11.1 Stability of Structures

Imagine you are standing on a public bus (Figure 1). The bus is speeding up and slowing down. You probably would feel more stable with your feet flat on the floor and spread apart. Why is this so?

Figure 1 How do you keep from falling when you are standing on a moving bus?

LINKING TO LITERACY

Reading for Meaning

When reading science texts, look for explanations or definitions of difficult or scientific words as you read. Sometimes, explanations are in the main text; sometimes they will be given in a sidebar or caption under a picture. Locate two definitions that are given on this page. How do these help you to better understand your reading?

Your body is a structure that is able to maintain its position when external forces try to push or pull it out of balance. **Stability** is the ability of a structure to maintain, or regain, a stable (balanced) position when external forces act on it. When engineers design structures, they must make sure that the structures are stable. Stable structures are safer because they do not easily topple over or fall down. Almost all structures, from small toys to huge buildings, are designed to be stable. Some toys and rides at amusement parks are designed to appear to be unstable to make them seem exciting and unpredictable.

stability: the ability of a structure to remain in or return to a stable, balanced position when forces act on it

An important characteristic of any structure is its centre of gravity. Finding a structure's centre of gravity helps designers determine its stability. **Centre of gravity** is the point around which a structure's mass is equally balanced in all directions. The centre of gravity is also the point at which the entire mass of an object seems to be concentrated.

centre of gravity: the point around which an object's mass is equally balanced in all directions; the point where the mass seems to be concentrated

TRY THIS: Finding the Centre of Gravity

SKILLS MENU: predicting, analyzing, evaluating, communicating

SKILLS HANDBOOK 2.B.3.

Locating the centre of gravity in an object is complicated. However, it is possible to find the horizontal balance point of long, thin objects. The horizontal balance point is very close to an object's centre of gravity. In this activity, you will predict, locate, and test the horizontal balance point of various objects.

Equipment and Materials: metre stick; tape; large rubber stopper; various long, thin, rigid objects; scissors; cardboard; pencil; 216 × 279 mm (8½ × 11 in.) piece of scrap paper; tape; pin; metal washer; string

Part A

1. Hold a metre stick by placing your index fingers near the two ends of the stick (Figure 2). *Slowly* slide your fingers toward each other until they meet. The location where they meet is the horizontal balance point of the metre stick. Record your observations.

Figure 2 Step 1

2. Tape a large rubber stopper at one end of a metre stick. With one hand, hold the metre stick with the rubber stopper to get a sense of how the metre stick's mass is distributed. Predict the location of the horizontal balance point of the metre stick with the stopper attached. Record your prediction. Test your prediction: repeat step 1 with the metre stick–stopper combination. Record your observations.
3. Predict and then find the horizontal balance point of other long, thin, rigid objects. Record your observations.

Part B

4. Work with a partner for Part B. Carefully cut a piece of cardboard into an L-shape. Tape a piece of scrap paper onto the shape so that the paper covers the shape, and also covers the space where the cardboard was cut out (Figure 3). Predict the location of the horizontal balance point of the shape, and mark it with a pencil.

Be very careful when using sharp objects.

Figure 3 Step 4

5. With a pin, make a hole near the edge of the shape. Make the hole slightly larger than the pin so that when the object is held up by the pin, the shape can rotate.
6. Make a plumb line by tying a washer to the end of a piece of string. Hold the shape by the pin, and hang the plumb line from the pin (Figure 4). Using a pencil, trace the line made by the hanging plumb line on the shape. Label this line AB.

Figure 4 Step 6

7. Make a second hole in the shape. Repeat step 6, but this time, label the new plumb line CD (Figure 5).

Figure 5 Step 7

8. Identify the point where line CD crosses line AB. Label this point X. Point X is very close to the shape's centre of gravity. Try to balance the shape horizontally by placing the blunt end of a pencil on point X. Will the shape balance on point X? Record your observations.
9. Repeat steps 4 to 8 with other unusual shapes cut out of cardboard. Record your observations.

