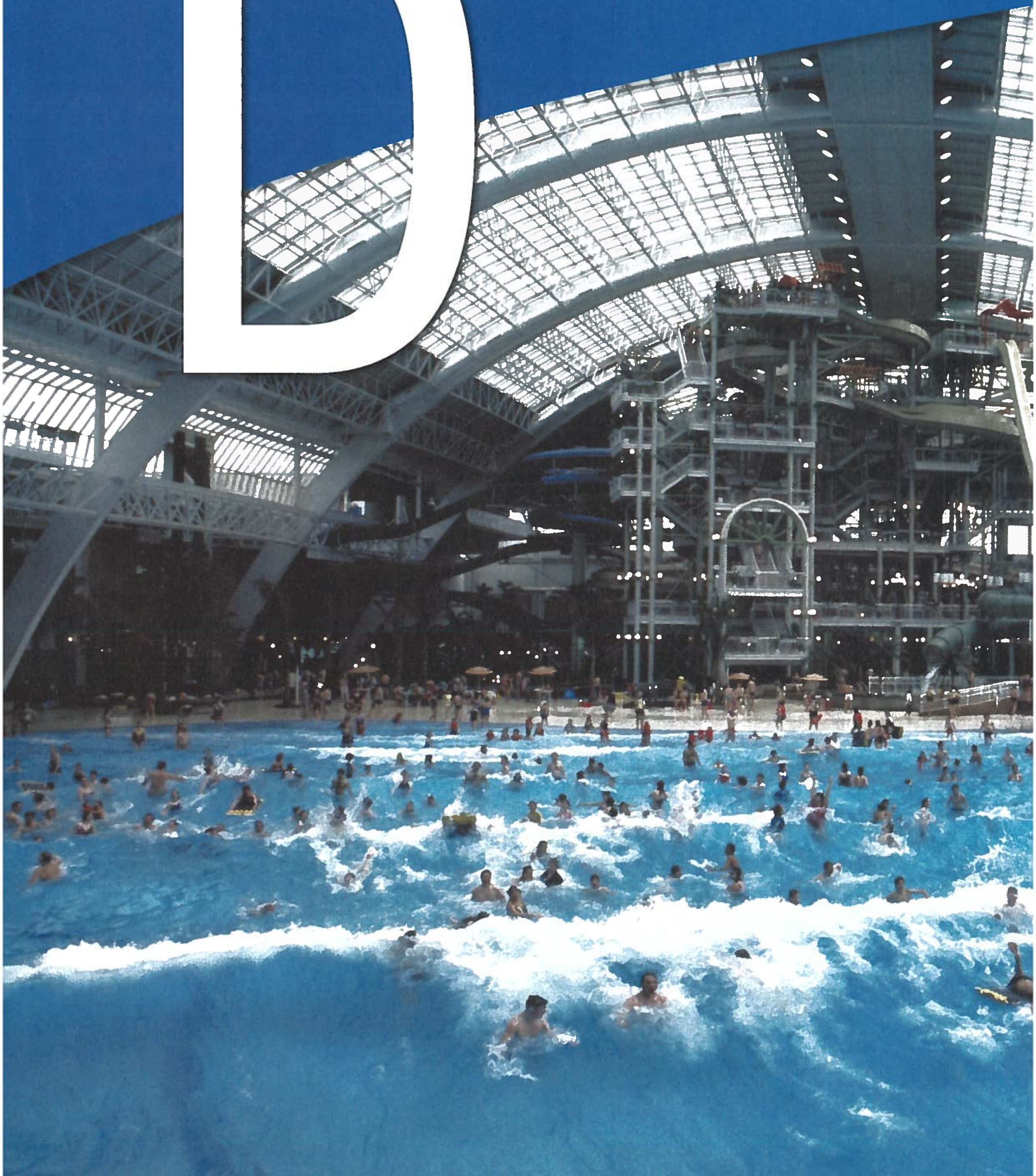
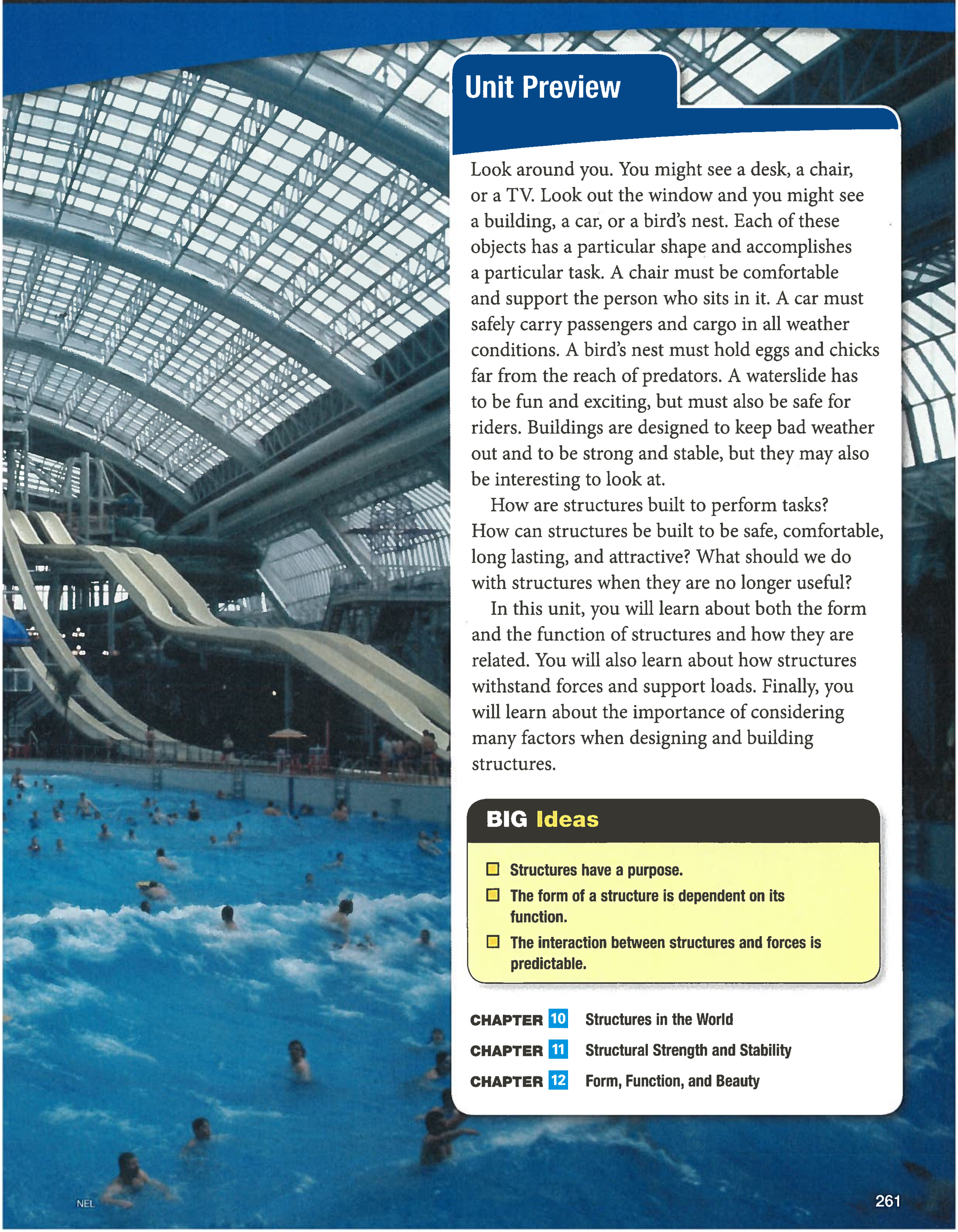
UNIT D

FORM AND FUNCTION





Unit Preview

Look around you. You might see a desk, a chair, or a TV. Look out the window and you might see a building, a car, or a bird's nest. Each of these objects has a particular shape and accomplishes a particular task. A chair must be comfortable and support the person who sits in it. A car must safely carry passengers and cargo in all weather conditions. A bird's nest must hold eggs and chicks far from the reach of predators. A waterslide has to be fun and exciting, but must also be safe for riders. Buildings are designed to keep bad weather out and to be strong and stable, but they may also be interesting to look at.

How are structures built to perform tasks? How can structures be built to be safe, comfortable, long lasting, and attractive? What should we do with structures when they are no longer useful?

In this unit, you will learn about both the form and the function of structures and how they are related. You will also learn about how structures withstand forces and support loads. Finally, you will learn about the importance of considering many factors when designing and building structures.

