3•4 Connecting Motion with Forces

Science Words

force
balanced forces
net force
inertia
friction

Objectives

- Recognize different examples of forces.
- Identify cause-and-effect relationships between force and changes in velocity.
- Give examples of the effects of inertia.
- State Newton's first law of motion.

Figure 3-13
The force exerted by the bat sends the ball flying.

What is a force?

Push a door open. Stretch a rubber band. Squeeze a piece of clay. Slide a book across a table. In each case, you are applying a force. A **force** is a push or a pull one body exerts on another. Sometimes, the effects of a force are obvious, as when a moving car crashes into a stationary object, such as a tree. Other forces aren't as noticeable. Can you feel the force the floor exerts on your feet?

List all the forces you might exert or encounter in a typical day. Think about actions such as pushing, pulling, stretching, squeezing, bending, and falling.

Effects of Forces on Objects

In your list, what happens to the objects that have forces exerted on them? If an object is moving, does the force change the object's velocity? Think of a swinging bat hitting a softball, as in **Figure 3-13.** The ball's velocity certainly changes upon impact.

Balanced Forces

Force does not always change velocity. **Figure 3-14** illustrates a game of tug-of-war with a dog. You plant yourself firmly and lean back to push against the ground, causing the ground to push back on you. Your dog does the same. If you don't move forward or backward, the force of the dog pulling you forward must be balancing the force of the ground pushing you back. Forces on an object that are equal in size and opposite in direction are called **balanced forces.**

Unbalanced Forces

Now what happens if your feet hit a slippery spot on the ground? Your feet slip, and the ground can't exert as much force back on you. The forces of the dog pulling you forward and the ground pushing you back become unbalanced, and there is a net force on you. A **net force** on an object *always* changes the velocity of the object. When the dog pulls you forward with more force than the ground pushes back on you, you accelerate in the direction of the greater force.

Remember that velocity involves both speed and direction. A net force acting on an object will change its speed, direction, or both. In the tug-of-war, the net force on you causes both your speed and direction to change.

Figure 3-14

When the forces on the girl are balanced, she does not move. *What happens if the forces on her become unbalanced?*

Inertia and Mass

Picture a hockey puck sliding across the ice as in **Figure 3-15.** Its velocity hardly changes until it hits something, such as the wall, the net, or a player's stick. The velocity of the puck is constant, and its acceleration is zero until it hits something that alters its speed or direction.

The sliding puck demonstrates the property of inertia. **Inertia** is the tendency of an object to resist any change in its motion. If an object is moving, it will keep moving at the same speed and in the same direction unless an unbalanced force acts on it. In other words, the velocity of the object remains constant unless a force changes it. If an object is at rest, it tends to remain at rest. Its velocity is zero unless a force makes it move.

Would you expect that a bowling ball would have the same inertia as a table-tennis ball? Why would there be a difference? The more mass an object has, the greater its inertia is. Recall that mass is the

Figure 3-15

The velocity and acceleration of a hockey puck are constantly changing during a game.

USING TECHNOLOGY

Air Bags

Seat belts are designed to reduce the effect of inertia in a crash by holding the passengers in place. However, in a high-speed crash, belts provide limited protection to the head and upper body. These parts of the body can be protected by air bags, which provide an instantaneous cushion for the head and upper body at the time of impact.

Air bags are designed to be used in addition to seat belts. An air-bag system consists of one or more crash sensors, an ignitor and gas generator, and an inflatable nylon bag. The nylon bag for the driver is stored in the steering wheel, and the bag for the front-seat passenger is stored inside the dashboard. If a car hits something with sufficient force (speeds in excess of 15 to 20 km/h), impact sensors trigger the flow of electric current to an ignitor. The ignitor causes an explosive chemical reaction to occur, producing harmless nitrogen gas. The nitrogen gas propels the air bag from its storage compartment just in time to absorb the inertia of the occupants. The bag then immediately deflates so it will not interfere with the driver.

Think Critically: Under what crash conditions would an air bag offer little or no protection?

