WHAT IS A FORCE?

We can’t see a force; we can only see its effects on things. For example, planets that revolve around the Sun and tectonic plates that collide have forces acting on them. The same applies to a ball rolling on a soccer field or the snow under a skier’s skis. Forces determine the movement, position and shape of everything in the universe.

Forces have two major effects. First, they can cause or change an object’s motion. Think of a ball: you can make it speed up, slow down, change direction or stop entirely. Second, forces can change an object’s shape. Think of plasticine that can be shaped however you want.

A force is an action that can make an object move or change the motion of an object that is already moving. A force can also change an object’s shape.

In this chapter, you will learn about the effects of forces on technical objects. Then, you will look at the types of motion that forces can cause. Finally, you will learn about the parts of a technical object that act as links and guiding controls.

The technological world
The effects of a force are a change of motion and of shape (deformation) of an object. This can involve:

- making a stationary object move;
- accelerating, slowing, stopping or changing the direction of an object already in motion.

### Change of motion

This can involve:

- be elastic (the object changes shape temporarily, then goes back to its original shape);
- be plastic (the object changes shape and stays that way);
- cause a fracture (the object breaks).

### Deformation

It can:

Examples of change of motion and deformation

Here are two examples showing the effects of a force on an object.

By pulling on the handle of the trolley, this person is changing the motion of the boxes by moving them forward.

By pressing on its lid, these two people are causing the suitcase to deform. This deformation is elastic: the suitcase will return to its original shape once it has been emptied.

Forces can affect objects in many different ways.
7.1.2 What are the effects of forces on a technical object?

In this section, we’re going to look more closely at how forces affect a technical object, that is a man-made object. These forces can act on an entire object, or on one or more of its parts.

**Definition**

The effects of forces on a technical object include change of motion (see section 7.2) and deformation of the object. More specifically, a force can change an object’s shape by pulling on it (tension), crushing it (compression), bending it (bending), twisting it (torsion) or cutting it (shearing).

- **Tension** (Also known as “traction.”)
  Caused by forces moving away from the object on which they are acting. They often pull or stretch the object.

- **Compression**
  Caused by forces pushing toward the object on which they are acting. They often crush or compress the object.

- **Bending**
  Caused by forces acting on different parts of an object. They often bend the object.

- **Torsion**
  Caused by forces that twist the object on which they are acting.

- **Shearing**
  Caused by opposing forces acting on nearly the same spot. They often tear apart the object on which they are acting.

**Why do balls bounce?**

Balls bounce because they are elastic. They flatten slightly when they hit the ground. They then push against the ground and return to their original shape. If the ground is hard, this can cause the ball to rise back into the air. A well-inflated ball will bounce better than a softer ball because it can push back harder against the ground. But if the ground is soft, like sand, it will change shape rather than the ball, meaning the ball won’t bounce.
Forces and deformation of objects in everyday life

Here are some examples of the effects described on the previous page. The symbols on the right are the ones used in design plans (see section 8.2) to describe the forces acting on an object.

<table>
<thead>
<tr>
<th>DEFORMATION OF TECHNICAL OBJECTS</th>
<th>EFFECT</th>
<th>ILLUSTRATION AND SYMBOL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TENSION (OR TRACTION)</strong></td>
<td>![Tension Illustration]</td>
<td>![Tension Symbol]</td>
</tr>
<tr>
<td>Elastic bands are often used in stretching exercises. These bands stretch when you pull on their ends. The more tension (or traction) there is, the more the elastic stretches. Tension almost always results in stretching, but sometimes the actual stretch is invisible to the naked eye. For example, when you hang a heavy plant on a hook, the hook stretches. However, the change is so small that we don’t notice it.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **COMPRESSION** | ![Compression Illustration] | ![Compression Symbol] |
| When someone sits on a cushion, they exert a type of force on it. We call that force “compression.” Compression causes the cushion to squish and flatten. Many objects squish when they are compressed, but return to their original shape when the force disappears. That happens with balls and most rubber objects. Other objects change shape permanently. Examples are modelling clay or plasticine. Even when the compression stops, these objects do not return to their original shape. |
Forces can change an object’s shape in many different ways.

