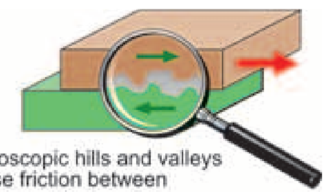
4.2 Friction

Friction is a force that resists motion. Friction is found everywhere in our world. You feel the effects of friction when you swim, ride in a car, walk, and even when you sit in a chair. Friction can act when an object is moving or when it is at rest. Many kinds of friction exist. Figure 4.7 shows some common examples.

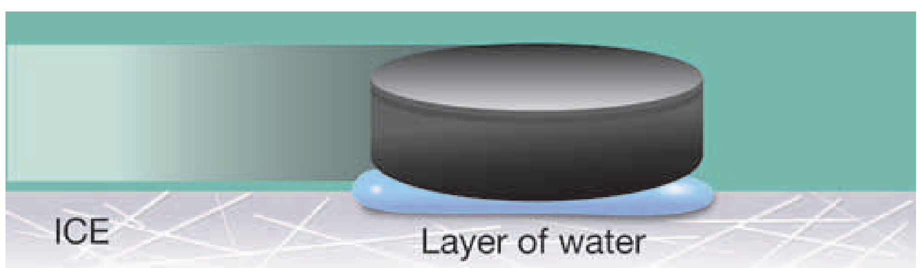
Some causes of friction

The cause of friction Imagine looking through a microscope at two smooth surfaces touching each other. You would see tiny hills and valleys on both sides. As surfaces slide (or try to slide) across each other, the hills and valleys grind against each other and cause friction. The tiny hills may change shape or wear away. If you rub sandpaper on a piece of wood, friction affects the wood's surface and makes it either smoother (hills wear away) or rougher (they change shape).



Microscopic hills and valleys cause friction between smooth surfaces.

Two surfaces are involved Friction depends on *both* of the surfaces in contact. The force of friction on a rubber hockey puck is very small when it is sliding on ice. But the same hockey puck sliding on a piece of sandpaper experiences a large friction force. When the hockey puck slides on ice, a thin layer of water between the rubber and the ice allows the puck to slide easily. Water and other liquids, such as oil, can greatly reduce the friction between surfaces.



VOCABULARY

friction - a force that resists motion.

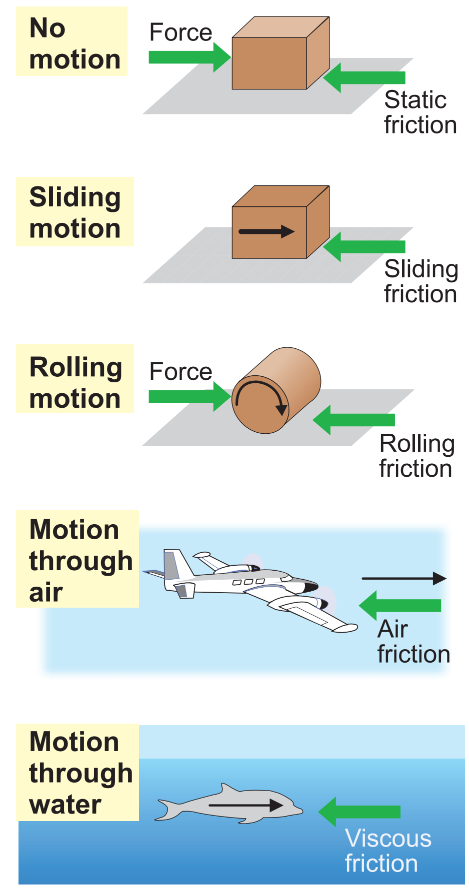


Figure 4.7: *There are many types of friction.*

Identifying friction forces

Direction of the friction force

We think of friction as a force, measured in newtons just like any other force. You draw the force of friction with a force vector. To figure out the direction of the vector, always remember that friction *resists motion between surfaces*. The force of friction acting *on* a surface always points opposite the direction of the motion *of that surface*. Imagine pushing a heavy box across the floor (Figure 4.8). If the box is moving to the right, then friction acts to the left against the surface of the box touching the floor. If the box were moving to the left instead, the force of friction would point to the right. This is what we mean when we say friction resists motion.

Sliding friction

Sliding friction is a force that resists dry sliding motion between any two surfaces. If you push a box across the floor toward the right, sliding friction acts toward the left. The friction force acts between the floor and the bottom surface of the box. If you stop pushing the box, sliding friction keeps causing a force as long as the box is moving. Sliding friction is what eventually slows the box to a stop when you stop pushing.

