section 3

* Annotated *

Motion and Forces

Reading Guide

What You'll Learn

- **Explain** how force and motion are related.
- **Describe** what inertia is and how it is related to Newton's first law of motion.
- **Identify** the forces and motion that are present during a car crash.

Why It's Important

Force and motion are directly linked—without force, you cannot have motion.

Review Vocabulary

scientific law: statement about something that happens in nature that seems to be true all the time

New Vocabulary

- force
- net force
- balanced force
- inertia

What is force?

Passing a basketball to a team member or kicking a soccer ball into the goal are examples of applying force to an object. A **force** is a push or pull. In both examples, the applied force changes the movement of the ball. Sometimes it is obvious that a force has been applied. But other forces aren't as noticeable. For instance, are you conscious of the force the floor exerts on your feet? Can you feel the force of the atmosphere pushing against your body or gravity pulling on your body? Think about all the forces you exert in a day. Every push, pull, stretch, or bend results in a force being applied to an object.

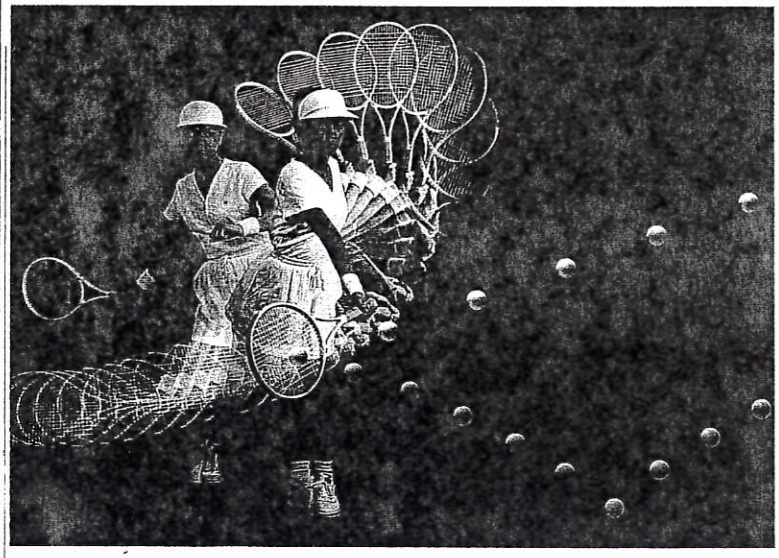
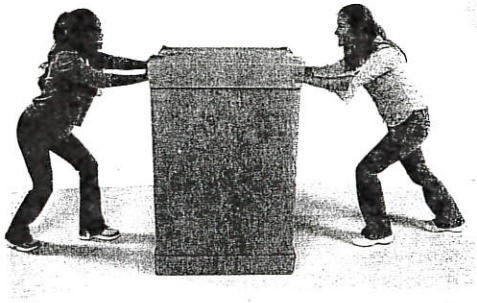


Figure 15 This ball is hit with a force. The racket strikes the ball with a force in the opposite direction of its motion. As a result, the ball changes the direction it is moving.

Changing Motion What happens to the motion of an object when you exert a force on it? A force can cause the motion of an object to change. Think of hitting a ball with a racket, as in **Figure 15.** The racket strikes the ball with a force that causes the ball to stop and then move in the opposite direction. If you have played billiards, you know that you can force a ball at rest to roll into a pocket by striking it with another ball. The force of the moving ball causes the ball at rest to move in the direction of the force. In these cases, the velocities of the ball and the billiard ball were changed by a force.

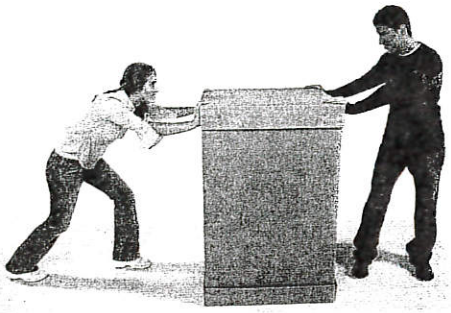
Figure 16 Forces can be balanced and unbalanced.



→ + ← = 0

Net Force = 0

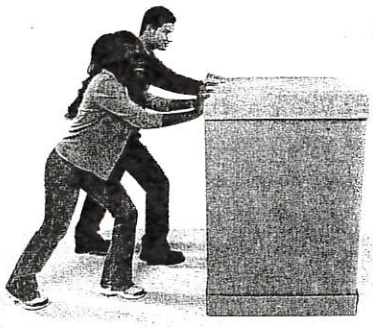
A These students are pushing on the box with an equal force but in opposite directions. Because the forces are balanced, the box does not move.



