

External and Internal Forces

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.

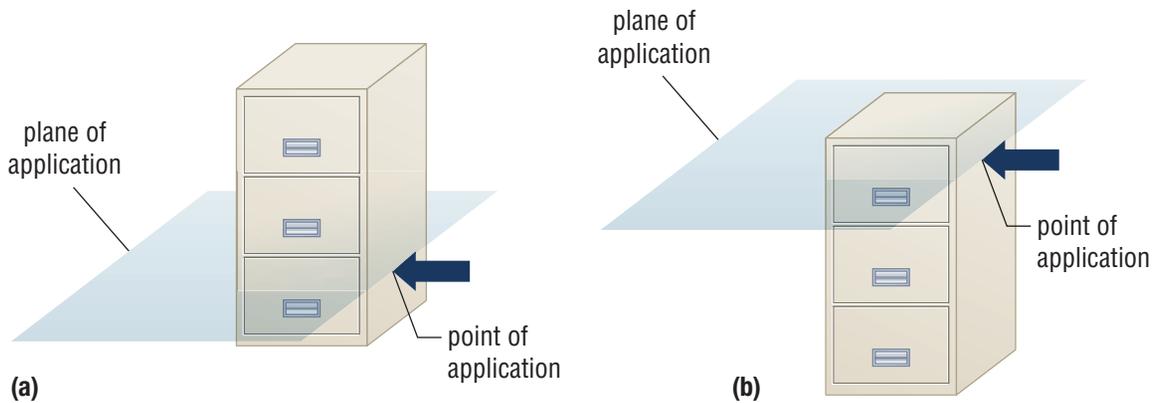


Figure 2 Illustrating point of application and plane of application of force applied to a filing cabinet

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.

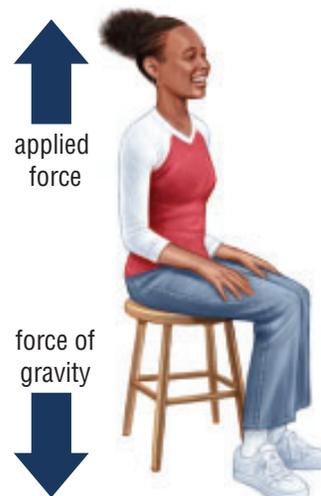


Figure 3 The upward applied force of the stool on the student is equal in magnitude to the downward force of gravity.

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

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.

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.

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



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

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



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

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

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.

Torsion

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.

Shear

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. 



✓ CHECK YOUR LEARNING

- Classify these forces as external or internal:
 - shear
 - gravity
 - torsion
 - the force of the floor on your feet when you are standing
- You are lying in bed.
 - List the internal forces that are acting on the mattress.
 - What is the external force acting on the mattress?
- Explain the difference between the direction of force and the plane of application of force. Use a diagram to help you.

- Figure 8 shows a solid block-shaped structure in four different situations involving applied forces (the arrows). Name the internal forces in each diagram.

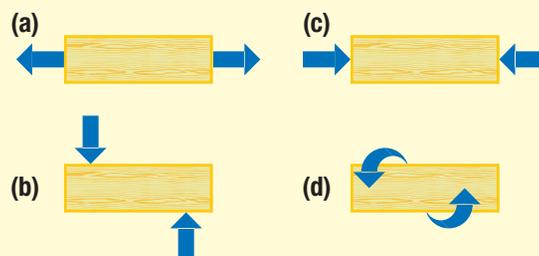


Figure 8