LESSON **6**

The Force of Friction

What force stops the baseball player as he slides into third base?

INTRODUCTION

In Lesson 5, you investigated the properties of gravity and elastic forces in a rubber band. In this lesson, you will explore another force—friction. Friction is a force you experience every day. People spend time, money, and effort to reduce it. You might be surprised to learn that friction is not always bad. It can be very helpful.

You will investigate the force of friction as you pull a wooden block at a constant speed across a surface. As you do so, you will investigate three variables—surface type, weight (load), and surface area (base area)—and determine how each affects the frictional force between the block and the surface. In each trial, you will change one variable and keep the other two the same. This method is an example of good experimental design. As in the previous inquiries, you will record observations, collect data, and draw conclusions based on what you discover about friction. Understanding friction will help you understand motion, which you will study later in this module.

OBJECTIVES FOR THIS LESSON

Observe the properties of sliding friction.

Measure the force of friction on a wooden block pulled across different surfaces.

Measure the force of friction on loads of different weights.

Measure the force of friction on a wooden block with different base areas in contact with a surface.

Getting Started

1. Discuss what you know about friction with your lab partner and then with the rest of the class.

2. Identify a situation in which friction works against you. Then identify one in which friction works for you. Think of situations where friction is very low or almost zero. What would happen if there were no friction at all?

3. Your teacher will share information with you about how to use the spring scales to measure the force of friction. Listen carefully and ask questions if you are not sure how to make the measurements.

MATERIALS FOR LESSON 6

For you

- 1 copy of Student Sheet 6.1: What a Drag!
- 1 copy of Student Sheet 6.2: Changing the Load

For you and your lab partner

- 2 wooden blocks with attached screw hook
- 1 0- to 2.5-N spring scale
- 1 0- to 10-N spring scale
- 1 piece of waxed paper
- 1 piece of paper towel
- 1 piece of fine sandpaper
- 1 piece of coarse sandpaper
- 1 meterstick
- 1 rubber band
- 1 piece of masking tape

Inquiry 6.1
Pulling a Block Across Different Surfaces

PROCEDURE

1. Lay the spring scales on the tabletop. Does the pointer register zero? If not, adjust it to read zero.

2. In this inquiry, you will investigate the force of friction on a block as you pull it across each of the following surfaces: the plain tabletop, waxed paper, a paper towel, fine sandpaper, and coarse sandpaper. Tape the four surface strips (waxed paper, paper towel, fine sandpaper, coarse sandpaper) to the tabletop. Measure and mark off another 27-cm length on the bare tabletop.

3. You will need to decide which spring scale to use for your measurements. If you are not sure which to use, try making some measurements of the forces needed to pull the block using the scale. The best scale to use is one that will register the force to pull the block, yet not go off scale when you exert the maximum force needed to pull the block.

4. Attach the hook on the spring scale to the round screw hook on the wooden block, as shown in Figure 6.1.

5. How do you think the frictional force on the block will compare as you pull the block across the different surfaces? Write your prediction in your science notebook.

6. Before you start to collect data, practice by pulling the wooden block with the spring scale across a surface at a steady rate, as shown in Figure 6.2. Make sure you hold the spring scale parallel to the tabletop and pull horizontally on the block. As you move the block at a steady speed, observe the force reading. You will probably find that the force is not perfectly steady. When the spring scale reading is not steady, it is best to do several trials and average your results. How many trials should you do for each surface? Discuss this with your partner and decide on the number of trials needed in order to obtain accurate force data.