<table>
<thead>
<tr>
<th>EFFECT</th>
<th>ILLUSTRATION AND SYMBOL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BENDING</strong></td>
<td></td>
</tr>
<tr>
<td>Forces can cause an object to flex or bend. For example, when you put too many books on a shelf, the shelf bends because the force exerted by the books acts in a different place than the forces exerted by the shelf’s supports. The more books there are, the greater the forces, and the more the shelf bends.</td>
<td><img src="image" alt="Bending Illustration" /></td>
</tr>
<tr>
<td><strong>TORSION</strong></td>
<td></td>
</tr>
<tr>
<td>Every time you wring out a wet cloth, you’re producing torsion. How so? Simply by twisting different parts of the cloth in opposite directions.</td>
<td><img src="image" alt="Torsion Illustration" /></td>
</tr>
<tr>
<td><strong>SHEARING</strong></td>
<td></td>
</tr>
<tr>
<td>When you tear a piece of paper, you’re exerting two forces in opposite directions at nearly the same place. That results in shearing. If you look at the gesture in slow motion, you’ll see that the paper begins to resist the forces, then gives up and tears. Many tools, like scissors, make shearing easier. Each blade of a pair of scissors exerts opposite forces on two points that are parallel and very close to each other.</td>
<td><img src="image" alt="Shearing Illustration" /></td>
</tr>
</tbody>
</table>
1. What is the difference between a force and the effect of a force?
A force is an action on an object. The effect of a force is to cause or alter the motion of an object, or to cause its deformation.

2. In each of the following situations, an object is exerting a force on another object. Indicate whether that force causes a change in motion or a deformation.

   a) The jackhammer is exerting a force on the ground.
      Deformation of the ground (to the point of causing a break).

   b) The washing machine is exerting a force on clothing.
      Change in motion of the clothes.

   c) The knife is exerting force on a pepper.
      Deformation of the pepper (until it breaks).

   d) The stapler is exerting force on a staple.
      Deformation of the staple.

   e) The pump is exerting force on oil.
      Change in motion of oil.

   f) A mixer exerts force on egg whites.
      Deformation of the egg whites.
3. In each of the following situations, an object is being deformed. Indicate which type of deformation it is experiencing (tension, compression, bending, torsion or shearing).

   a) A corkscrew digs into a cork.  Compression.
   b) The corkscrew pulls the cork from the bottle.  Tension.
   c) A spring holds the two parts of a clothespin together.  Compression.
   d) A lawnmower cuts the grass.  Shearing.

4. Name the effect shown in each image.

   a) Setting a mouse-trap.  Torsion.
   b) Trimming a hedge.  Shearing.
   c) Bungee jumping.  Tension.
   d) Grilling a sandwich.  Compression.
   e) Mashing potatoes.  Compression.

5. Can the deformation of an object that’s being acted on by a force always be seen? Explain your answer.

   No. Some deformations are very small. For example, when a force changes the motion of an object, the deformation can be so small that it is invisible to the naked eye.
6. Draw the arrows that represent the forces needed to act on the following objects.

   a) The handles of a bike pump.
   b) A screwdriver.
   c) The chain on a lamp.
   d) The pedals on a bike.

7. What happens when you blow too much air into a birthday balloon beyond its maximum capacity? Explain your answer.

   It pops (the latex breaks) because it has reached the limits of its elasticity and can’t deform any more.
7.2 Types of motion

The arms on a pair of glasses need to fold so they can be stored. When a technical object like that is made, you need to figure out how to make parts move in exactly the right way so they do what you need them to. The parts in technical objects can follow three different types of motion: translational, rotational and helical.

7.2.1 What is translational motion?

A slice of bread that slides down into a toaster before popping back up is experiencing translational motion.

Definition

Translational motion happens when a part or piece of an object moves in a straight line.