→ + ← = →

Net Force = →

B These students are pushing on the box with unequal forces in opposite directions. The box will be moved in the direction of the larger force.



→ + → = →

Net Force = →

C These students are pushing on the box in the same direction. The combined forces will cause the box to move.

Balanced Forces Force does not always change velocity. In **Figure 16A,** two students are pushing on opposite sides of a box. Both students are pushing with an equal force but in opposite directions. When two or more forces act on an object at the same time, the forces combine to form the **net force.** The net force on the box in **Figure 16A** is zero because the two forces cancel each other. Forces on an object that are equal in size and opposite in direction are called **balanced forces.**

Unbalanced Forces Another example of how forces combine is shown in **Figure 16B.** When two students are pushing with unequal forces in opposite directions, a net force occurs in the direction of the larger force. In other words, the student who pushes with a greater force will cause the box to move in the direction of the force. The net force that moves the box will be the difference between the two forces because they are in opposite directions. They are considered to be unbalanced forces.

In **Figure 16C,** the students are pushing on the box in the same direction. These forces are combined, or added together, because they are exerted on the box in the same direction. The net force that acts on this box is found by adding the two forces together.

Reading Check *Give another example of an unbalanced force.*

Think of an object that's moving!

ScienceOnline

Topic: Forces and Fault Lines

Visit [illegible] for Web links to information about the unbalanced forces that occur along Earth's fault lines.

Activity Use inexpensive materials such as bars of soap to model the forces and movements along the fault lines. Share your models and demonstrations with your class.

Mini LAB

Observing Inertia

Procedure

1. Create an inclined plane between 25° and 50° using a **board** and **textbooks.** Place a **stop block** (brick or other heavy object) at the end of the plane.
2. Place a **small object** in a **cart** and allow both to roll down the plane. Record the results in your Science Journal.
3. Secure the object in the cart with **rubber bands** (safety belts). Allow both to roll down the plane again. Record the results.

Analysis

1. Identify the forces acting on the object in both runs.
2. Explain why it is important to wear safety belts in a car.

Try at Home

Inertia and Mass

The dirt bike in **Figure 17** is sliding on the track. This sliding bike demonstrates the property of inertia. **Inertia** (ih NUR shuh) is the tendency of an object to resist any change in its motion. If an object is moving, it will have uniform motion. It will keep moving at the same speed and in the same direction unless an unbalanced force acts on it. 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.

Does a bowling ball have the same inertia as a table-tennis ball? Why is there a difference? You couldn't change the motion of a bowling ball much by swatting it with a table-tennis paddle. However, you easily could change the motion of the table-tennis ball. A greater force would be needed to change the motion of the bowling ball because it has greater inertia. Why is this? Recall that mass is the amount of matter in an object, and a bowling ball has more mass than a table-tennis ball does. The inertia of an object is related to its mass. The greater the mass of an object is, the greater its inertia.

Newton's Laws of Motion Forces change the motion of an object in specific ways. The British scientist Sir Isaac Newton (1642–1727) was able to state rules that describe the effects of forces on the motion of objects. These rules are known as Newton's laws of motion. They apply to the motion of all objects you encounter every day such as cars and bicycles, as well as the motion of planets around the Sun.

