

Section 3

Friction: A Force That Opposes Motion

Key Concept Friction is a force that can balance other forces to prevent motion. Friction is also a force that, when unbalanced, can change the velocity of an object.

What You Will Learn

- The magnitude of the force of friction can vary.
- Kinetic friction is a force that, when unbalanced, can change the velocity of a moving object.
- Static friction balances an applied force and can prevent motion.
- Friction can be both harmful and helpful.

Why It Matters

By controlling friction, you can make tasks easier.

While playing ball, your friend throws the ball out of your reach. Rather than running after the ball, you walk after it. You know that the ball will slow down and stop. An unbalanced force is needed to change the velocity of objects. So, what force is stopping the ball? The ball is stopped by friction. **Friction** is a force that opposes motion between two surfaces that are touching. Friction can cause a moving object to slow down and stop.

The Source of Friction

The surface of any object is rough. Even surfaces that feel smooth are covered with microscopic hills and valleys. When two surfaces are touching, the hills and valleys of one surface stick to the hills and valleys of the other surface, as shown in **Figure 1**. This contact causes friction. The magnitude of friction between two surfaces depends on many factors. One factor is the force pushing the surfaces together. Another factor is the materials that make up the surfaces.

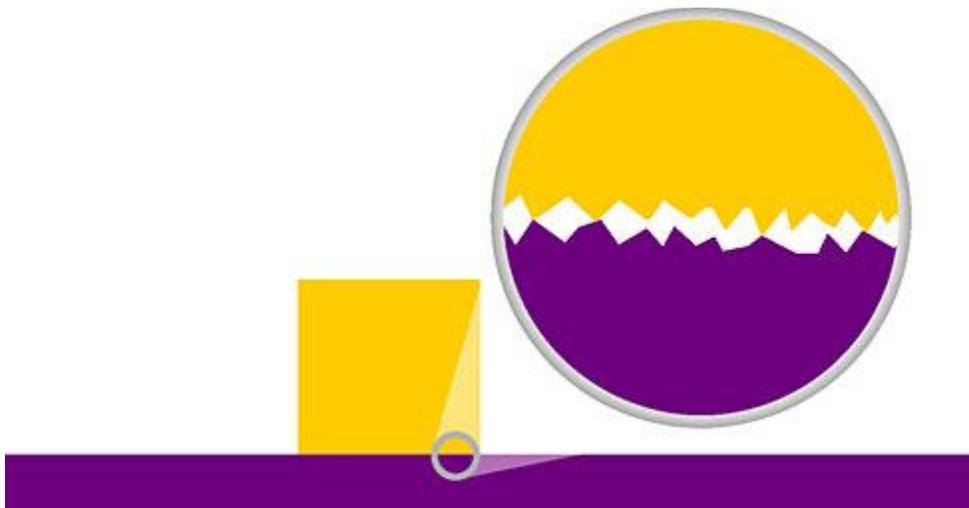


Figure 1 When the hills and valleys of one surface stick to the hills and valleys of another surface, friction is created.

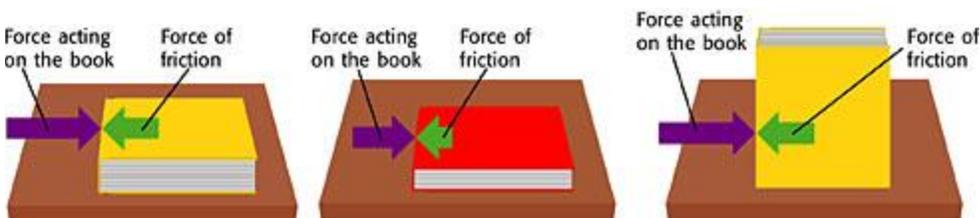
The Effect of Force on Friction

If the force pushing surfaces together increases, the hills and valleys of the surfaces come into closer contact. This close contact increases the friction between the surfaces. Objects that weigh less exert less downward force than objects that weigh more do, as **Figure 2** shows. But the amount of surface touching another surface does not affect the amount of friction.