Examples of translational motion

Translational motion can occur in a single direction or in two directions.

Unidirectional translation

When a hammer hits a nail, the nail moves in a straight line. It is experiencing translational motion. However, the translation is unidirectional: the nail moves only in one direction.

Bidirectional translation

When you apply a force to a drawer, it slides in a straight line in one of two directions. Therefore, it is experiencing translational motion. More specifically, it is experiencing bidirectional translation because it can move in two different directions (forward and backward).

Translational motion occurs in a straight line. It can happen in one direction or in two directions (back and forth).
7.2.2 **What is rotational motion?**

The wheels on a car rotate.

**DEFINITION**

**Rotational motion** happens when a part or piece of an object rotates around an axis.

**Examples of rotational motion**

Here are two examples of rotational motion.

**Unidirectional rotation**

As a clock ticks, its hands move in the same direction around its axis. This is a unidirectional rotation: the hands rotate in one direction.

**Bidirectional rotation**

When you apply a force to the handle of the hose reel, the device rotates around its axis. That makes it possible to wind and unwind the hose. This is a bidirectional rotation: the reel rotates in two directions.

Rotational motion occurs around an axis. It can occur in one or in two directions.

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**A BRIEF HISTORY OF SCIENCE**

**Gramophones and records**

In September 1887, Émile Berliner, a German immigrant to the United States, invented records. He also invented a machine called the “gramophone”, which was used to play them. Gramophones are predecessors to record players and optical disc drives (CD and DVD players). They have plates on them that are rotated using a crank. Sound is produced through a needle, which vibrates as an etched disc rotates with the plate. In 1899, Berliner started the first record company in Montréal, Canada.
7.2.3 **What is helical motion?**

The word “helical” comes from the Greek word *helix*, meaning “spiral.” Taps that need to rotate several times to be turned on are performing a helical motion.

**DEFINITION**

*Helical motion* occurs when a part or piece of an object revolves around an axis while moving along that axis.

**Examples of helical motion**

Here are two examples of helical motion.

**Unidirectional helical motion**

Some objects, like this football, can experience translational and rotational motion at the same time. Together, the two types of motion create helical motion. With this football, the movement is happening only in one direction. In other words, it is experiencing unidirectional helical motion.

**Bidirectional helical motion**

When a screw is rotated, its spiral threads also cause it to perform a translational motion as it moves into or out of the wood. This means it is performing a bidirectional helical motion.

Helical motion is what happens when translational and rotational motion are combined. As with the other types of motion, it can occur in one or in two directions.

The symbols used to show the types of motion are illustrated on page 238.
1. Name the type of motion (translational, rotational or helical) that the following objects are performing.

a) A kiteboard moving on the water.  
   **Translational.**

b) A cork being pulled from a bottle.  
   **Translational.**

c) A clapperboard operated by a technician.  
   **Rotational.**

2. Name the type of motion (translational, rotational or helical) that the moving parts of each object are experiencing.

   a) The pedals of a bike.  
      **Rotational.**

   b) A laptop screen.  
      **Rotational.**

   c) Skis on a trail.  
      **Translational.**

   d) The propellers on a plane.  
      **Rotational.**

   e) The tray on a DVD player.  
      **Translational.**

   f) A DVD being played.  
      **Rotational.**

3. Name the motion caused by the following forces.

a) Wind pushing against the cyclist’s back.  
   **Translational.**

b) The change in direction caused by the handlebars moving.  
   **Rotational.**

c) Feet pushing against the pedals.  
   **Rotational.**
4. In each box, draw the symbol that represents each object’s motion. Remember to check whether the motion is uni- or bidirectional. Use the following symbols:

<table>
<thead>
<tr>
<th>Unidirectional translation</th>
<th>Bidirectional translation</th>
<th>Unidirectional rotation</th>
<th>Bidirectional rotation</th>
<th>Unidirectional helical motion</th>
<th>Bidirectional helical motion</th>
</tr>
</thead>
</table>

a) The button on a bell.

b) A drill bit.

c) Automatic doors.

d) A door handle.