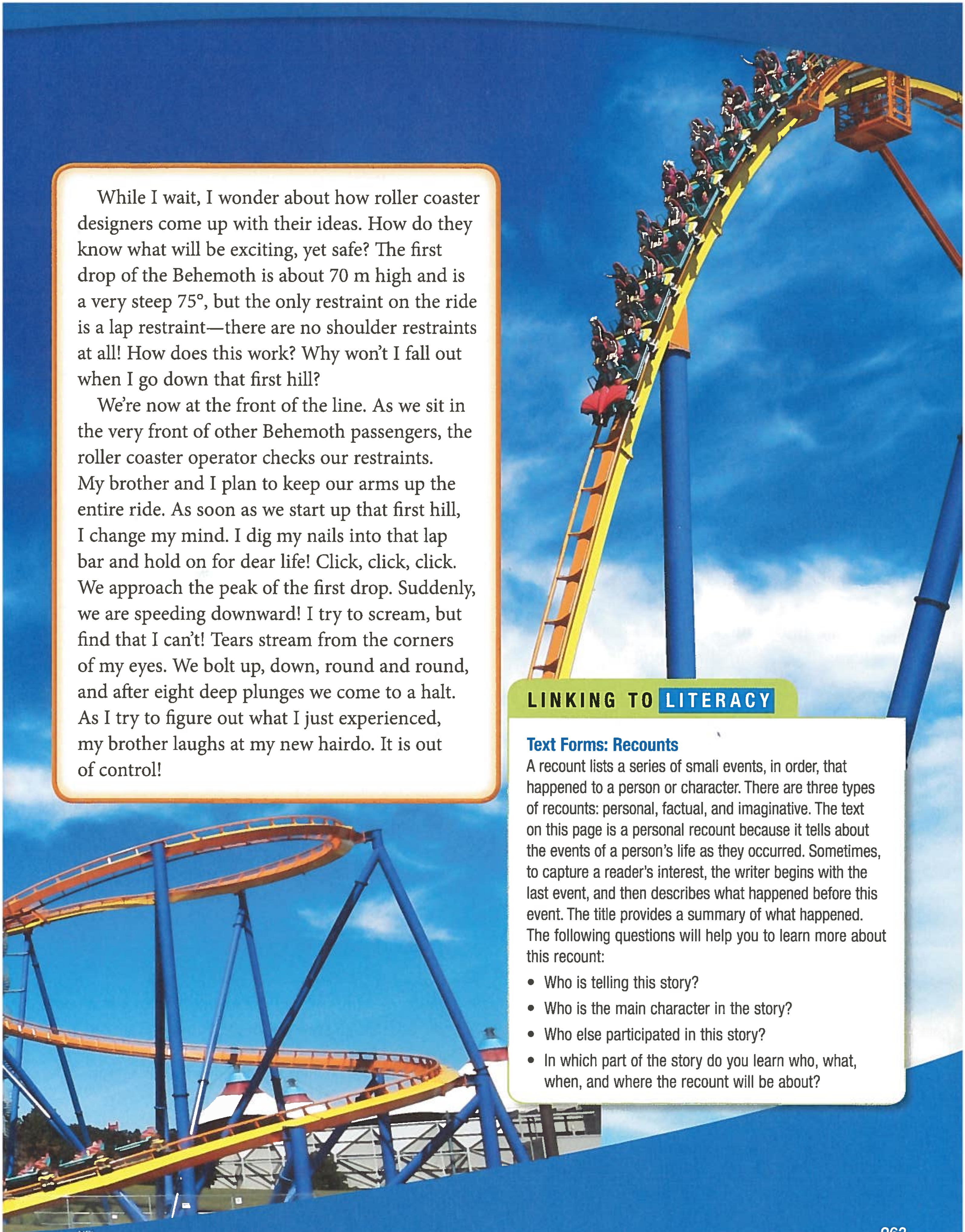
BIG Ideas

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

RIDING THE BEHEMOTH!

I have been looking forward to this for months. I read on the Canada's Wonderland website last year that something big was coming. Well, it's finally here—The Behemoth.

On the day we finally go to Canada's Wonderland, I am so excited that I can hardly stand it. Seeing the Behemoth from the parking lot, I realize that everything about the roller coaster is true. Once we get into the park, my brother and I run to the Behemoth. Hundreds of eager thrill-riders are waiting for their 3 min and 10 s of airborne excitement. We join the line to wait with them.



While I wait, I wonder about how roller coaster designers come up with their ideas. How do they know what will be exciting, yet safe? The first drop of the Behemoth is about 70 m high and is a very steep 75°, but the only restraint on the ride is a lap restraint—there are no shoulder restraints at all! How does this work? Why won't I fall out when I go down that first hill?

We're now at the front of the line. As we sit in the very front of other Behemoth passengers, the roller coaster operator checks our restraints. My brother and I plan to keep our arms up the entire ride. As soon as we start up that first hill, I change my mind. I dig my nails into that lap bar and hold on for dear life! Click, click, click. We approach the peak of the first drop. Suddenly, we are speeding downward! I try to scream, but find that I can't! Tears stream from the corners of my eyes. We bolt up, down, round and round, and after eight deep plunges we come to a halt. As I try to figure out what I just experienced, my brother laughs at my new hairdo. It is out of control!

LINKING TO LITERACY

Text Forms: Recounts

A recount lists a series of small events, in order, that happened to a person or character. There are three types of recounts: personal, factual, and imaginative. The text on this page is a personal recount because it tells about the events of a person's life as they occurred. Sometimes, to capture a reader's interest, the writer begins with the last event, and then describes what happened before this event. The title provides a summary of what happened. The following questions will help you to learn more about this recount:

- Who is telling this story?
- Who is the main character in the story?
- Who else participated in this story?
- In which part of the story do you learn who, what, when, and where the recount will be about?

Build a Textbook Holder

Your chair is a structure that supports you when you are sitting. Your desk is a structure that supports your notebooks and your upper body when you lean on it. In this activity, you and a partner will use building rods to construct a structure that will support a textbook without falling over.

1. Your task is to build a structure, using "building rods," that supports a textbook at a height of at least 20 cm above your desk. Your structure should be able to stand on its own without tipping over. Think back to what you learned in previous grades about structures.
2. To make a building rod, roll a piece of scrap paper, 216 × 279 mm (8½ × 11 in.), tightly into a cylinder and secure it with tape. (Figure 1). You can attach building rods to each other with tape.

Figure 1 A building rod constructed out of scrap paper

3. Each building rod costs 10¢ and each metre of tape costs 50¢. Working in pairs, build your textbook holder for as low a cost as possible.
4. After completion, you and your partner will present your textbook holder and total building cost to the rest of the class. Explain
   (a) why you built your textbook holder the way you did
   (b) why it cost what it did to build it

Answer the following questions on your own:

A. How expensive was your textbook holder? How did you try to keep the cost to a minimum?

B. How did the total cost of construction of your textbook holder compare with that of other groups?

C. What parts of your textbook holder worked well? If you had the chance to build it again, what would you do differently to improve its performance? Why would these changes be effective?

D. Predict how you would change your textbook holder if:
   (a) the height of the textbook holder had to be greater than 20 cm
   (b) you had to support two textbooks at the 20 cm level
   (c) part of the textbook had to extend beyond the edges of the textbook holder

E. Test your predictions by building new textbook holders. Get permission from your teacher. Make sure you have enough time and materials.

Unit Task Preview

Play Time Is the Best Time

All structures are designed and built for specific uses. Think about a playground. Each piece of equipment is designed to do something different. Slides are used for one kind of play, while swings are used for another.

Your task is to work with a partner to construct, test, and promote a piece of playground equipment. This task will consist of three parts:

1. **Design and Construction** Research how playgrounds are designed and built, and the factors that are considered when building a safe and interesting play area. Then, design and construct a model of a piece of playground equipment. Your model must be constructed to scale, be structurally sound, apply ideas you learn in this unit, and be safe for all potential users.
2. **Promotion and Advertising** Prepare an audiovisual advertisement for your playground equipment. Your ad must include audio (verbal) and visual components, such as a poster, a product brochure, or a radio broadcast or video clip. Your goal is to convince community organizations that are planning to build new playgrounds to use your design.
3. **Presentation** Present your multimedia advertisement to a group of your classmates. In your presentation, convince your audience that your playground equipment is
   - safe
   - environmentally friendly
   - structurally sound
   - fun for as many users as possible

Unit Task By the end of the Form and Function unit, you will be able to demonstrate your learning by completing this Unit Task. As you work through the unit, continue to think about how you might meet this challenge. Read the detailed description of the Unit Task on page 340, and look for the Unit Task icon at the end of selected sections for hints related to the task.