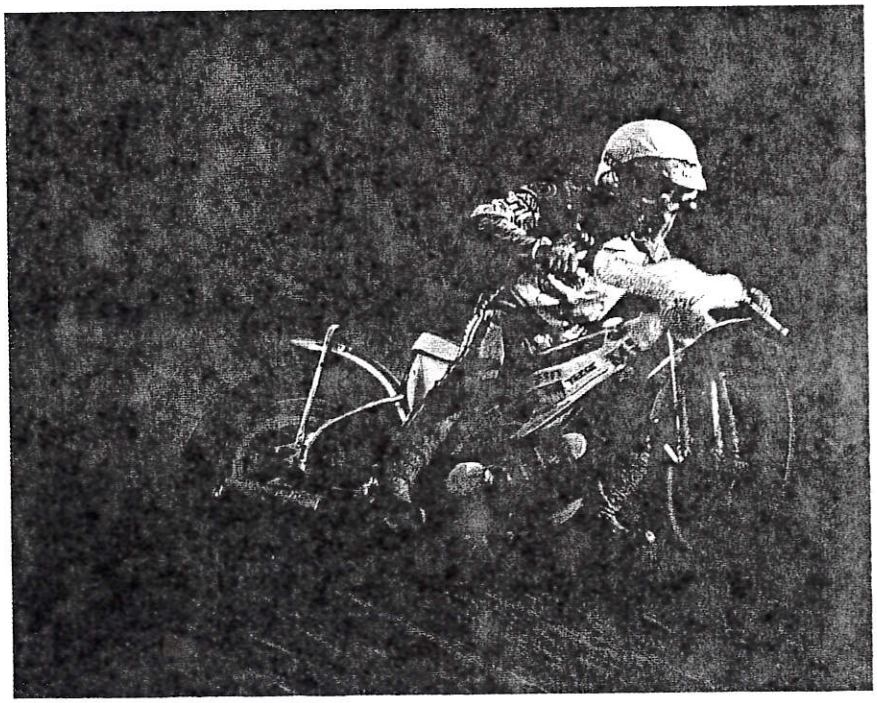


Figure 17 This racer is skidding because of inertia. The bike tends to move in a straight line with constant speed despite the efforts of the rider to steer the bike around the curve.

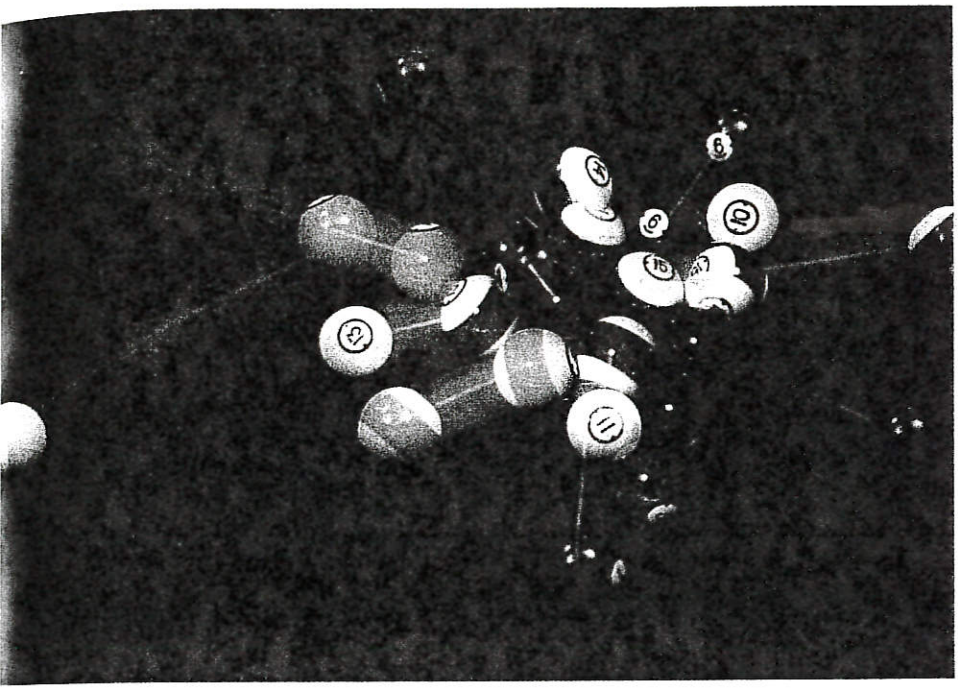


Figure 18 The inertia of the billiard balls causes them to remain at rest until a force is exerted on them by the cue ball.

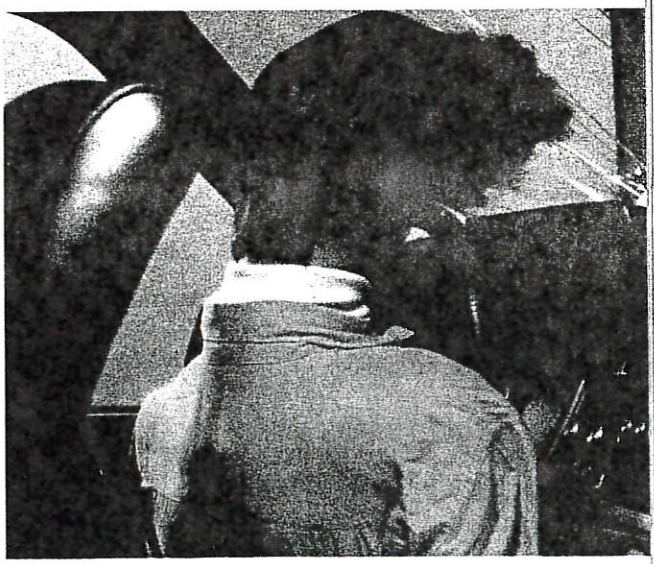
Newton's First Law of Motion Newton's first law of motion states that an object moving at a constant velocity keeps moving at that velocity unless an unbalanced net force acts on it. If an object is at rest, it stays at rest unless an unbalanced net force acts on it. Does this sound familiar? It is the same as the earlier discussion of inertia. This law is sometimes called the law of inertia. You probably have seen and felt this law at work without even knowing it. **Figure 18** shows a billiard ball striking the other balls in the opening shot. What are the forces involved when the cue ball strikes the other balls? Are the forces balanced or unbalanced? How does this demonstrate the law of inertia?