5. Name the motion shown in each image. In each case, specify whether the motion is uni- or bidirectional.

a) The passengers on a swing ride. Bidirectional helical motion.

b) The head of an electric mixer. Unidirectional rotation.

c) The buttons on a calculator. Bidirectional translation.

The technological world
6. In each box, draw the symbol that represents the motion of the moving parts of each object. Use the symbols from the previous page. Draw a line between the box and the moving part.

a) The handle on the reel of a fishing rod.
   - Bidirectional rotation.

b) The blade of a metal saw.
   - Bidirectional helical motion.

c) The tuning pegs of a guitar.
   - Bi-directional rotation.

d) The line on a fishing rod.
   - Unidirectional translation.
A link is anything that helps connect two or more parts of a technical object together.

**DEFINITION**

A link is anything that helps connect two or more parts of a technical object together.

### Non-removable and removable links

A non-removable link is one that cannot be removed without damaging the pieces that have been combined. They are also sometimes known as “permanent links.”

A removable link is one that can be removed: the linked parts can be separated without damaging the object’s parts. They are sometimes called “non-permanent links.”

### Complete and partial links

Complete links are a type of link that do not allow any movement. They are also known as “stationary links.”

Partial links are a type of link that allow the parts to move. They are also known as “mobile links.”

---

**Why doesn’t glue stick to its container?**

Glue doesn’t stick to its container because it is missing a crucial element: air. Glue is designed to act only when there is lots of air to dry it. That’s why it’s important to make sure your glue container is closed properly.
Examples of links

To choose the best link for a technical object, you need to ask some questions. Is this object meant to stay together, or do you need to be able to take it apart? Will all of the pieces be stationary, or will some of them need to move?

**Non-removable or removable link?**

A link made with glue or nails is generally meant to be permanent. It’s very difficult to separate two pieces of paper that have been glued together. Similarly, it’s very difficult to disassemble a chair that has been nailed together without damaging it. Therefore, these links are non-removable.

If you need to be able to disassemble an object, you should use a removable link. Furniture that’s assembled using screws or nuts and bolts are relatively easy to disassemble. Another example: objects with lids that come off or can be unscrewed are built with removable links.

**Complete or partial link?**

The head and the handle of a hammer have a complete link. The head needs to stay put for the hammer to be safe to use. To make sure that happens, hammer-makers use small pieces of metal called “wedges” (also known as “eyes”) to attach the head and the handle. Glue and nails are often used as complete links.

A partial link allows parts of an object to move. For scissors to cut properly, they need to be able to open and close. The blades are linked using a rivet, which is a small, cylindrical rod. The rivet acts as an axis on which the blades rotate.

The type of link used in an object depends on the object’s intended use.
How to link the parts of a technical object?

When making a technical object, it’s important to connect the pieces using the appropriate links. Here are some common linking components.

NAILS
Nails are often used to assemble pieces of wood together. There are many different types of nails available. The most common type is the round-head nail. They hold permanent joints firmly in place. Finishing nails are often used on objects where appearances are more important. They have no head, so they’re almost invisible once they’re in.

SCREWS
Screws are used in objects that may need to be taken apart. They can also be used to reinforce other links. To prevent wood from splitting when a screw is inserted, a drill is used to pierce a hole beforehand. Screws can also be used in concrete, metal and drywall.

NUTS AND BOLTS
There are many different types of nuts and bolts. They are used in situations where nails and screws won’t work, like when you need to link pieces of thin metal. They are also used to make very sturdy objects. Before inserting a bolt, a hole needs to be drilled in the parts being linked. To prevent the nut from falling off, a locking washer is attached before the bolt is inserted.

RIVETS
Rivets are small, cylindrical objects that are used to permanently attach two pieces together. They are usually made of metal. As with other linking objects, a hole needs to be made in the parts being linked before the rivet can be inserted. Once the rivet is in, a riveter is used to flatten the end of the rivet that doesn’t have a head. This way, the rivet doesn’t fall out and all parts stay firmly attached.

