and financially sound. A company called Strait Crossing Development Inc. won the privilege of designing, building, financing, and operating a bridge. This 12.9-km-long bridge would have to span waters that are ice covered in winter, as shown in Figure 4.32.

Many safety features were incorporated into the design, construction, and monitoring of the Confederation Bridge. For example, the "design life" of the bridge was 100 years. This is more than twice the design life of most other buildings and bridges. The bridge features over 750 sensors that monitor deformities in the bridge's concrete, changes in temperature, and vibrations caused by traffic or natural disasters such as earthquakes. Universities, the government, and private companies do the monitoring.

The Confederation Bridge has a 24-hour-per-day bridge patrol and visual monitoring. In addition, the maximum speed allowed on the bridge is changed according to weather conditions. In good weather, the maximum speed is 80 km per hour, and it takes about 10 minutes to cross the bridge.

In 1994, the Canadian Construction Association awarded the Environmental Achievement Award to Strait Crossing Development Inc. This award was given even before the bridge opened because the construction company took special care to ensure the safety of wildlife in both the water and the land affected by the construction of the bridge.

A live web cam lets you see the Confederation Bridge in real time. This is especially interesting in rough weather. Go to ScienceSource for a link to the Web cam.

Questions

1. Why was the bridge built?
2. What were some of the challenges of building this particular bridge?
3. What are some of the safety features incorporated into the bridge's design?

4.0 Chapter Review

Assess Your Learning

After Reading — Thinking Literacy

Summarizing

Revisit your mind map to help you summarize what you have learned in the form of a 5-4-3-2-1organizer. To do this, list:

- 5 key ideas you learned in this chapter
- 4 internal forces acting on structures
- 3 ways to classify structures
- 2 ways to prevent the failure of a structure
- 1 question you still have

Key Concept Review

1. Review three ways in which structures can be classified. When might each classification system be best used? (k)

2. Classify the following list into three columns, titled Solid, Frame, and Shell: comb, candle, bridge, apple, ladder, egg, igloo, tent, car, book, house, and eraser. (k)

3. Define "form" in your own words. Sometimes designers design for form but sacrifice function. Describe a structure you have used that seems to fit this description. (k)

4. Define "function" in your own words. Sometimes designers design for function but sacrifice form. Describe a structure you have used that seems to fit this description. (k)

5. Describe three different structures that are useful for carrying school supplies. How are they similar in form and function? How are they different? What forces are these structures designed to withstand? (a)

6. For each of the structures below, describe its form, its function, and the forces that act on it. (k)
   (a) banana
   (b) laptop computer
   (c) elastic band
   (d) ice skates
   (e) shopping cart

7. For each of the following structures, describe the static and dynamic loads it must support. (a)
   (a) a road
   (b) a book
   (c) a CD jewel case
   (d) a wall of a house

8. For each structure in question 7, describe the magnitude, direction, and point and plane of application of an external

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

force that acts on it. Describe how each structure might experience at least one internal force. (a)

Connect Your Understanding

9. Suggest another way to classify structures that is not described in this chapter. What are the advantages and disadvantages of your method? (t)

10. Many structures are designed to be stronger than they need to be. Give an example of this and explain why. (a)

11. Think about the route you take between home and school. Briefly describe an example of each of the following that you pass: a shell structure, a frame structure, a solid structure, and the structure that supports the biggest load. (k)

12. Why do governments pass legislation to ensure minimum levels of safety in the design of structures? (k)

13. After some fires, firefighters have found that smoke alarms were either missing or not working properly. How can firefighters encourage people to make better use of these safety devices? (t)

Practise Your Skills

14. The human body and a house are both structures. In a chart, compare these two structures by explaining their similarities and differences in words and pictures or diagrams. (a)

Unit Task Link

As you plan for your unit task, consider the form and function of different structures that use energy in your home. What forces affect them, and what safety features do they include? Think about how you could incorporate newer technology into one of these structures in order to improve the energy efficiency of your home.

B21 *Thinking about Science and Technology*

STSE

Structures and Technology

What to Do

1. Think about one activity that you do each day. What structures do you use in this activity? Do they put any stresses on your body?

Consider This

With a classmate, discuss the following questions.

2. Are the structures you use for that activity comfortable to use?
3. Are the structures ergonomically designed?
4. How could you improve the structures you use for that one activity?