Static friction

Static friction keeps an object that is standing still (at rest) from moving. Imagine trying to push a heavy box with a small force. The box stays at rest because the static friction force acts against your force and cancels it out. As you increase the strength of your push, the static friction also increases. Eventually your force becomes strong enough to overcome static friction and the box starts to move (Figure 4.8). The force of static friction balances your force up to a limit. The limit of the static friction force depends on the types of surfaces and the weight of the object you are pushing.

Comparing sliding and static friction

How does sliding friction compare with static friction? If you have ever tried to move a heavy sofa or refrigerator, you probably know the answer. It is harder to get something moving than it is to keep it moving. This is because static friction is almost always greater than sliding friction at slow speeds.

VOCABULARY

sliding friction - the friction force that resists the motion of an object moving across a surface.

static friction - the friction force that resists the motion between two surfaces that are not moving.

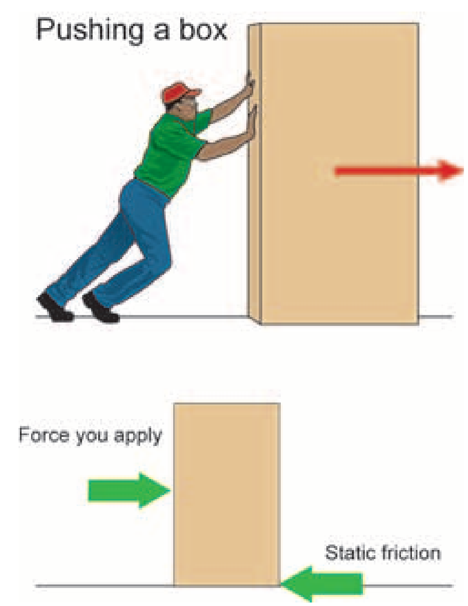


Figure 4.8: *The direction of friction is opposite the direction the box is pushed.*

A model for friction

Different amounts of friction The amount of friction generated when a box is pushed across a smooth floor is very different from when it is pushed across a carpet. Friction depends on materials, roughness, how clean the surfaces are, and other factors. Even the friction between two identical surfaces changes as the surfaces are polished by the sliding motion. No single formula can accurately describe all types of friction.

An example An easy experiment to measure friction is to pull a piece of paper across a table with a force scale. The paper slides smoothly, and the scale measures almost no force. Now put a brick on the piece of paper (Figure 4.9). Friction increases and you must pull with a greater force to keep the paper moving.

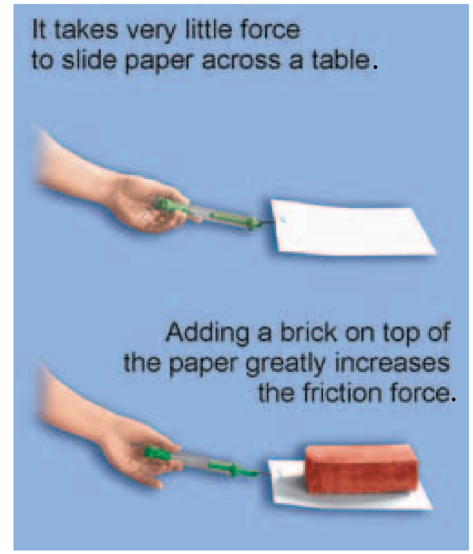


Figure 4.9: *Friction increases greatly when a brick is placed on the paper.*

Friction depends on the force between surfaces Why does the brick have an effect on friction? The two surfaces in contact are still the paper and the tabletop. The brick causes the paper to press harder into the table's surface. The tiny hills and valleys in the paper and in the tabletop are pressed together with a much greater force, so the friction increases. The same is true of most dry sliding friction. Increasing the force that pushes surfaces together increases the amount of friction.

The greater the force squeezing two surfaces together, the greater the friction force.

Why sliding friction increases with weight The friction force between two smooth, hard surfaces is approximately proportional to the force squeezing the surfaces against each other. Consider sliding a heavy box across a floor. The force between the bottom of the box and the floor is the weight of the box. Therefore, the force of friction is proportional to the weight of the box. If the weight doubles, the force of friction also doubles.

Other kinds of friction act differently This rule is NOT true if the surfaces are wet, or if they are soft. Rubber is soft compared to pavement. The friction between rubber and pavement also depends on how much rubber is contacting the road. Wide tires have more friction (traction) than narrow tires.

Reducing the force of friction

All surfaces experience some friction

Unless a force is constantly applied, friction will slow all motion to a stop eventually. For example, bicycles have low friction, but even the best bicycle slows down as you coast on a level road. It is impossible to completely eliminate friction. However, many clever inventions have been devised to reduce friction. You use them every day.

Lubricants reduce friction in machines

Putting a liquid such as oil between two sliding surfaces keeps them from touching each other. The tiny hills and valleys don't become locked together, so there is less friction. The liquid also keeps the surfaces from wearing away as quickly. You add oil to a car's engine so that the moving parts slide or turn with less friction. Even water can be used to reduce friction between objects if they are not too hot.