Figure 2 Force and Friction

a The friction between the heavier book and the table is greater than the friction between the lighter book and the table. A harder push is needed to move the heavier book.

b Turning a book on its edge does not change the amount of friction between the table and the book.



The Effect of Material on Friction

The material that makes up a surface affects the magnitude of friction. For example, friction is usually greater between materials that have rough surfaces than it is between materials that have smooth surfaces. A table-tennis ball rolling on carpet slows down and stops because of friction between the ball and the carpet. The amount of friction is large because the carpet has a rough surface. But a table-tennis ball rolling on a wood floor rolls for a long time before stopping. The ball keeps rolling because the wood floor has a smooth surface. So, the amount of friction between the ball and the floor is small.

Standards Check Why does a ball rolling on a carpet slow down and stop?

□



Types of Friction

There are two types of friction. The friction observed when you slide books across a tabletop is *kinetic friction*. The other type of friction is *static friction*. You observe static friction when you push on a piece of furniture that you cannot move.

Kinetic Friction

The word *kinetic* means “moving.” So, kinetic friction is friction between moving surfaces. The amount of kinetic friction between two surfaces depends in part on how the surfaces move. Surfaces can slide past each other. Or a surface can roll over another surface. Often, the force of sliding kinetic friction is greater than the force of rolling kinetic friction. Thus, things on wheels are often easier to move than things that must be slid along the floor, as **Figure 3** shows.

Figure 3 Comparing Kinetic Friction

a Moving a heavy piece of furniture in your room can be difficult because **the force of sliding kinetic friction is large.**



b Moving a heavy piece of furniture is easier if you put it on wheels. **The force of rolling kinetic friction is smaller and easier to overcome.**



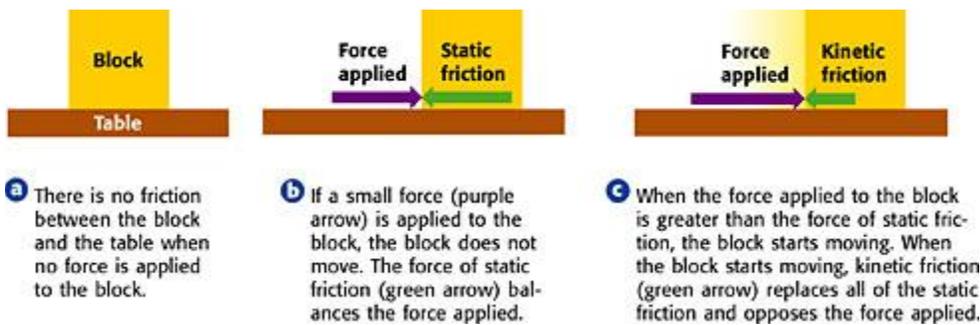
Kinetic friction is very useful in everyday life. You use sliding kinetic friction when you apply the brakes on a bicycle and when you write with a pencil. Rolling kinetic friction is an important part of almost all means of transportation. Anything that has wheels—bicycles, in-line skates, cars, trains, and planes—uses rolling kinetic friction.

Kinetic friction is often an unbalanced force acting on moving objects. Thus, kinetic friction often changes the velocity of a moving object by slowing down the object.

Static Friction

Often, a force is applied to an object but does not cause the object to move. The object does not move because the force of static friction is balancing the force applied. Static friction can be overcome by applying a large enough force. As soon as an object starts moving, static friction has gone and has been replaced by kinetic friction. Look at **Figure 4** to understand when static friction affects an object.

Figure 4 Static Friction



The middle image in **Figure 4** shows that the force of static friction is equal in magnitude but opposite in direction to the force applied. So, the forces on the object shown are balanced, and the motion of the object does not change. In fact, some static objects do not move because the force of static friction balances the other forces acting on the object. For example, a ladder leaning against a wall does not move because of static friction between the ladder and the wall and between the ladder and the ground.

Standards Check Suppose that you push on a heavy desk, but it does not move. What force opposes your push? How do you know that the opposing force balances the force that you exert?