Assessment

You will be assessed on how well you

- meet the established criteria
- demonstrate an understanding of concepts, principles, and terminology
- carry out the plan using technical skills and procedures when necessary
- relate your finished product to society and how it could affect the lives of people

CHAPTER

10 Structures in the World

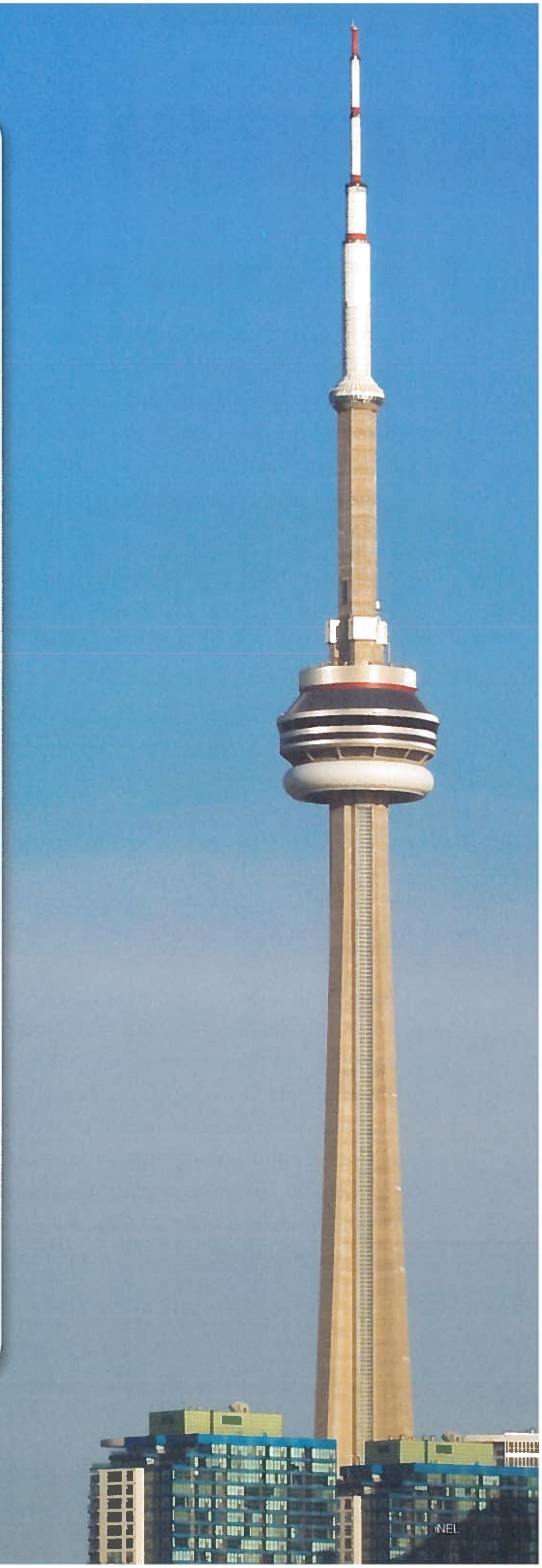
KEY QUESTION: How do structures resist forces?

Looking Ahead

- A structure is anything made of parts that are put together in a specific way for a specific purpose (or purposes).
- A force is either a push or pull on an object.
- Structures can be classified as solid, frame, shell, or a combination of these.
- Forces acting on structures have certain characteristics.
- The skills of scientific inquiry can be used to investigate the effects of forces on structures.

VOCABULARY

structure	solid structure
function	frame structure
form	shell structure
force	external force
gravity	internal force
mass	point of application
weight	plane of application
load	tension
dead load	compression
live load	torsion
dynamic load	shear



Reading **Science and Technology**

Inbox

New | Reply | Forward | Print | Send & Receive

From: Gordon

To: Dad

Subject: Three Gorges Dam—We finally made it!

Hi Dad,

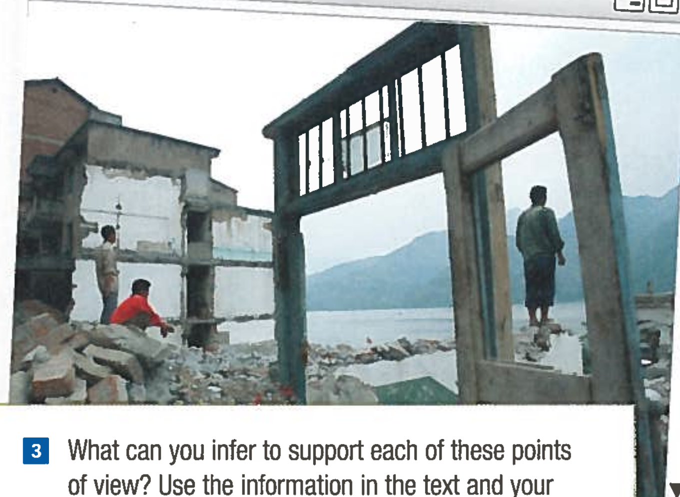
When Mom first told me I would be able to come with her and the rest of the Canadian engineering team to the Three Gorges Dam in China, I thought I would be bored. When we first arrived at the dam, all I could do was stare—it's so huge! Even the engineers who know all about the dam are astonished at just how big it is. I definitely will not be bored on this trip!

First, we met with the chief engineer of the dam. He explained that the Three Gorges Dam on the Yangtze River was built to provide hydro-electric power for the people of China. It now provides almost 10 times more power than the generating stations in Niagara Falls. The power is clean and better for the environment than burning coal or using nuclear power.

Later, Mom explained that China had asked for help to assess the dam and all the problems it was causing. Over a million people had been moved from their homes. Thousand-year-old villages and temples were now underwater from when the river valley was flooded. One of the environmental specialists said the damage to the environment was really bad and was going to get worse. The fish and animals that depended on the Yangtze River were dying and algae were starting to bloom downriver. Rockslides and flooding could mean that even more people would have to be moved and lose their homes—maybe as many as 4 million people!

Seeing the dam was really thrilling, Dad. The dam is probably one of the most amazing engineering feats of this century (Mom said that part). Now that I've seen the problems with the environment and the people losing their homes, I'm wondering if the power from the dam is worth it.

Gordon



LINKING TO LITERACY

Share Your Thoughts: Point of View

Take a few moments to reflect on the following questions. Then, share your thoughts with a partner.

1. How might points of view be the same or different for the engineers, the villagers, environmentalists, and Gordon?
2. What information does the text give you to support each of these points of view?
3. What can you infer to support each of these points of view? Use the information in the text and your background knowledge to make an inference.
4. Make a connection. How does this situation remind you of other environmental situations that have occurred in Canada?
5. Write two questions that you have after reading this e-mail. How will you find the answer to your questions?

10.1 Structures All Around Us

When you think of structures, you probably think of buildings, such as your home, your school, or the movie theatre. However, structures are more than just buildings. A telephone pole, a railway car, a cup, a pencil, and an umbrella are all examples of structures. A **structure** is something made of parts that are put together for a particular purpose. These objects can be as large and complicated as a car parking lot (Figure 1), or as small and simple as a saltshaker.

structure: anything made of parts put together for a particular purpose (or purposes)

Figure 1 The VW Autostadt structure in Wolfsburg, Germany, stores cars until the automated system retrieves them.

Figure 2 This Vitelline Masked-weaver's nest in Samburu National Reserve, Kenya, is an example of a structure.

Structures can be human-made or found in nature. A coral reef, a spiderweb, and an anthill are examples of structures in nature. The bird's nest and beehive seen in Figures 2 and 3 are also structures in nature. What are some other examples of structures in nature you would recognize?

All structures have at least one main **function**, which is the task or purpose that the structure is designed to perform. However, function is only one feature of a structure. Another feature is the structure's **form**, which is the physical appearance of a structure. A structure's shape and appearance can be related to its function.

function: the task or purpose of a structure

form: the shape and physical appearance of a structure

Figure 3 A beehive is an example of a structure found in nature.

Function

The main function of the roof of a house is to protect the house from weather conditions. The shape of a roof in an area of high snowfall is usually steep (Figure 4). The shape of the roof in a desert area might be flat because there is little rain and no snow to damage the roof (Figure 5).

Natural structures perform useful functions as well. What is the main function of a spiderweb? How many functions are performed by an elephant's trunk?

Figure 4 The steep shape of this chalet roof allows heavy snowfalls to slide off.

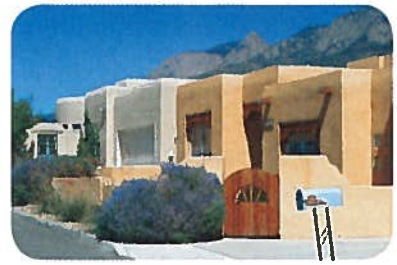


Figure 5 The flat roofs on these adobe homes work well in areas with very little rainfall.

Form

Function is often the main purpose of a structure, but humans usually want their structures to look good, too (Figure 6).

Figure 6 This distinctive building in Prague, Czech Republic, is known as the Dancing House. Does its form make you think of dancers?

Companies and organizations sometimes want people to pay attention to their structures. As with any structure, the form must be both safe and functional. The Burj Dubai in Dubai, United Arab Emirates (Figure 7) is an example of a very noticeable form.

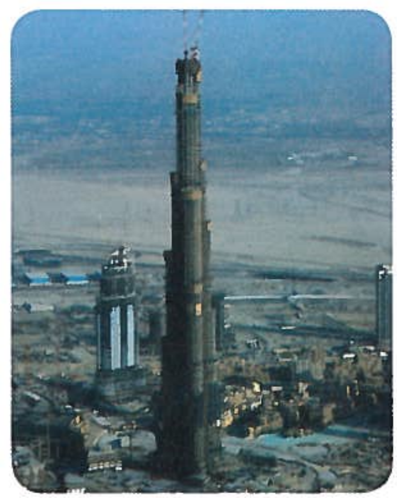


Figure 7 On May 12, 2008, the Burj Dubai reached 629.18 m, making it the tallest human-made object on Earth.

Unit Task How will you take form and function into account when designing your playground equipment for the Unit Task?