A. Evaluate each of the predictions you made in the activity.

B. Write your own definition for "horizontal balance point."

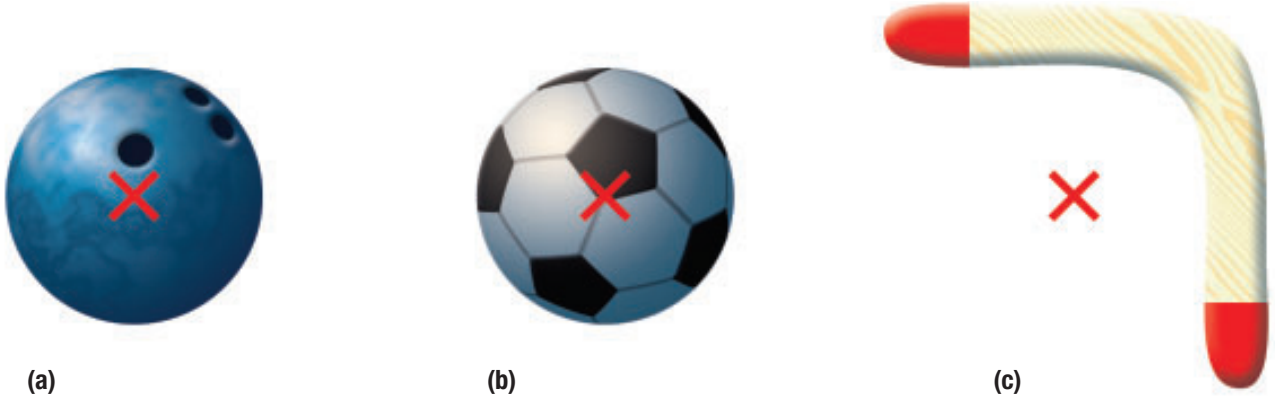
C. Can the horizontal balance point of an object be outside the object itself? How do you know?

The Centre of Gravity of Common Structures

All structures have a centre of gravity. In the previous Try This activity, you used several different methods for locating an object's horizontal balance point. (Remember, the horizontal balance point is close to the centre of gravity.) An object's centre of gravity is usually located deep inside the object, not on its surface. For example, when you are standing upright, your centre of gravity is located deep inside your body, just below your belly button (Figure 6).

Figure 6 Centre of gravity of the human body when standing

However, your body's centre of gravity changes every time you move or bend your body into different shapes. The centre of gravity of an object depends on the shape of the object and how its mass is distributed. In some cases, the centre of gravity is outside the object itself (Figure 7).



(a) (b) (c)

Figure 7 The centre of gravity of various objects
(a) middle of a solid ball
(b) middle of a hollow ball
(c) outside of a boomerang

TRY THIS: Centre of Gravity and Stability

SKILLS MENU: predicting, analyzing, evaluating, communicating

If you bend forward and let your arms hang in front of you, you may feel as though you are going to fall forward. Your body feels less stable in this position because its centre of gravity has moved in front of the centre of its base (your feet). In this activity, you will learn how a structure's (your body's) stability relates to its centre of gravity and its support base.

Equipment and Materials: object that can be lifted with one hand (for example, a dumbbell or textbook)

If you have any problems in lifting objects or bending over, be careful in deciding which steps to follow. These activities should be performed with a partner, with one partner acting as a spotter. Work on a gym mat.

1. Refer to Figure 8. The region enclosed by the footprints is shaded and represents the support base of a person standing upright.

(a) Stand upright with your arms at your sides and your feet about 50 cm apart. Have your partner look at you from a place in front of position F. Above which point, A to G, does your body's centre of gravity feel like it is positioned?

(b) Slowly raise your right foot off the floor. Above which point, A to G, does your body's centre of gravity feel like it is positioned now?

(c) Stand erect with your feet together. Hold a heavy (but not too heavy) object in one hand near your stomach. With your partner still in front of position F, determine what happens to your body, especially to your hips, as you move the object out to one side (toward either A or E). Where does your centre of gravity appear to lie now?

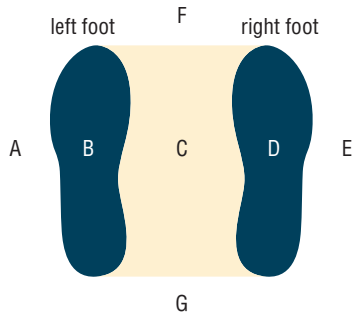


Figure 8

2. (a) Stand sideways against a wall with the side of one foot pressed against the wall. *Slowly* raise the other foot off the floor. Describe what happens. Where is your body's centre of gravity relative to your support base?

(b) Stand with your back to the wall and your heels pressed against the wall. *Slowly* bend over to try to touch your toes. Describe what happens. Where is your body's centre of gravity relative to your support base?

A. Which provides greater stability, a high centre of gravity or a low one? Support your answer with an example.

B. Which provides greater stability, a small support base or a large one? What evidence supports your answer?

C. Explain the observations you made in step 2. (Hint: Think of how your centre of gravity moved with each position that you attempted.)

Conditions for Greatest Stability

Consider the sports car and the truck in Figure 9. The truck is more likely to tip over. The car has greater stability because of two features: it has a low centre of gravity, and it has a wide support base (when compared to its height). Objects with a low centre of gravity and a wide support base tend to be stable.