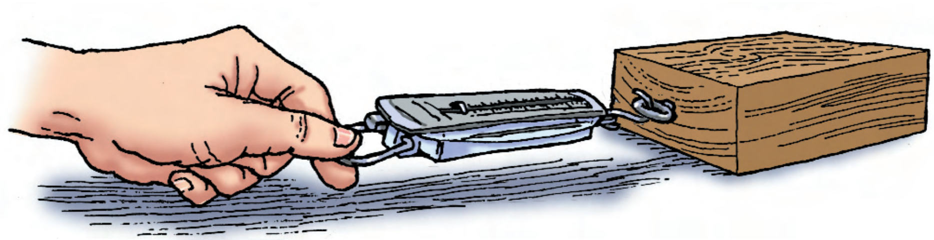

Figure 6.1 *Wooden block connected to a spring scale*

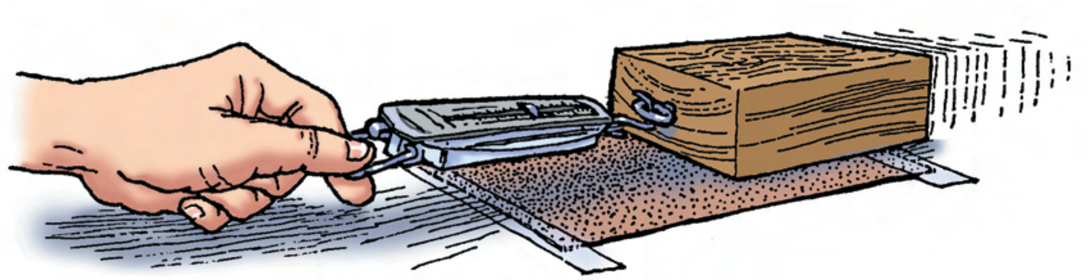

Figure 6.2 *Pulling a wooden block across a surface to measure the force of friction*

7. Pull the block across each of the five surfaces and collect force data for each surface. Be sure to pull the block across the entire length of the surface. Record your data in Table 1 on Student Sheet 6.1: What a Drag! Calculate the average force for each surface.

8. How can you graphically represent the average force data for each surface? What kind of graph should you use? Construct a graph on Student Sheet 6.1.

9. In your science notebook, record your answers to the following questions:

A. Which surface required the greatest force to pull the wooden block across it?

B. Which surface required the least force?

C. Did the weight of your wooden block change as the surfaces changed?

D. Review the variables for this lesson. Which variables did not change as you tested each surface?

10. Be prepared to discuss your answers to the questions in Step 9 with the class.

Inquiry 6.2
Changing the Load

PROCEDURE

1. Think about and discuss with your lab partner the following question: What will happen to the effort force needed to pull the block if you change the weight of the block? Write your prediction in your science notebook.

2. This inquiry requires that you and your lab partner work as a team and collaborate with the other teams in your class. Each team should collect data. But there is not enough time for each individual team to check all surfaces with different loads. Therefore, you will need to work together as a class and assign different surfaces to different teams. Each surface needs to be assigned to at least two teams.

3. Design a data table on Student Sheet 6.2: Changing the Load to record your measurements. Discuss with the class how you will measure the weight of the load in each trial.

4. Change the weight of the load by stacking more blocks, one at a time, on the original block. Each time you add a block, measure the force it takes to pull this load at a steady speed across the surface. Share blocks with another team so both teams can gather data for a load of up to four blocks.

5. Graph your data.

6. Compare your data and graph with that of a team that used the same surface. Discuss with your partner and the other team the relationship between the load (total weight of the block or blocks) and the frictional force. Record the description in your science notebook.

7. Compare your data with the data of groups that used different surfaces. What do you find? Record your findings in your science notebook.

8. Think about the variables in this investigation. What did you keep constant as you changed the weight of the blocks? Record your answer in your science notebook.

9. Share your results with the class.

Inquiry 6.3
Changing the Surface Area

PROCEDURE

1. Look at your block. You can turn the block on its wide side and pull on it, or stand it on one of its narrow sides and pull on it. When the block is on its wide side, the area in contact with the surface is greater than when it is on its narrow side. You pulled the block across the surfaces on its wide side in previous trials. Predict what will happen to the force of friction if you pull the block on a narrow side across the surface. Write your prediction in your science notebook.

2. Construct a data table in your notebook to record the description of each surface area of the block (wide or narrow) and the measurement of the force needed to pull the block at a steady rate across the surface (waxed paper, fine sandpaper, and so on). Different teams should use different surfaces. Make sure you record the surface you use. Be prepared to share the data you collect with the class. Your class should design a class data table on the board or on a transparency.

3. Put a rubber band around the block so that it is below the center (about one-fourth of the way to the top of the block as measured from the table). Attach the spring scale hook to the rubber band and pull the block so that it moves smoothly across the table, as shown in Figure 6.3. Measure the frictional force as the block slides at a constant speed along the surface. Do this for each side of the block.