Car Air Bags

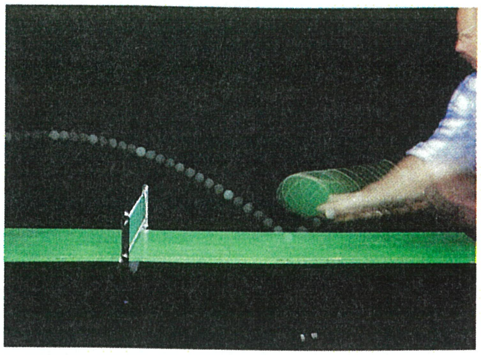

Figure 3-16

Besides the paddle, what else changes the ball's velocity?

amount of matter in an object, and a bowling ball certainly contains more matter than a table-tennis ball. So the bowling ball would have greater inertia than the table-tennis ball. You wouldn't change the velocity of a bowling ball very much by swatting it with a paddle, but you could easily change the velocity of the table-tennis ball in **Figure 3-16.** Because the bowling ball has greater inertia, a much greater force would be needed to change its velocity.

Newton's First Law

Forces change the motion of an object in very specific ways—so specific that Sir Isaac Newton (1642-1727) was able to state laws that describe the effects of forces.

Newton's first law of motion is that an object moving at a constant velocity keeps moving at that velocity unless a net force acts on it. If an object is at rest, it stays at rest unless a net force acts on it. Does this sound familiar? It is the same as the earlier discussion of inertia. Thus, you'll understand why this law is sometimes called the *law of inertia*. You've probably seen—and felt—this law at work without even knowing it. In **Figure 3-17**, you can see this law in action.

MiniLAB

How does friction act as a force?

Procedure

1. Place a sheet of plain white paper near the edge of a flat surface, then set a 100-g mass on the paper about 7 cm from the far end of the paper.
2. Grip the end of the paper near the table's edge and give it a quick, smooth, downward yank. What happens?
3. Replace the paper with a sheet of coarse sandpaper, rough side up, and repeat the procedure. Observe what happens to the mass.

Analysis

1. How do you interpret the different results?
2. How can Newton's first law help explain your observations?

Figure 3-17

You can observe many common examples of Newton's first law in action.

A The young man is pushing the hand truck at a constant velocity. The boxes are also moving at the same constant velocity. There is no net force acting on either the hand truck or the boxes.

B The hand truck bumps into the curb and stops. However, the boxes keep moving forward even though no one has pushed them. Their inertia keeps them moving forward. The boxes also begin to fall because the force of gravity pulls them downward.

C The boxes finally come to rest on the ground. *Are the forces acting on them balanced or unbalanced?*

Friction

You've just learned that inertia causes an object that is moving at constant velocity to keep moving at that velocity unless a net force acts on it. But you know that if you slide a book across a long table, it eventually slows down and stops. Why does it stop?

An unseen force is acting between the book and the table. The force is friction. **Friction** is the force that opposes motion between two surfaces that are touching each other. Would you expect more friction between an oily floor and a slick, leather shoe sole or between a rough sidewalk and the bottom of a tennis shoe? The amount of friction depends on two factors—the kinds of surfaces and the force pressing the surfaces together.

Figure 3-18

Soccer requires players to run, jump, pivot, and kick. *How is friction helping this soccer player?*

Life Without Friction

If there were no friction, your life would be much different. You wouldn't be able to walk or hold things between your fingers. Your shoes would fall off. Friction between the soles of your shoes and the floor makes it possible for you to walk. You can hold something with your fingers because of friction. Shoelaces remain tied because of friction. **Figure 3-18** shows the effect of friction on a soccer player.

As you complete this section, you should be more aware that force and motion are part of everything you do and everything that happens around you.

Section Wrap-up

Review

1. Before dancing on a smooth wooden floor, ballet dancers sometimes put a sticky powder called rosin on their shoe soles. Why? What force are they taking advantage of?
2. Explain which has greater inertia, a speeding car or a jet airplane sitting on a runway.
3. **Think Critically:** Think of and describe three examples from sports in which a force changes the velocity of an object or a person.

Skill Builder

Recognizing Cause and Effect

Explain what happens to your body in terms of inertia, friction, and forces when you slip and fall on an icy sidewalk. If you need help, refer to Recognizing Cause and Effect in the **Skill Handbook.**

Science Journal

Inertia plays an important role in most sports. In your Science Journal, write a paragraph describing the role of inertia in your favorite sport.