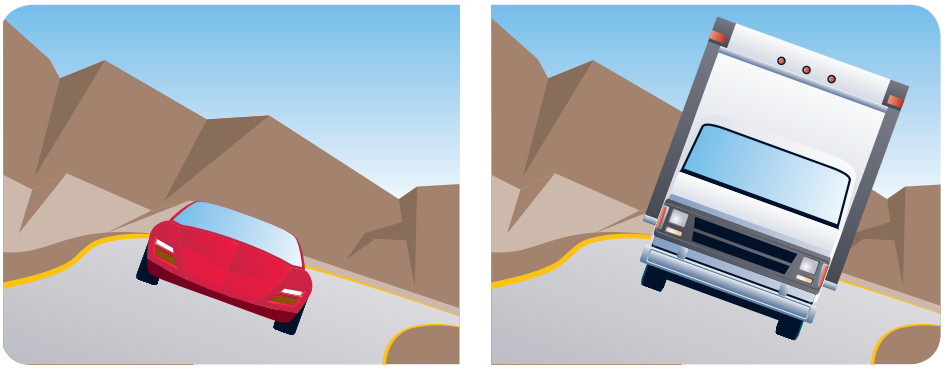


Figure 9 Which vehicle is more stable?

To maintain stability, the centre of gravity must lie directly over the support base. Stability decreases as the centre of gravity rises. If the centre of gravity rises higher and is no longer above the support base, the object will fall over. This is shown in Figure 10 for a truck going around a banked curve with different-sized loads. The truck on the far right will tip because its centre of gravity (the red X) lies outside of the two wheels.

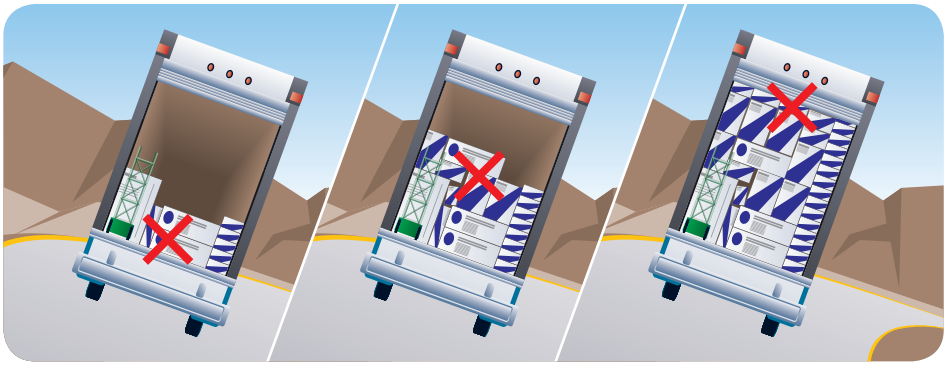


Figure 10 The truck is unstable when its centre of gravity does not lie above its support base.

LINKING TO LITERACY

Compare and Contrast

Good readers gain meaning from texts by analyzing the information they read. One way to analyze is to look for ways that information is the same or different. On this page, the author gives four examples of how stability works: trucks, boats, a bird, and an acrobat.

After you read this page, take a moment to reflect and analyze what you have read. How are these examples the same? How are they different?

Stability is also important for ships, boats, and canoes. Canoeists know how important it is to maintain a low centre of gravity. Standing in a canoe is dangerous. It raises the centre of gravity, and the canoe could easily tip over.

Examples of stability are also found in nature. The loon is a bird that is well adapted to water. The loon's feet help it to dive and swim quickly. However, on land, the loon is very awkward. Its centre of gravity lies ahead of its feet. The loon has to lean backward as it walks forward.

Figure 11 The long pole helps lower the acrobat's centre of gravity.

Thinking about how your own body reacts to external forces helps you to understand other structures. When you carry a backpack on your back, hold a suitcase by your side, or stand on your toes, your body has to adjust to help you keep stable. An acrobat walking on a tightrope applies a similar principle. The acrobat carries a downward curving pole that is heavy at both ends (Figure 11). The pole helps to lower the centre of gravity, and that means greater stability.

Unit Task How will you use what you learned about centre of gravity and stability when designing your playground equipment?

CHECK YOUR LEARNING

1. Describe how you would find the approximate centre of gravity of
   - **(a)** a golf club
   - **(b)** a framed painting
   - **(c)** a coat hanger
   - **(d)** a tennis racquet
2. State the location of the centre of gravity of
   - **(a)** a golf ball
   - **(b)** a bagel
3. What two features of an object provide good stability?
4. State the conditions needed for stability.
5. Which is more stable? Explain why in each case.
   - **(a)** a turtle or a giraffe
   - **(b)** the CN Tower or your school building