CHECK YOUR LEARNING

1. (a) What is a structure?
   (b) Name three examples of structures.
   (c) Describe one function for each structure in (b).
2. Why do humans consider the form of structures in their designs?
3. Describe the form and main function of
   (a) a baseball bat
   (b) an umbrella
   (c) a STOP sign

10.2 Forces

How would you move a stool? You could push the stool away from you (Figure 1(a)), pull the stool toward you (Figure 1(b)), or lift the stool upward (Figure 1(c)). Each case involves the application of a **force**, which is a push or a pull.

force: a push or a pull

LINKING TO LITERACY

Graphic Organizer: K-W-L Chart

Make a three-column chart in your notebook with the following headings: What I Know, What I Want to Know, What I Learned.

Before you read, ask yourself what you already know about forces. Write it in the first column. Then, ask yourself what you would like to know about forces. Write it in the second column.

As you read, list information that is new to you about forces in the third column.

After your reading, review your chart. How much of what you read in this section did you already know? How many of your 'Want to Know' questions were answered? What new information did you learn about forces?

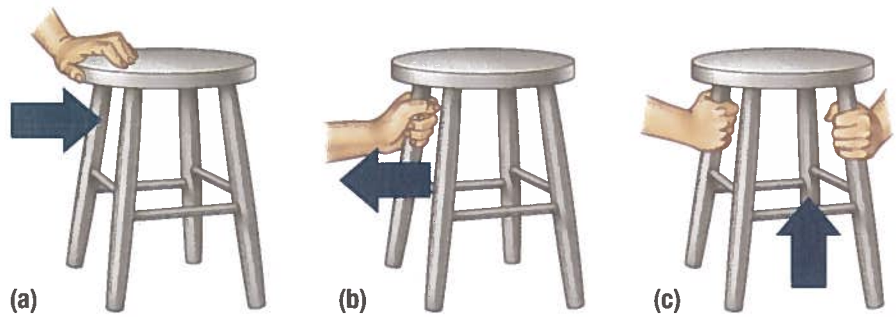


Figure 1 The application of a force on a stool

To lift the stool, you must overcome the downward pull of Earth. This pull is known as gravitational force, or gravity. **Gravity** is a force of attraction that exists between all objects. Gravity acts differently on objects with different masses. The gravity that pulls objects of small mass together is very weak. Any movement of the objects toward each other is not visible. However, the gravity of objects with very large mass, such as Earth, is able to move an object with a small mass, such as an eraser, a large distance. This is why an eraser falls to the ground when it is released.

gravity: the force of attraction between all objects; it is noticeable when at least one of the objects has a large mass; it is a non-contact force

In most cases, a force can only be applied when objects come in contact with each other. For example, your hand must contact a ball to push it (Figure 2). However, gravity pulls a ball down to the ground without Earth and the ball coming into contact (Figure 3). Forces that push or pull things without contact include gravity, magnetic force (the force that pulls two magnets together), and electrostatic force (the force that causes static cling).

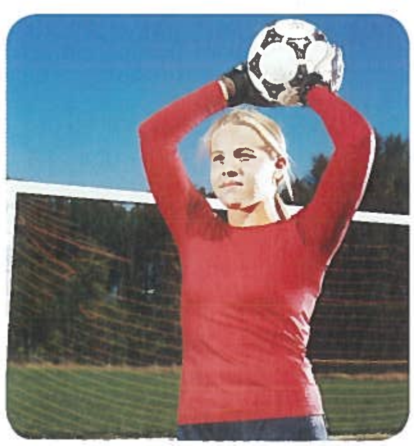


Figure 2 You must be in contact with a ball to apply force to it.

Figure 3 Earth and this basketball do not have to come into contact for gravity to act on the ball.

Forces that push or pull objects when the objects come in contact are called applied forces. The following are common examples of applied forces:

- your feet applying a downward force on a bicycle's pedals
- an oar of a boat applying a force on water (Figure 4)
- a hailstone striking a window
- a tennis racket hitting a tennis ball (Figure 5)
- your heart pushing blood through your blood vessels

Figure 4 The oar of a rower applies a force to water to move the boat.

Figure 5 When you hit a tennis ball with a racket, you apply a force to the ball. This makes the ball move.

Forces Have Magnitude and Direction

Every force has a strength and a direction. Common directions include up, down, left, right, and sideways. In diagrams, forces are represented by arrows. The thickness of the arrow indicates the magnitude, or strength, of the force. The arrow's point shows the direction of the force. Figure 6 illustrates three forces of different magnitudes and directions.

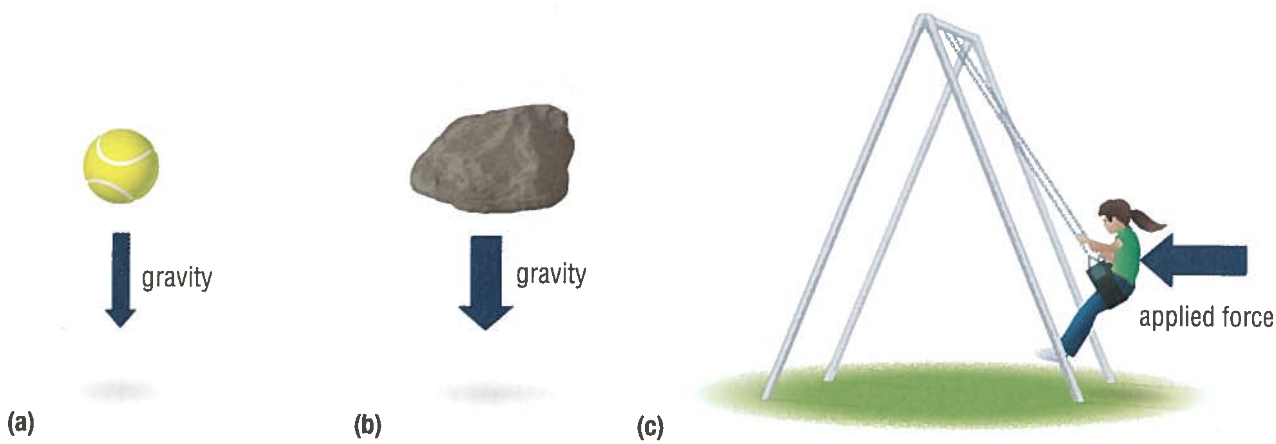


Figure 6 The direction of force in (a) and (b) is the same, but the magnitude is different. The magnitude of the force of gravity on a rock (b) is greater than that on a tennis ball (a). When someone pushes another person on a swing (c), the force applied is in a different direction than the force of gravity.

Distinguishing between Mass and Weight

In everyday speech, the words "mass" and "weight" are often used to mean the same thing. For example, a grocery store package might say that a hamburger patty weighs 200 g. In science, however, mass and weight have different meanings and different units of measurement. **Mass** is the quantity of matter in an object. Mass can be measured using a balance or a scale. Common units of mass are grams (g) and kilograms (kg). **Weight** is the force of Earth's gravity acting on an object. It is measured in newtons (N). The newton is named after Sir Isaac Newton, a famous scientist who lived in England from 1642 to 1727. A spring scale, like the one shown in Figure 7, can be used to measure weight. Some spring scales can also measure mass. Weight is the measure of a force, so it has magnitude and direction. A mass of 1 kg has a weight of nearly 10 N downward (toward Earth's centre).

mass: the quantity of matter in an object, commonly measured in grams (g) or kilograms (kg)

weight: the force of gravity acting downward on an object, measured in newtons (N)

To learn more about Sir Isaac Newton,
Go to Nelson Science

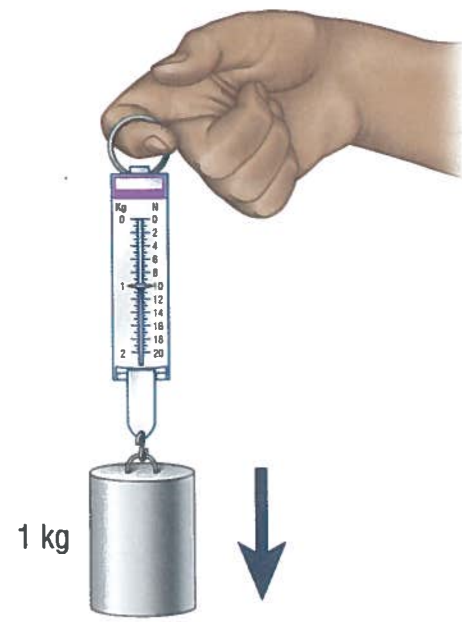


Figure 7 A 1 kg mass has a weight of about 10 N. Weight is commonly measured with a spring scale.

The mass of an object remains the same anywhere in the universe, but its weight can change depending on its location. The weight of an object on Earth is very different from the weight of the same object on the Moon. For example, an astronaut with a weight of 900 N downward on Earth would weigh only one-sixth as much (150 N downward) on the Moon. This occurs because the Moon has a smaller force of gravity than Earth. Imagine how different high jumping or playing baseball would be on the Moon!

LINKING TO LITERACY

Questioning the Text

To maintain your reading focus and get more meaning from a text, ask questions as you read.

Begin by scanning the page and reading the title and headings. What questions come to mind?

Read the first paragraph. Stop and reflect on what you have read. What questions do you have? What more do you want to learn about this topic? What words do you find confusing?