Ball bearings

A ball bearing you might find in a machine

Ball bearings reduce friction in rotating motion (Figure 4.10). Ball bearings change sliding motion into rolling motion, which has much less friction. For example, a metal shaft rotating in a hole rubs and generates a lot of friction. Ball bearings that go between the shaft and the inside surface of the hole allow the shaft to spin more easily. The shaft rolls on the bearings instead of rubbing against the walls of the hole. Well-oiled bearings rotate easily and greatly reduce friction.

Magnetic levitation

Another method of decreasing friction is to separate the two surfaces with a cushion of air. A hovercraft floats on a cushion of air created by a large fan. Magnetic forces can also be used to separate surfaces. A magnetically levitated (or maglev) train uses magnets that run on electricity to float on the track once the train is moving (Figure 4.11). There is no contact between train and track, so there is far less friction than with a standard train on tracks. The ride is smoother, so maglev trains can move at very fast speeds. Maglev trains are not widely used yet because they are much more expensive to build than regular trains. They may become more popular in the future.

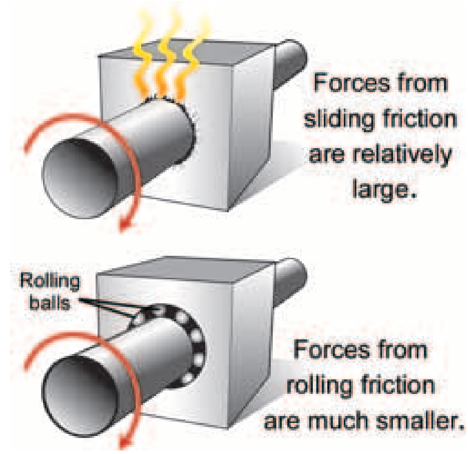
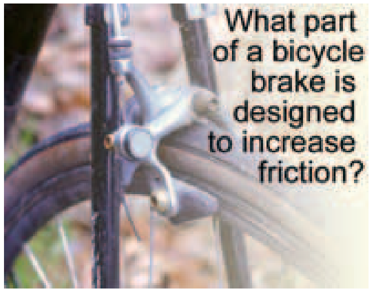


Figure 4.10: *The friction between a shaft (the long pole in the picture) and the inner surface of the hole produces a lot of heat. Friction can be reduced by placing ball bearings between the shaft and the hole surface.*

Figure 4.11: *With a maglev train, there is no contact between the moving train and the rail—and thus there is little friction.*

Using friction

Friction is useful for brakes and tires



There are many times when friction is very useful. For example, the brakes on a bicycle create friction between the brake pads and the rim of the wheel. Friction makes the bicycle slow down or stop. Friction is also needed to make a bicycle go. Without friction, the bicycle's tires would not grip the road.

Tires designed for bad weather

Friction is also important to anyone driving a car. Tires are specially designed to maintain friction on pavement in rain or snow. Tire treads have grooves that allow space for water to be channeled away where the tire touches the road (Figure 4.12). This allows good contact between the rubber and the road surface. Special groove patterns, along with tiny slits, are used on snow tires to increase traction in snow. These grooves and slits keep snow from getting packed into the treads.

Nails

Friction keeps nails in place (Figure 4.13). When a nail is hammered into wood, the wood pushes against the nail on all sides. The force of the wood against the nail surface creates a lot of friction. Each hit of the hammer pushes the nail deeper into the wood. The deeper the nail goes, the more surface there is for friction to grab onto.

Cleated shoes

Shoes are designed to increase the friction between your foot and the ground. Many athletes, including football and soccer players, wear shoes with cleats. Cleats are like teeth on the bottom of the shoe that dig into the ground. Players wearing cleats can apply much greater force against the ground to help them move and to keep them from slipping.

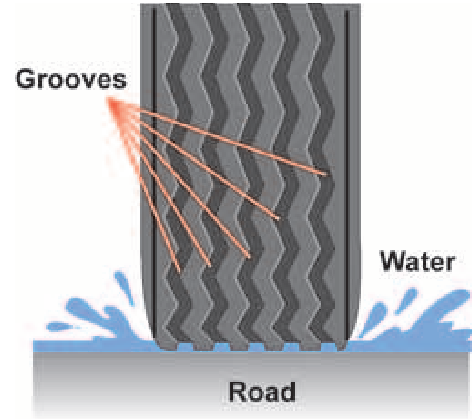


Figure 4.12: *Grooved tire treads allow space for water to be channeled away from the road–tire contact point, allowing for more friction in wet conditions.*