Friction: Harmful and Helpful

Friction is both harmful and helpful to you and to the world around you. Friction can cause holes in your socks. Friction by wind and water can cause erosion. On the other hand, friction between your pencil and your paper is needed for the pencil to leave a mark. Without friction, you would slip and fall when you tried to walk. Because friction can be both harmful and helpful, sometimes it should be decreased and sometimes it should be increased.

Ways to Reduce Friction

Using lubricants (LOO bri kuhnts) is one way to reduce friction. *Lubricants* are substances that are put on surfaces to reduce the friction between the surfaces. Some examples of lubricants are motor oil, wax, and grease. Lubricants are usually liquids, but they can be solids or gases. An example of a gas lubricant is the air that comes out of the

tiny holes on an air-hockey table. **Figure 5** shows one use of a lubricant.



Figure 5 When you work on a bicycle, watch out for the chain! You may get dirty from the grease or oil that keeps the chain moving freely. Without this lubricant, friction between the sections of the chain makes riding difficult.

Friction can also be reduced by switching from sliding kinetic friction to rolling kinetic friction. Ball bearings placed between the wheels and axles of in-line skates and bicycles make the wheels turn more easily by

reducing friction.

Another way to reduce the magnitude of friction is to smooth surfaces that rub against each other. For example, rough wood on a park bench can snag your clothes or scratch your skin because there is a large amount of friction between you and the bench. Rubbing the bench with sandpaper makes the bench smoother. As a result, the friction between you and the bench is less. So, the bench will no longer snag your clothes or scratch you.

Standards Check How can the magnitude of friction be reduced?



Ways to Increase Friction

One way to increase friction is to make surfaces rougher. For example, sand spread on icy roads keeps cars from sliding. Baseball players often wear textured batting gloves to increase the friction between their hands and the bat. The increased friction helps stop the bat from flying out of their hands.

Another way to increase friction is to increase the force pushing surfaces together. Suppose that you are sanding a piece of wood. You can sand the wood faster by pressing harder on the sand paper. Pressing harder increases the force pushing the sandpaper and wood together. So, the friction between the sandpaper and wood increases. **Figure 6** shows another example of pushing on something to increase friction.



Figure 6 No one likes cleaning dirty pans. To get this job done quickly, press down with the scrubber to increase friction.

Section Summary

- Friction is a force that acts in a direction opposite to the direction of motion.
- Factors that affect the magnitude of friction include the force pushing the surfaces together and the materials that make up the surfaces.
- Kinetic friction is a force that, when unbalanced, can change the velocity of a moving object.
- Static friction can balance other forces and can prevent changes in motion.
- Friction can be helpful or harmful.

Chapter Summary

The Big Idea

Forces act on objects and can produce motion.

Section 1 Measuring Motion

Key Concept Motion can be measured and described in many ways.

- Properties used to describe the motion of an object include a reference point, direction, speed, velocity, and acceleration.
- Average speed can be calculated by dividing total distance by total time.
- A change in velocity is due to a change in speed, direction, or both.
- Speed and acceleration can be represented on graphs.



The velocity of these cars is their speed and their direction of motion.

Section 2 What Is a Force?

Key Concept Forces acting on an object can be combined and may cause changes in motion.

- A force is a push or a pull that acts on an object. Forces have magnitude and direction.
- Net force is the combined effect of two or more

forces acting on an object.

- Balanced forces do not cause changes in motion.
- Unbalanced forces cause changes in an object's velocity.

The net force on the rope is the combined effect of the forces exerted by the dogs.

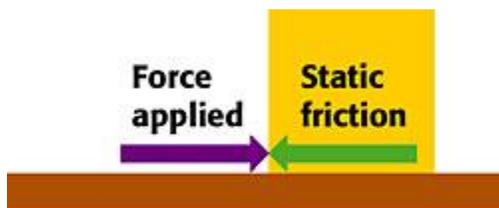


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Static friction balances an applied force and prevents motion.