Move to the next paragraph, and again, stop to ask questions. As you read and question, you will create a conversation in your head. Your conversation will help you to make connections and think more deeply about your reading.

Loads

Structural designers have to consider all the forces that will act on a structure. For example, a bridge designer has to consider what will travel on top of a bridge and what forces will affect the sides and the underside of the bridge. A stable structure must be able to withstand all of the forces that act on it. The force acting on a structure is called the **load**.

load: a force acting on a structure

Figure 8 illustrates how loads can be classified. Static loads result from gravity, which always acts downward. Static loads are further classified as "dead" or "live." **Dead load** is the weight of the structure itself. **Live load** is the weight of the objects that a structure supports. The bridge in Figure 8 is strong enough to support its own weight plus the weight of whatever crosses the bridge.

dead load: a type of static load caused by the weight of the structure itself

live load: a type of static load caused by the weight of the objects it supports

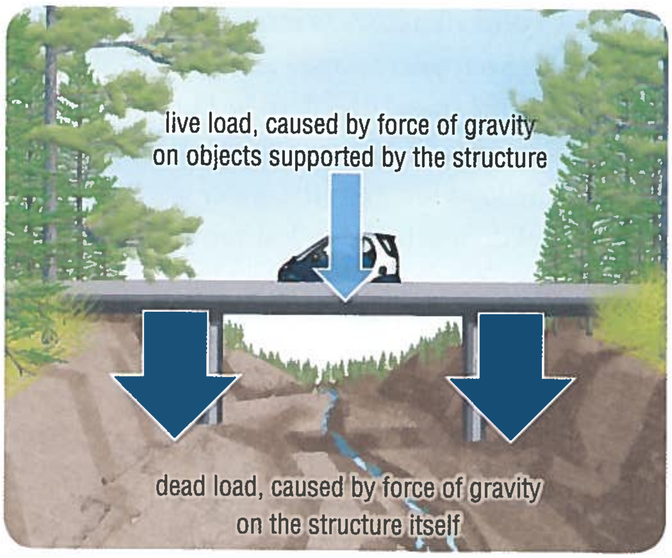


Figure 8 Static loads consist of both dead and live loads.

In addition to static loads, a structure may be affected by dynamic loads. A **dynamic load** is a load caused by forces other than the force of gravity. Moving water and high winds are examples of dynamic loads that must be considered when designing structures. In Figure 9, the dynamic load is the rushing water in the flooded river pushing against the bridge. Other examples include a car that strikes a guardrail (think of both the guardrail and the car!) and the forces that occur when a baseball bat strikes a ball.

dynamic load: any load on a structure that is not caused by gravity; for example, wind or rushing water

Figure 9 Rushing water striking a bridge is an example of a dynamic load.

CHECK YOUR LEARNING

1. Provide four examples of forces that you have experienced today. Classify each force as either non-contact or applied.
2. Earth's gravity pulls down on a skydiver with 845 N of force.
   (a) What is the magnitude of the force of gravity on the skydiver?
   (b) In what direction is the force of gravity acting?
3. Distinguish between mass and weight. Include the definitions, units of measurement, how they are measured, and what they depend on.
4. For a playground swing, identify at least one example of
   (a) a dead load
   (b) a live load
   (c) a dynamic load

10.3 Classifying Structures

What makes some structures similar and others different? We can group structures based on their function. Bridges serve one function (connecting two areas separated by a gap), while houses serve another (keeping people warm and comfortable).

Structures can also be classified using three basic forms: solid, frame, or shell. More complex structures are often combinations of these three forms. Each one of these forms can withstand different loads. Designers must consider the loads that the structures will experience before they can decide which forms to use.

Solid Structures

solid structure: an object that uses solid construction to support loads

A concrete dam, a wooden telephone pole, and a marble statue are all solid structures. A **solid structure** is strong, relying on solid construction materials to support loads. Large, strong structures have a large mass. The dam in Figure 1 is made of concrete that is very thick at the bottom where the load forces of the water are huge. A well-made solid structure can last for a very long time.

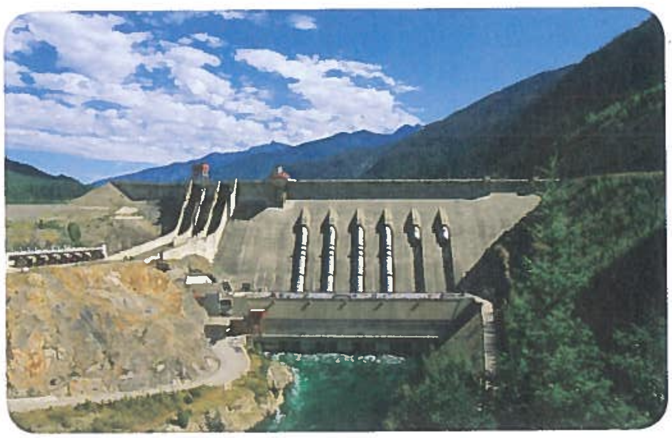


Figure 1 A dam is made of poured concrete, which is a mixture of sand, cement, and water that hardens to become very strong, solid concrete.

Frame Structures

frame structure: a network of parts that supports loads

Frame structures use a network, or skeleton, of materials that support each other (Figure 2). Your body's skeleton is a frame structure. Other examples are a goalie's net, a spiderweb, and the network of steel or wood beams supporting a bridge or a building (Figure 3). Frame structures can be very strong if their parts support each other and help resist forces. A single part of a frame structure cannot support the mass of the structure by itself.

Figure 2 A glass sponge has a skeleton composed of silica (glass).

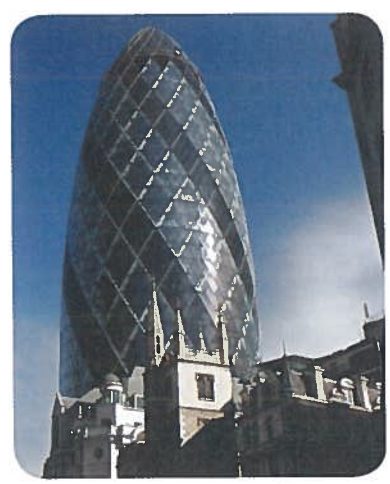


Figure 3 The St. Mary Axe building in London, England, shows its frame structure.

The individual parts of a frame structure are connected to one another. These connections require special support so that they do not bend and collapse. A frame structure may have a membrane stretched over it (for example, a tent), but the membrane does not help support loads. Frame structures are widely used and can be very sturdy. They have the advantage of being lighter than solid structures.

Shell Structures

A **shell structure** is a structure with a hollow, curved shape. A bird's beak, a pop can, and a bike helmet (Figure 4) are all shell structures. Shell structures can be very light, and yet have a great deal of strength and rigidity (Figure 5).

shell structure: a hollow structure with a curved shape providing high strength and rigidity

Figure 4 A helmet is an example of a shell structure.

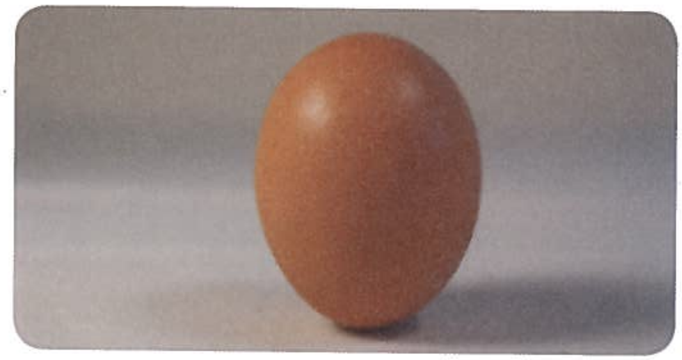


Figure 5 An egg is a shell structure too!

Combination Structures

The human skeleton is a framework of bones that hold muscles, tendons, and ligaments (Figure 6). The skull is curved, hard, and hollow like a shell structure. The femur, located in the thigh, can be considered a solid structure. The human body is a combination structure containing various solid, frame, and shell components.

LINKING TO LITERACY

Summarize Your Understanding

Work with a partner to complete this activity. In your own words, briefly retell what you have learned about solid, frame, shell, and combination structures. Refer to the photos to support your understanding. Then, have your partner take a turn to share his or her understanding. Compare your summaries to make sure you included all the main ideas.

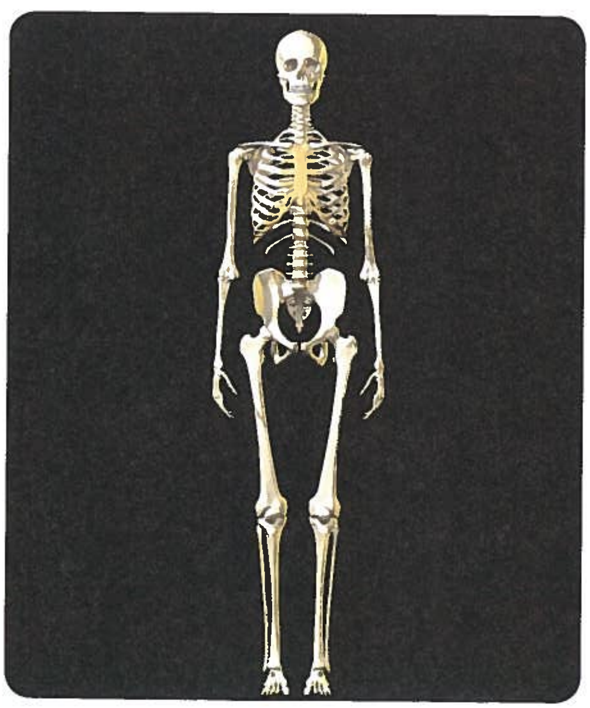


Figure 6 The human skeleton is a combination structure.