Reading Check *What is Newton's first law of motion?*

Figure 19 The crash dummy is not restrained in this low-speed crash. Inertia causes the dummy to slam into the steering wheel. **Explain** *how safety belts can help keep passengers from being seriously injured.*

What happens in a crash?

The law of inertia can explain what happens in a car crash. When a car traveling about 50 km/h collides head-on with something solid, the car crumples, slows down, and stops within approximately 0.1 s. Any passenger not wearing a safety belt continues to move forward at the same speed the car was traveling. Within about 0.02 s (1/50 of a second) after the car stops, unbelted passengers slam into the dashboard, steering wheel, windshield, or the backs of the front seats, as in **Figure 19.** They are traveling at the car's original speed of 50 km/h—about the same speed they would reach falling from a three-story building.



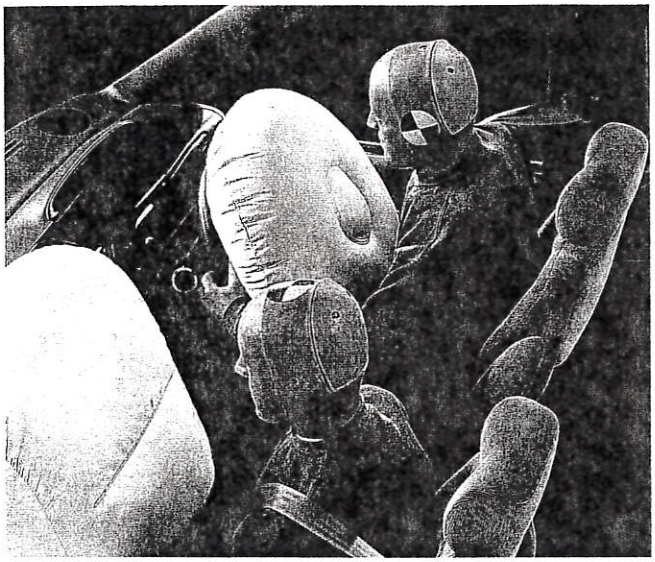


Figure 20 These crash dummies were restrained safely with safety belts in this low-speed crash. Usually humans would have fewer injuries if they were restrained safely during an accident.

Safety Belts The crash dummy wearing a safety belt in **Figure 20** is attached to the car and slows down as the car slows down. The force needed to slow a person from 50 km/h to zero in 0.1 s is equal to 14 times the force that gravity exerts on the person. The belt loosens a little as it restrains the person, increasing the time it takes to slow the person down. This reduces the force exerted on the person. The safety belt also prevents the person from being thrown out of the car. Car-safety experts say that about half the people who die in car crashes would survive if they wore safety belts. Thousands of others would suffer fewer serious injuries.

Air bags also reduce injuries in car crashes by providing a cushion that reduces the force on the car's occupants. When impact occurs, a chemical reaction occurs in the air bag that produces nitrogen gas. The air bag expands rapidly and then deflates just as quickly as the nitrogen gas escapes out of tiny holes in the bag. The entire process is completed in about 0.04 s.

section 3 review

Summary

What is Force?

- A force is a push or a pull on an object.
- The net force on an object is the combination of all the forces acting on the object.
- When the forces on an object are balanced, the net force on the object is zero.
- Unbalanced forces cause the motion of objects to change.

Inertia and Newton's First Law of Motion

- The inertia of an object is the tendency of an object to resist a change in motion.
- The larger the mass of an object, the greater its inertia.
- Newton's first law of motion states that the motion of an object at rest or moving with constant velocity will not change unless an unbalanced net force acts on the object.
- In a car crash, inertia causes an unrestrained passenger to continue moving at the speed of the car before the crash.

Self Check

1. **Infer** whether the inertia of an object changes as the object's velocity changes.
2. **Explain** whether or not there must be an unbalanced net force acting on any moving object.
3. **Explain** Can there be forces acting on an object if the object is at rest?
4. **Infer** the net force on a refrigerator if you push on the refrigerator and it doesn't move.
5. **Think Critically** Describe three situations in which a force changes the velocity of an object.

Applying Math

6. **Calculate Net Force** Two students push on a box in the same direction, and one pushes in the opposite direction. What is the net force on the box if each pushes with a force of 50 N?
7. **Calculate Acceleration** The downward force of gravity and the upward force of air resistance on a ball are both 5 N. What is the ball's acceleration?