WEDGES
Wedges are triangular pieces of metal. The head of an axe is a wedge that cuts wood by separating it. Small wedges are often inserted into the handles of tools to widen the wood, to attach the handle firmly to the head.
7.3.2 **What is a guiding control?**

Sometimes the moving parts of a technical object need to be controlled so that they only move in certain ways.

**Definition**

A *guiding control* is a device that controls the motion of a technical object’s moving parts. Thus, the parts can only move in a translational, rotational or helical motion.

**Main guiding controls**

Here are the main types of guiding controls. The symbols on the right are the ones used in technical diagrams (see section 8.3).

<table>
<thead>
<tr>
<th>Translational Guiding Control</th>
<th>Illustration and Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>This type of guiding control directs parts that need to travel in a straight line only. Train tracks and the tracks on glass doors are both examples of translational guiding controls.</td>
<td><img src="image" alt="Symbol" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rotational Guiding Control</th>
<th>Illustration and Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>This type of guiding control directs parts as they turn or rotate. Door hinges contain small posts that force the two metallic parts to rotate around them. Similarly, the rivet that holds the blades on a pair of scissors together creates a rotational guiding control.</td>
<td><img src="image" alt="Symbol" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Helical Guiding Control</th>
<th>Illustration and Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Translational and rotational guiding controls can combine to create a helical guiding control, which direct the motion of a part around and along an axis. In a C-clamp, for example, the clamping screw moves up and down as it rotates. The threaded mount inside the clamp guides the screw’s rotational and translational motion.</td>
<td><img src="image" alt="Symbol" /></td>
</tr>
</tbody>
</table>

Guiding controls direct the motion of a technical object’s moving parts.
1. Are the following links removable or non-removable? Explain your answers.
   
   **Sample answers:**
   
   a) The plate on a beam balance.
   Removable. The plate needs to come off so it can be cleaned.

   b) The arm of a microscope.
   Non-removable. The arm needs to stay in place to support the fragile slides and to act as a handle for the microscope.

   c) The handle of a shovel.
   Non-removable. A removable link could be dangerous for the person using the shovel.

2. Write each of the links from the previous question in the correct column below.

<table>
<thead>
<tr>
<th>COMPLETE LINK</th>
<th>PARTIAL LINK</th>
</tr>
</thead>
<tbody>
<tr>
<td>The arm of a microscope.</td>
<td></td>
</tr>
<tr>
<td>The handle of a shovel.</td>
<td></td>
</tr>
<tr>
<td>The plates on a beam balance.</td>
<td></td>
</tr>
</tbody>
</table>

3. Fill in the following table.

<table>
<thead>
<tr>
<th>OBJECT</th>
<th>LINK</th>
<th>GUIDING CONTROL</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) The eraser on the end of a pencil</td>
<td>NON-REMOVABLE</td>
<td>REMOVABLE</td>
</tr>
<tr>
<td>b) A piano lid that can be raised or lowered</td>
<td>NON-REMOVABLE</td>
<td>REMOVABLE</td>
</tr>
<tr>
<td>c) A paper attached to a corkboard with a thumbtack</td>
<td>NON-REMOVABLE</td>
<td>REMOVABLE</td>
</tr>
<tr>
<td>d) A refrigerator door.</td>
<td>NON-REMOVABLE</td>
<td>REMOVABLE</td>
</tr>
</tbody>
</table>
4. Technical objects need their parts to be linked to work properly. Check (√) the boxes that describe the links in each object.

<table>
<thead>
<tr>
<th>OBJECT</th>
<th>LINK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NON-REMOVABLE</td>
</tr>
<tr>
<td>a)</td>
<td>√</td>
</tr>
<tr>
<td>b)</td>
<td>√</td>
</tr>
<tr>
<td>c)</td>
<td>√</td>
</tr>
<tr>
<td>d)</td>
<td></td>
</tr>
<tr>
<td>e)</td>
<td></td>
</tr>
<tr>
<td>f)</td>
<td></td>
</tr>
</tbody>
</table>
5. Check (✓) the appropriate boxes, then draw the symbol for the guiding control beside each object. Use the table on page 243 if you need help.