To learn more about classifying structures,
Go to Nelson Science

TRY THIS: Classifying Structures

SKILLS HANDBOOK 2.B.7.

SKILLS MENU: observing, analyzing, communicating

In this activity, you will work with a partner to analyze the photographs of structures that appear in this textbook and classify them as solid, frame, shell, or combination structures.

1. Copy Table 1 into your notebook.

Table 1

Photograph	Classification (solid, frame, shell, or combination)	Justification
CN Tower		
Three Gorges Dam		
beehive honeycomb		
bird's nest		
Dancing House		
Burj Dubai		

2. With your partner, analyze the structure in each photograph. Does it match the definition of a solid, frame, or shell structure? Is it a combination structure? Record your observations in your table.
3. Choose three familiar objects from your classroom and add them to your table. Analyze their structure and classify the objects as solid, frame, shell, or combination. Remember to justify your classification.
4. Share your results with the class.

A. Did any of the classifications surprise you?

B. Did all the groups classify the structures the same way? How would you resolve any conflicting classifications?

Figure 7 This automobile chassis is a combination structure with both shell and frame components.

Most structures are combination structures. Houses, and most other buildings, have a solid foundation. They also have a frame of wood or metal that supports a shell of brick, concrete, wood, or metal. Other combination structures include cars (metal frame and a shell of plastic or metal) (Figure 7), some bridges (solid piers and steel frame girders), and domed stadiums (solid concrete walls and frame and shell roof).

Unit Task Which shape—solid, frame, shell, or combination—will be best suited for the design of your playground equipment?

CHECK YOUR LEARNING

1. Classify each of these structures as solid, frame, shell, or combination: garbage can, airplane, hydro tower, pebble, basket, bicycle.
2. List the advantages and disadvantages of the three basic forms of structures (solid, frame, or shell).
3. The Cinesphere was the world's first Imax theatre (Figure 8). Classify the Cinesphere's structure. Justify your answer.
4. A turtle shell, the canopy of an umbrella, and the roof of a domed stadium are all curved. Classify each of these structures as solid, frame, shell, or combination.

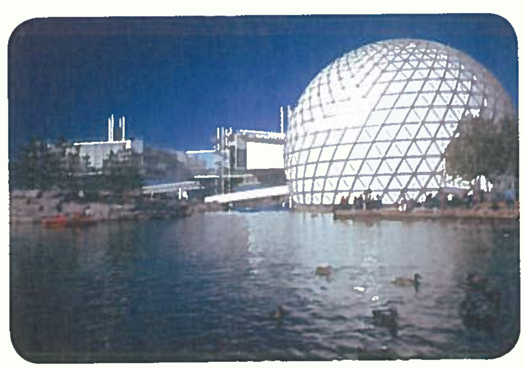


Figure 8

External and Internal Forces

10.4

Designers must consider all forces that can act on a structure. For example, when architects are designing buildings in an area that experiences earthquakes, they must design the buildings carefully. They must use the right types of materials to withstand an earthquake and any aftershocks that may occur. If the area is also close to a coastline, then designers must also consider problems related to water acting on structures as well. If all possible forces are not considered, then buildings can collapse (Figure 1).

Figure 1 This building was destroyed by the earthquakes in Sichuan Province, China, in 2008.

There are two types of forces that designers have to consider. **External forces** are forces that act on a structure from the outside. Forces that act between two different parts of a structure are called **internal forces**.

External Forces

The most obvious external force acting on structures is gravity. On Earth, gravity always acts downward. Gravity is a non-contact force. Non-contact forces are those applied to an object by another object not in contact with it. Applied forces, or contact forces, also act on an object from the outside. You apply external forces when you push a swing, pull an elastic, or throw a ball. External forces on buildings include wind, earthquakes, the weight of people on the floors of the building, and the weight of the building itself. A structure is designed so that external forces will not cause it to break or fall over.

LINKING TO LITERACY

Synthesizing

Synthesizing means to summarize what you read, reflect on your learning, and make connections with what you already knew. This helps you form new opinions, draw conclusions, apply your learning to new ideas, and construct new meaning or ideas.

To synthesize Section 10.4, read the section. Then, summarize what you have read. Think about what you already knew about this topic. What connections can you make? Reflect on ways in which you can draw a conclusion, come up with a new idea, or form an opinion about these forces.

external force: a force acting on an object or structure from the outside

internal force: a force acting between two parts of a body

point of application: the location on an object where an external force is applied or concentrated

plane of application: an imaginary flat surface through which an applied force passes

To move a filing cabinet across the floor, you can apply an external force on one of its sides. Examine Figure 2. The **point of application** is the location on an object where an external force is applied. The **plane of application** is an imaginary flat surface through which the applied force passes.

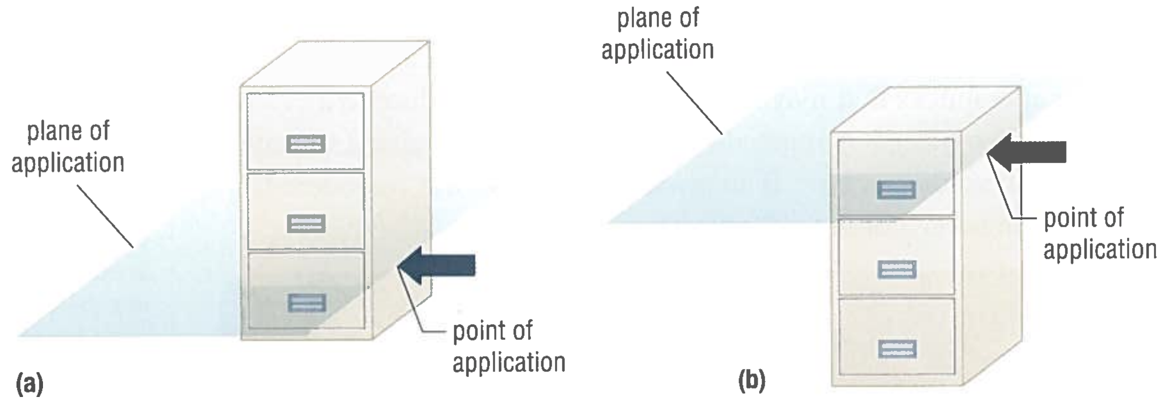


Figure 2 Illustrating point of application and plane of application of force applied to a filing cabinet

In Figure 2, the magnitude and direction of the applied force are the same. However, the point of application and the plane of application are different. If you push low on the cabinet, it will slide sideways (Figure 2(a)). If you push high on the cabinet, it is likely to tip over (Figure 2(b)). The point and plane of application make a difference in how an applied force affects a structure.

Another important external force is the force in the direction opposite to gravity. Think of the forces on you when you are sitting on a stool. You know that the force of gravity on you (your weight) is an external force that pulls you downward. However, if the force is pulling you toward the centre of Earth, why are you not moving toward Earth's centre? The reason is that the stool is also applying a force on you, pushing upward. The magnitude of the downward force (gravity) equals the magnitude of the upward force (stool on you) (Figure 3). This means that you are able to sit still.

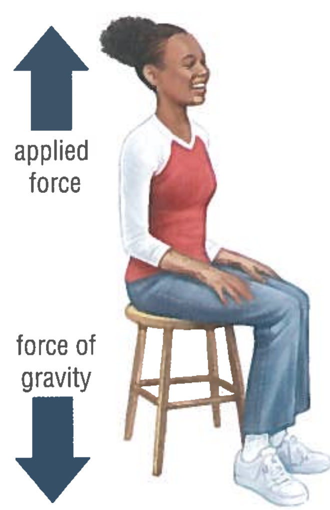


Figure 3 The upward applied force of the stool on the student is equal in magnitude to the downward force of gravity.

Internal Forces

Internal forces act between different parts of the same structure. There are four types of internal forces: tension, compression, torsion, and shear.

tension: an internal force pulling the particles of an object apart

Tension

When you pull on an elastic band, the force of your finger pulling on the elastic band is an external force. This force creates an internal force called **tension**, which causes all of the particles of the elastic band to pull apart. Tension can act on a variety of objects, for example, a stretched skipping rope, a trampoline, an electrical power line, guitar strings, and the cables of a suspension bridge (Figure 4). You know that if an elastic band is stretched too far, it breaks. The particles of an elastic material can move apart only up to a maximum distance. This point is called the breaking point. If stretched to this point, the particles in an object break apart and can no longer pull the material back together.