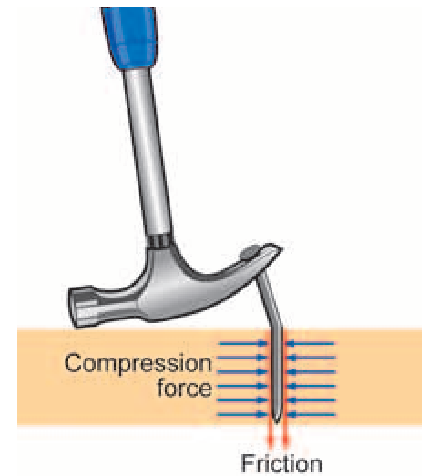
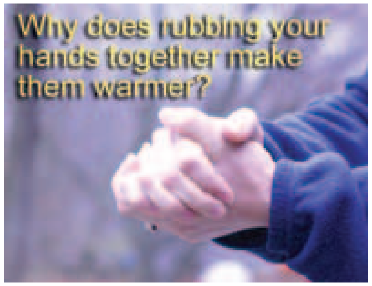


Figure 4.13: *Friction is what makes nails hard to pull out, and what gives nails the strength to hold things together.*

Friction and energy

Friction changes energy of motion into heat



Why does rubbing your hands together make them warmer?

Earlier we learned that energy moves through the action of forces. Energy also changes into different forms. Friction changes energy of motion into heat energy. You may have noticed that rubbing your hands together quickly can make them warmer on a cold day. You are feeling the effect of friction changing energy of motion into heat.

Heat in machines

Friction is always present in any machine with moving parts. If the machine is small, or the forces are low, the amount of heat produced by friction may also be small. A sewing machine gets warmer as it runs, but usually not so hot that parts melt or break. Larger machines have more problems with heat. In many machines, oil is pumped around moving parts. The oil does two important things. First, oil reduces friction so less heat is generated. Second, the oil absorbs the heat and carries it away from the moving parts. Without the flow of cooling oil, moving parts in an engine would quickly heat up and melt.

Friction causes wear

Which rocks have been worn by friction and which have not?

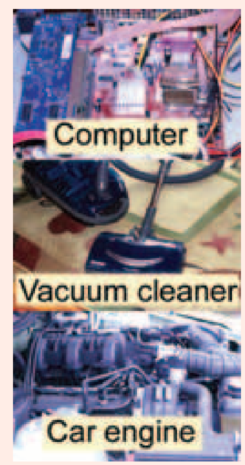
Another way friction changes energy is by wearing away moving parts. You have probably noticed that objects that slide against each other often get rounded or smoothed. Each time two moving surfaces touch each other, tiny bits of material are broken off by friction. Breaking off bits of material uses energy. Sharp corners and edges are rounded off and flat surfaces may be scratched or even polished smooth and shiny. This is why water flowing over stones in a stream causes the stones to be rounded and smooth.

TECHNOLOGY

Dealing with the heat

Every machine releases heat from friction. The faster the parts move, and the larger the forces inside the machine, the more heat is released. Electronic machines, like computers, are no exception, even though they may have no moving parts! Electricity moving though wires also creates friction.

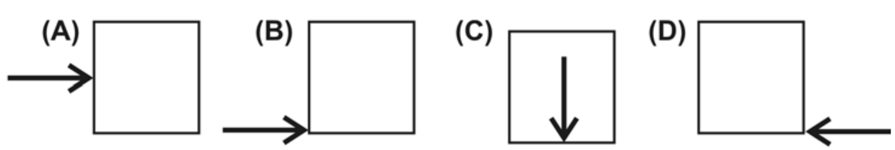
If a machine gets too hot, parts may melt and the machine may stop working. Because of this, many machines have special systems, parts, and designs to get rid of unwanted heat energy.



Here are three machines you probably see every day. How does excess heat get removed from each one?

4.2 Section Review

1. Name three devices or inventions that are designed to decrease friction.
2. Name three devices or inventions that are designed to increase friction.
3. If the force squeezing two surfaces together is decreased, the force of friction between the two surfaces will most likely
   a. increase.
   b. decrease.
   c. stay about the same.
4. True or false: A well oiled machine has no friction. Explain your answer.
5. The difference between static friction and sliding friction is that
   a. sliding friction is always greater.
   b. static friction is always greater.
   c. sliding friction occurs at rest and static friction occurs in motion.
   d. static friction occurs at rest and sliding friction occurs in motion.
6. A box is sliding across the floor from left to right. Which diagram correctly shows the force of friction acting on the box?



7. True or false: Friction makes energy vanish. Explain your answer.

MY JOURNAL

Friction every day

Write a paragraph telling how the events of your day would not have been possible without friction.

Write another paragraph telling how your day would have been easier if there were less friction.