<table>
<thead>
<tr>
<th>OBJECT</th>
<th>SYMBOL</th>
<th>GUIDING CONTROL</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Mouse Wheel" /></td>
<td><img src="image" alt="Symbol" /></td>
<td>✓</td>
</tr>
<tr>
<td>a) The wheel on a mouse.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><img src="image" alt="Clothesline" /></td>
<td><img src="image" alt="Symbol" /></td>
<td>✓</td>
</tr>
<tr>
<td>b) Clothes on a clothesline.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><img src="image" alt="Toothpaste Cap" /></td>
<td><img src="image" alt="Symbol" /></td>
<td>✓</td>
</tr>
<tr>
<td>c) The cap on a tube of toothpaste.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><img src="image" alt="Mousetrap Spring" /></td>
<td><img src="image" alt="Symbol" /></td>
<td>✓</td>
</tr>
<tr>
<td>d) The spring on a mousetrap.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><img src="image" alt="Office Chair Wheels" /></td>
<td><img src="image" alt="Symbol" /></td>
<td>✓</td>
</tr>
<tr>
<td>e) The wheels on an office chair.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1. What am I?

   a) We are the motions that revolve around an axis.
      **Rotational and helical motions.**

   b) I am the type of deformation that happens when two opposing forces act on
      the same point.
      **Compression.**

   c) I am the motion that happens when two other types of motion combine.
      **Helical motion.**

   d) I am the motion in a straight line.
      **Translational motion.**

2. This photo shows a car moving in a straight line.

   a) In the box, draw the symbol for the forces acting on the car.

   b) In the circle, draw the symbol for the motion of the moving parts (the wheels).

   c) Which motion is being caused by the forces being applied to the vehicle?
      **Translational motion.**

3. Link each situation (on the left) to the deformation caused by forces applied to
   the object (on the right).

   a) Cracking a nut. **Tension**

   b) Cutting a thread. **Compression**

   c) Wringing out a cloth. **Shearing**

   d) Covering a container in plastic wrap. **Torsion**
4. Draw the motion symbols for each moving part of the forklift in the boxes.

5. Use this image of a cheese grater to answer the questions on the following page.
a) Fill in the following table to show the forces being applied and the effects they produce.

<table>
<thead>
<tr>
<th>PART</th>
<th>FORCE SYMBOL</th>
<th>EFFECT PRODUCED BY THE FORCE (DEFORMATION OR MOVEMENT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lever</td>
<td><img src="image" alt="Compression" /></td>
<td>Compression of the cheese against the blades.</td>
</tr>
<tr>
<td>Crank</td>
<td><img src="image" alt="Rotation" /></td>
<td>Rotation of the blades and barrel.</td>
</tr>
<tr>
<td>Blades</td>
<td><img src="image" alt="Shearing" /></td>
<td>Shearing of the cheese.</td>
</tr>
</tbody>
</table>

b) Fill in the following table to describe the types of links in the grater.

<table>
<thead>
<tr>
<th>LINKED PARTS</th>
<th>TYPE OF LINK</th>
</tr>
</thead>
<tbody>
<tr>
<td>The rivet connects the lever and the handle.</td>
<td>Non-removable and partial.</td>
</tr>
<tr>
<td>The crank is attached to the barrel by a screw.</td>
<td>Removable and complete.</td>
</tr>
<tr>
<td>The blades are inserted into the barrel.</td>
<td>Removable and complete.</td>
</tr>
</tbody>
</table>

c) Name the two parts that serve as guiding controls and name the type of guiding that they do.
- **The rivet**: it guides the rotation of the lever.
- **The barrel**: it guides the rotation of the blades.

d) Name the three moving parts and the type of motion that they perform.
- **The lever**: it rotates.
- **The barrel**: it rotates.
- **The blades**: they rotate.