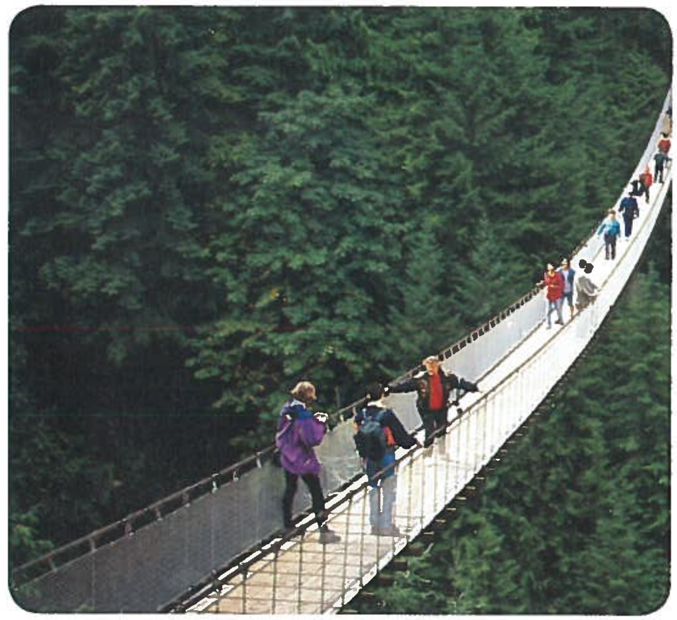


Figure 4 The main cables in a suspension bridge, like the Capilano Bridge in British Columbia, have tension forces acting on them.

Compression

An object that is pressed or squeezed experiences compression. **Compression** is an internal force that presses the particles of an object together. The springs inside a mattress undergo compression when you lie down on the mattress (Figure 5). Compression also occurs when you kick a soccer ball, step on the sole of your shoe, or lay your head on a foam cushion. Compressed objects usually return to their original shape after the external force is removed.

compression: an internal force that presses or squeezes the particles of an object together

Figure 5 These mattress springs have compression forces acting on them.

Torsion

torsion: internal twisting forces created in an object as a result of a twisting motion being applied to the object

Torsion acts in an object when the object is twisted (Figure 6). Torsion is evident when a skater twists in a jump, a washcloth is wrung out, and a doorknob is turned. Torsion can be created when both ends of a structure are twisted. Torsion can also be created when only one end of a structure is twisted while the other end remains stationary.

Figure 6 This figure skater is experiencing torsion force as she twists her body in a spin.

Shear

shear: forces acting in an object as a result of pushes and/or pulls in opposite directions; usually results in rips or tears in an object

Shear forces occur when forces push or pull in opposite directions within an object. Shear forces usually result in an object being bent, torn apart, or cut. A strong wind that is blowing horizontally against a tree anchored to the ground causes shear forces inside the tree. These forces can cause it to bend or break (Figure 7). Scissors use shear force to cut paper in half. The blades of the scissors move in opposite directions and create two pushing forces against the paper, which result in the paper being cut.

To learn more about internal forces,
Go to Nelson Science

Figure 7 Shear forces inside the trees may cause them to snap in a strong wind.

CHECK YOUR LEARNING

1. Classify these forces as external or internal:
   (a) shear
   (b) gravity
   (c) torsion
   (d) the force of the floor on your feet when you are standing
2. You are lying in bed.
   (a) List the internal forces that are acting on the mattress.
   (b) What is the external force acting on the mattress?
3. Explain the difference between the direction of force and the plane of application of force. Use a diagram to help you.
4. Figure 8 shows a solid block-shaped structure in four different situations involving applied forces (the arrows). Name the internal forces in each diagram.

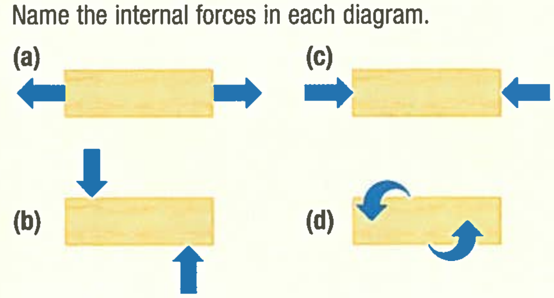


Figure 8

AWESOME SCIENCE

Tacoma Narrows Bridge: When Structures Fail

The Tacoma Narrows Bridge in Tacoma, Washington, was the third-largest suspension bridge in the United States when it opened on July 1, 1940. Its graceful, curved design was very attractive. However, this design also had the flaw of swaying and rippling in the wind. Residents dubbed the bridge "Galloping Gertie." People from hundreds of kilometres away would come to drive on the bridge to watch the cars in front of them disappear, and then reappear as the road structure rippled in the wind.

On November 7, 1940, a windstorm hit the Tacoma area. Winds of 67 km/h caused Gertie to twist in a torsional way (Figure 1). The left side of the bridge would rise and the right would fall, and then vice versa. Eventually, the bridge collapsed (Figure 2). Although there was no human life lost, there was one fatality—a dog named Tubby.

Figure 1 Blowing wind resulted in the torsional twisting of the Tacoma Narrows Bridge, photographed shortly before its collapse.

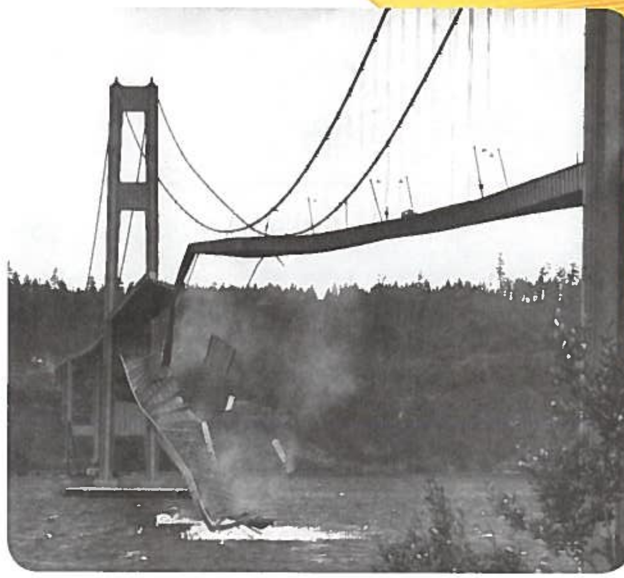


Figure 2 The collapse of the Tacoma Narrows Bridge

The Tacoma Narrows Bridge was rebuilt, starting in 1948. This time, however, engineers built a small scale model of the new bridge and tested it in a wind tunnel—a long, tunnel-like building in which models can be tested under conditions of high wind. The research showed engineers exactly why the first Tacoma Narrows Bridge collapsed. It also allowed engineers to determine how to avoid another such collapse.

As a result of the collapse of the Tacoma Narrows Bridge, all major structures today undergo a test in a wind tunnel. The wind tunnel demonstrates any problems with the design before the structure is actually built.

To learn more about the collapse of the Tacoma Narrows Bridge,
Go to Nelson Science

10.5 PERFORM AN ACTIVITY

Modelling Internal Forces

If the internal forces in structures are too great, then the structure may fail or collapse (Figure 1). In this activity, you will model some internal forces that can affect the ability of structures to maintain their forms.

SKILLS MENU

- ☐ Questioning
- ☐ Hypothesizing
- ☐ Predicting
- ☐ Planning
- ☐ Controlling Variables
- ☒ Performing
- ☒ Observing
- ☒ Analyzing
- ☒ Evaluating
- ☒ Communicating

Figure 1 This road failed because of shear forces. An earthquake caused the two sides of the road to slide in opposite directions.

Purpose

To create models of the internal forces that act on structures.

Equipment and Materials

- permanent marker
- scissors (optional)
- 2–3 cellulose or synthetic sponges

permanent marker

scissors

2–3 cellulose or synthetic sponges

Procedure

Part A

1. Copy Table 1 into your notebook. Make sure to create enough room for your sketches.

Table 1

Internal force	Diagram of shape of the lines before force applied	Diagram of the shape of the lines as force is applied	Description of the effect of force on the lines of the sponge
compression			
tension			

2. Use a marker to make a series of parallel, horizontal lines on the side of the sponge (Figure 2).

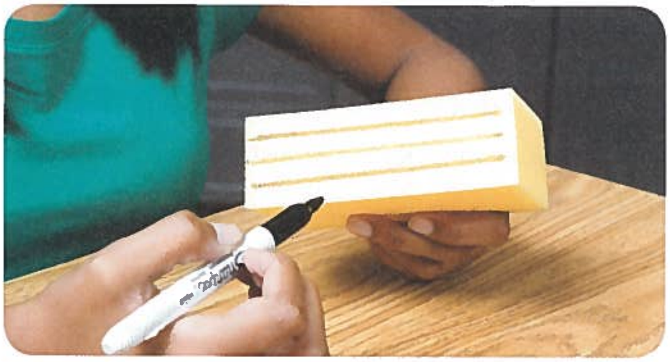


Figure 2 The horizontal markings on your sponge

3. Use your hands to squeeze the sponge from top and bottom. This creates compression forces inside the sponge. Observe any effects on the shape of the lines on the sponge. Record your observations, including a sketch of the sponge, in your table.
4. Using step 3 as a guide, design a method to determine the effect of tension on a sponge. Record your procedure.
5. Construct your model and test for the effect of tension using the same sponge as in step 2, or a new sponge. Record your observations in your table.
6. Using the sponge from step 5, apply a force on the sponge that creates torsion. Observe any effects on the spacing of the lines on the sponge after the application of this force. Record your observations.

