

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 PointSkills **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?

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.

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.



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

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.

Describing Forces

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.

WORDS MATTER

“Dynamic” means changing, and “static” means not changing.

External Forces and Loads

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.

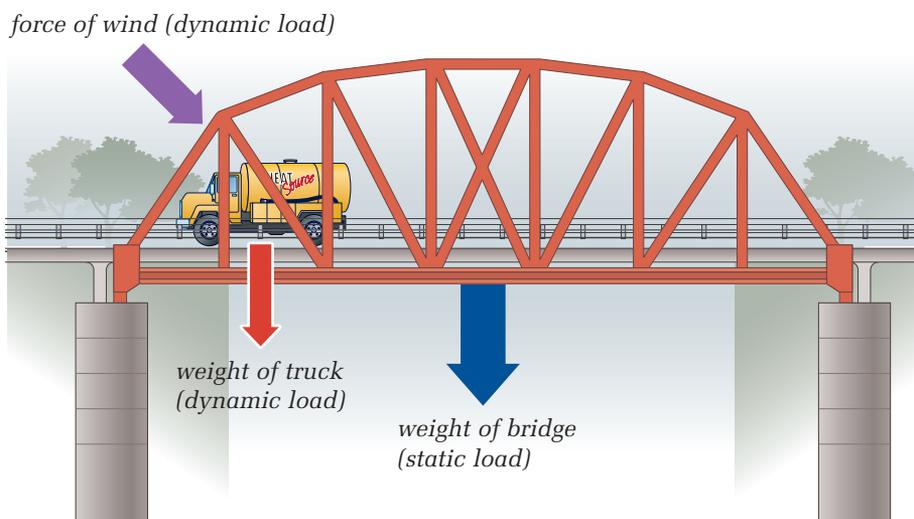


Figure 4.18 Forces acting on this bridge include the weight of the bridge (static load), as well as two dynamic loads: the weight of the truck and the force of the wind.

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.



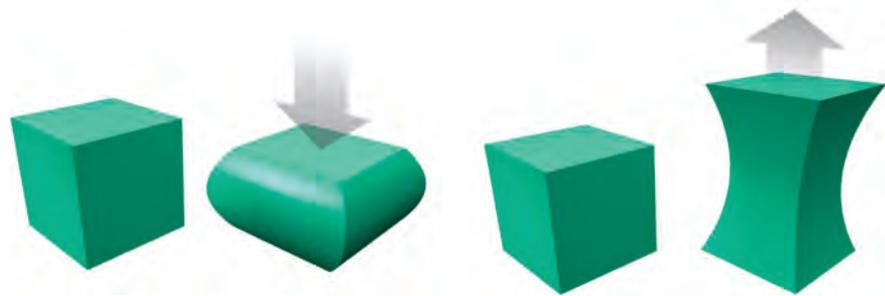
Figure 4.19 When the books are placed in the middle of the shelf (a), the shelf may sag from the unsupported dynamic load. If you place the books nearer the supports ((b) and (c)), the shelf does not sag.

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.

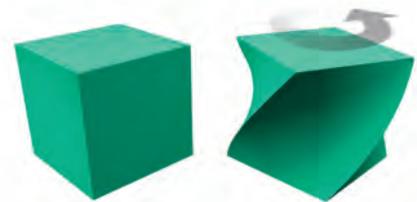


(a) **Compression:** A force that squeezes or presses something together

(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.

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.

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?

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



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.