CHAPTER 12  Force and Newton’s Laws

Force

A soccer ball sits on the ground, motionless, until you kick it. Your science book sits on the table until you pick it up. If you hold your book above the ground, then let it go, gravity pulls it to the floor. In every one of these cases, the motion of the ball or book was changed by something pushing or pulling on it. An object will speed up, slow down, or turn only if something is pushing or pulling on it.

A force is a push or a pull. Examples of forces are shown in Figure 1.

Think about throwing a ball. Your hand exerts a force on the ball, and the ball accelerates forward until it leaves your hand. After the ball leaves your hand, the force of gravity causes its path to curve downward. When the ball hits the ground, the ground exerts a force, stopping the ball.

A force can be exerted in different ways. For instance, a paper clip can be moved by the force a magnet exerts, the pull of Earth’s gravity, or the force you exert when you pick it up. These are all examples of forces acting on the paper clip.

Newton’s First Law

Figure 1  A force is a push or a pull.

This golf club exerts a force by pushing on the golf ball.

The magnet on the crane pulls the pieces of scrap metal upward.
Combining Forces More than one force can act on an object at the same time. If you hold a paper clip near a magnet, you, the magnet, and gravity all exert forces on the paper clip. The combination of all the forces acting on an object is the net force. When more than one force is acting on an object, the net force determines the motion of the object. In this example, the paper clip is not moving, so the net force is zero.

How do forces combine to form the net force? If the forces are in the same direction, they add together to form the net force. If two forces are in opposite directions, then the net force is the difference between the two forces, and it is in the direction of the larger force.

Balanced and Unbalanced Forces A force can act on an object without causing it to accelerate if other forces cancel the push or pull of the force. Look at Figure 2. If you and your friend push on a door with the same force in opposite directions, the door does not move. Because you both exert forces of the same size in opposite directions on the door, the two forces cancel each other. Two or more forces exerted on an object are balanced forces if their effects cancel each other and they do not cause a change in the object’s motion. If the forces on an object are balanced, the net force is zero. If the forces are unbalanced forces, their effects don’t cancel each other. Any time the forces acting on an object are unbalanced, the net force is not zero and the motion of the object changes.

Biomechanics Whether you run, jump, or sit, forces are being exerted on different parts of your body. Biomechanics is the study of how the body exerts forces and how it is affected by forces acting on it. Research how biomechanics has been used to reduce job-related injuries. Write a paragraph on what you’ve learned in your Science Journal.
Newton’s First Law of Motion

If you stand on a skateboard and someone gives you a push, then you and your skateboard will start moving. You will begin to move when the force was applied. An object at rest—like you on your skateboard—remains at rest unless an unbalanced force acts on it and causes it to move.

Because a force had to be applied to make you move when you and your skateboard were at rest, you might think that a force has to be applied continually to keep an object moving. Surprisingly, this is not the case. An object can be moving even if the net force acting on it is zero.

The Italian scientist Galileo Galilei, who lived from 1564 to 1642, was one of the first to understand that a force doesn’t need to be constantly applied to an object to keep it moving. Galileo’s ideas helped Isaac Newton to better understand the nature of motion. Newton, who lived from 1642 to 1727, explained the motion of objects in three rules called Newton’s laws of motion.

Newton’s first law of motion describes how an object moves when the net force acting on it is zero. According to Newton’s first law of motion, if the net force acting on an object is zero, the object remains at rest, or if the object is already moving, continues to move in a straight line with constant speed.

Friction

Galileo realized the motion of an object doesn’t change until an unbalanced force acts on it. Every day you see moving objects come to a stop. The force that brings nearly everything to a stop is friction, which is the force that acts to resist sliding between two touching surfaces, as shown in Figure 3. Friction is why you never see objects moving with constant velocity unless a net force is applied. Friction is the force that eventually brings your skateboard to a stop unless you keep pushing on it. Friction also acts on objects that are sliding or moving through substances such as air or water.
**Friction Opposes Sliding** Although several different forms of friction exist, they all have one thing in common. If two objects are in contact, frictional forces always try to prevent one object from sliding on the other object. If you rub your hand against a tabletop, you can feel the friction push against the motion of your hand. If you rub the other way, you can feel the direction of friction change so it is again acting against your hand’s motion. Friction always will slow a moving object.