Part B: Teacher Demonstration

7. Make observations as your teacher creates shear forces in a sponge. Observe any effects on the spacing of the lines on the sponge as it is being torn apart. Record your observations, including a sketch of the lines on the sponge, in your table.

Analyze and Evaluate

SKILLS HANDBOOK 2.B.7.

(a) Describe what happened to the spaces between the lines as you created each of the internal forces in the sponge.

(b) In which case(s) was the sponge able to return to its original form?

(c) In which case(s) was the sponge not able to return to its original form? Explain.

(d) Exchange your procedure for modelling tension with a classmate. Using a Venn diagram, compare the two procedures. Which procedure models tension more accurately? Justify your answer.

Apply and Extend

(e) Would your answers to (b) and (c) have changed if you had created the four forces in a rigid foam cup? Explain.

(f) Find an example of each of the four forces acting within structures in your home.

(g) Identify which internal forces are at work in each of the following:

i) the beams of a roof (Figure 3)
ii) the support cables of a suspension bridge
iii) a twisted plastic ruler
iv) the pin that holds scissors together

Figure 3 What force is at work in roof beams?

Unit Task When designing your playground equipment, be sure to consider the internal forces that can act on a structure.

CHAPTER 10 SUMMARY

Structures in the World

BIG Ideas

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

Looking Back

A structure is anything made of parts that are put together in a specific way for a specific purpose (or purposes).

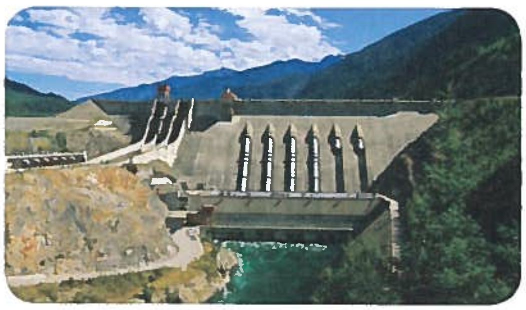
- Every structure has a function or task that it is meant to perform.
- Form is the physical appearance and shape of a structure.
- Humans often want structures to be attractive.

A force is either a push or pull on an object.

- Gravity is a force that pulls two objects together.
- The magnitude of force refers to the size or strength of a force.
- The direction of force is the direction in which a force is applied.
- The point of application of force is the point of contact between a force and a structure.
- The plane of application of force is the flat, imaginary, two-dimensional surface in line with an applied force.

Structures can be classified as solid, frame, shell, or a combination of these.

- Solid structures rely on solid construction materials to support and transfer loads to the ground (for example, a dam).
- Frame structures use a network of materials to support loads. Frame structures sometimes have sheets of materials stretched over them (for example, a tent).
- Shell structures have curved shapes that enclose a hollow space and provide support (for example, an egg).
- Combination structures contain a combination of solid, frame, and shell components (for example, the human body).



Forces acting on structures have certain characteristics.

- External forces act on a structure from the outside.
- Internal forces act between parts of the same object.
- The internal forces that act within structures are compression, tension, torsion, and shear.
  - Compression forces are created when an object is squeezed.
  - Tension forces are created when an object is pulled or stretched.
  - Torsion forces are created when an object is twisted.
  - Shear forces are created when an object is pushed or pulled in opposite directions, and the object bends, rips, tears, or snaps.

The skills of scientific inquiry can be used to investigate the effects of forces on structures.

- The four internal forces can be modelled using everyday materials.
- The effect of internal forces on structures can be observed using models.

VOCABULARY

structure, p. 268
function, p. 268
form, p. 268
force, p. 270
gravity, p. 270
mass, p. 272
weight, p. 272
load, p. 273
dead load, p. 273
live load, p. 273
dynamic load, p. 273
solid structure, p. 274
frame structure, p. 274
shell structure, p. 275
external force, p. 277
internal force, p. 277
point of application, p. 278
plane of application, p. 278
tension, p. 279
compression, p. 279
torsion, p. 280
shear, p. 280

CHAPTER 10 REVIEW

The following icons indicate the Achievement Chart categories: K/U Knowledge/Understanding; C Communication; T/I Thinking/Investigation; A Application

What Do You Remember?

1. What is a structure? K/U
2. What is the main function of the following structures? K/U
   (a) an airport
   (b) an apartment building
   (c) a bicycle
   (d) a dam
3. Clearly distinguish between function and form. K/U
4. In your notebook, complete the following sentences by filling in the most appropriate word(s): K/U

torsion	dead	pull	magnitude
internal	matter	push	gravity

   (a) Force is defined as either a ____________ or a ____________.
   (b) Mass is the amount of ____________ inside an object.
   (c) Your weight is due to the force of ____________ acting on you.
   (d) ____________ forces act between different parts of the same structure.
   (e) The strength of a force refers to its ____________.
   (f) A twisting force produces ____________.
   (g) The actual weight of a structure is known as the ____________ load.
5. Would your mass or weight change if you went to the Moon? Explain. K/U
6. What type of internal force is created in a wet dishcloth when you wring it out? K/U
7. Classify each structure in Figure 1 as solid, frame, shell, or combination. Justify your choice. K/U

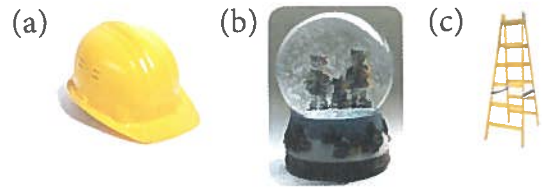


Figure 1

What Do You Understand?

8. Choose a building in your community. Which factor appears to have been more important in its design: function, form, or both? Explain. A C
9. Describe how tension and torsion are different from one another. K/U
10. Which of the internal forces is represented in each of the examples listed below? Provide a second example of your own for each example listed. K/U
    (a) ripping a piece of paper towel off the paper towel roll
    (b) pulling on ropes to set up a tent
    (c) twisting the lid off of a container
    (d) squeezing the tire on a bicycle to check its pressure
11. You are being pushed on a swing. Use the terms "point of application" and "plane of application" to describe this activity. K/U C
12. Pick a structure and identify parts that perform a function and parts that provide form. You may want to use a diagram to organize your answer. T/I A
13. Which do you feel is more important, form or function? Explain how this applies to some of the products that you have purchased in your own life. T/I

Solve a Problem!

14. (a) Freezing rain has caused the electrical wires to sag in your neighbourhood (Figure 2). Clearly distinguish between dead load and live load in this situation.
    (b) What can electric companies do to help prevent wires from breaking when ice accumulates on them? K/U A

Figure 2

Create and Evaluate!

15. Think of how you would design a science lab, the function of which is to allow students to perform investigations (Figure 3).
    (a) In a small group, brainstorm advantages and disadvantages of each design. Summarize your main arguments.
    (b) Compose a letter to the Director of Education to persuade her or him that your design should be considered in any renovation or new construction. T/I C

(a) Perimeter lab with outside benches

(b) Desk/Lab classroom

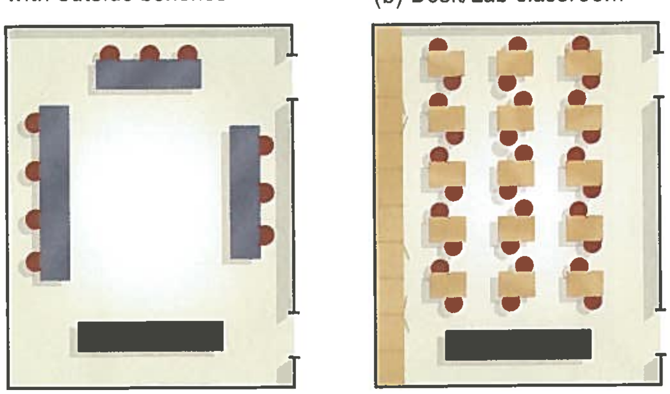


Figure 3

16. Reread the chapter narrative about the Three Gorges Dam. Pretend you are a member of the Canadian engineering team. Using your learning from this chapter, evaluate the dam in terms of form and function. K/U A
17. In the library or on the Internet, read the story of the Three Little Pigs.
    (a) Explain how the Big Bad Wolf applies a force on the little pigs' homes. In a paragraph, use the vocabulary in this chapter to describe the force and the factor(s) that may have led to the collapse of each pig's home.
    (b) What is the moral of the story in terms of the form and function of the structures commonly used in the construction of homes?
    (c) Write your own brief children's story that describes forces acting on structures, and the effects of those forces on the structures. K/U A C

Go to Nelson Science

Reflect on Your Learning

18. Look at structures in your home and list examples of the four internal forces. Are you surprised at how relevant this is to your home? Explain.
19. Think back to the Key Question on the first page of this chapter.
    (a) In a brief paragraph, answer the Key Question. You may use diagrams.
    (b) Write one or two more questions about the topic of this unit that you would like to explore.