What do the different forms of friction have in common?

**Older Ideas About Motion** It took a long time to understand motion. One reason was that people did not understand the behavior of friction and that friction was a force. Because moving objects eventually come to a stop, people thought the natural state of an object was to be at rest. For an object to be in motion, something always had to be pushing or pulling it to keep the object moving. As soon as the force stopped, the object would stop moving.

Galileo understood that an object in constant motion is as natural as an object at rest. It was usually friction that made moving objects slow down and eventually come to a stop. To keep an object moving, a force had to be applied to overcome the effects of friction. If friction could be removed, an object in motion would continue to move in a straight line with constant speed. **Figure 4** shows motion where there is almost no friction.

**Figure 4** In an air hockey game, the puck floats on a layer of air, so that friction is almost eliminated. As a result, the puck moves in a straight line with nearly constant speed after it’s been hit. **Infer how the puck would move if there was no layer of air.**
Static Friction If you’ve ever tried pushing something heavy, like a refrigerator, you might have discovered that nothing happened at first. Then as you push harder and harder, the object suddenly will start to move. When you first start to push, friction between the heavy refrigerator and the floor opposes the force you are exerting and the net force is zero. The type of friction that prevents an object from moving when a force is applied is called static friction.

Static friction is caused by the attraction between the atoms on the two surfaces that are in contact. This causes the surfaces to stick or weld together where they are in contact. Usually, as the surface gets rougher and the object gets heavier, the force of static friction will be larger. To move the object, you have to exert a force large enough to break the bonds holding two surfaces together.

Sliding Friction While static friction keeps an object at rest, sliding friction slows down an object that slides. If you push an object across a room, you notice the sliding friction between the bottom of the object and the floor. You have to keep pushing to overcome the force of sliding friction. Sliding friction is due to the microscopic roughness of two surfaces, as shown in Figure 5. A force must be applied to move the rough areas of one surface past the rough areas of the other. A sliding friction force is produced when the brake pads in a car’s brakes rub against the wheels. This force slows the car. Bicycle brakes, shown in Figure 6, work the same way.

What is the difference between static friction and sliding friction?

Figure 5 Microscopic roughness, even on surfaces that seem smooth, such as the tray and metal shelf, causes sliding friction.
Rolling Friction Another type of friction, rolling friction, is needed to make a wheel or tire turn. Rolling friction occurs between the ground and the part of the tire touching the ground, as shown in Figure 6. Rolling friction keeps the tire from slipping on the ground. If the bicycle tires are rolling forward, rolling friction exerts the force on the tires that pushes the bicycle forward.

It’s usually easier to pull a load on a wagon or cart that has wheels rather than to drag the load along the ground. This is because rolling friction between the wheels and the ground is less than the sliding friction between the load and the ground.

**Summary**

**Force**
- A force is a push or a pull.
- The net force on an object is the combination of all the forces acting on the object.
- The forces acting on an object can be balanced or unbalanced. If the forces are balanced, the net force is zero.

**Newton’s First Law of Motion**
- If the net force on an object at rest is zero, the object remains at rest, or if the object is moving, it continues moving in a straight line with constant speed.

**Friction**
- Friction is the force that acts to resist sliding between two surfaces that are touching.
- Three types of friction are static friction, sliding friction, and rolling friction.

**Self Check**
1. Explain whether a force is acting on a car that is moving at 20 km/h and turns to the left.
2. Describe the factors that cause static friction between two surfaces to increase.
3. Discuss why friction made it difficult to discover Newton’s first law of motion.
4. Discuss whether an object can be moving if the net force acting on the object is zero.
5. Think Critically For the following actions, explain whether the forces involved are balanced or unbalanced.
   - You push a box before it moves.
   - You push a box but it doesn’t move.
   - You stop pushing a box and it slows down.

6. Compare and contrast static, sliding, and rolling friction.