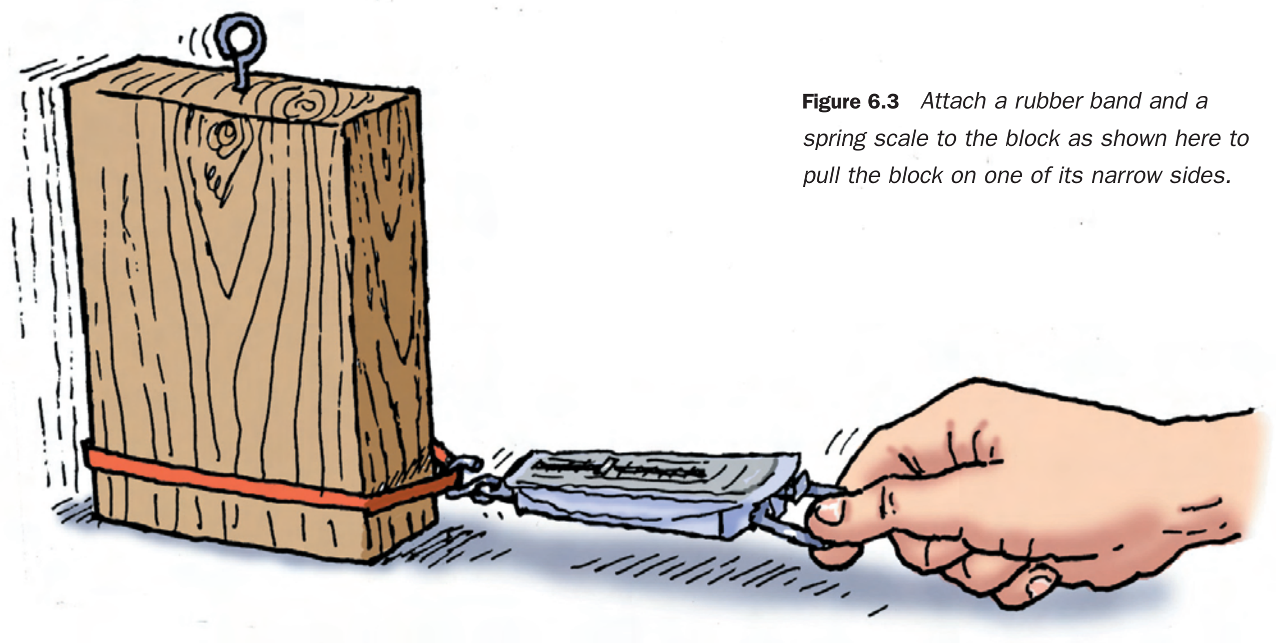

Figure 6.3 *Attach a rubber band and a spring scale to the block as shown here to pull the block on one of its narrow sides.*

4. Record your data, and then discuss the results with your team and share your results with the class. Add your results to the class data table.

5. Answer the following question in your notebook: How did your prediction compare with the results?

6. Think about the variables. Which variables did you keep constant this time? Record your answer in your science notebook.

REFLECTING ON WHAT YOU'VE DONE

Write answers to the following questions in your science notebook:

A. What have you learned about friction in this lesson? In your science notebook, summarize in several paragraphs what you have learned about the force of friction. In your summary, include factors that affect frictional force and explain how you measure it.

B. In this lesson, you measured sliding friction. Why does the force on the spring scale measure the force of friction while the block moves at a steady speed?

C. Suppose you used ice as a surface for the block to slide on. What results would you get in this lab? Consider results for all three variables—surface type, weight of the block, and surface area.

NATURE PUTS ON THE BRAKES

Skydiving is a sport that many people enjoy. But it takes courage! When skydivers leap from planes, you might think that the constant pull of gravity would make them fall faster and faster until their parachutes opened and allowed them to glide safely back to the earth. But that's not quite what happens.

At the beginning of a skydive, a diver's fall does speed up or accelerate rapidly. But as the diver falls, the acceleration continually decreases until the diver stops speeding up. The diver then falls at a constant velocity. ("Velocity" is the speed at which an object is traveling in a single direction—in the case of a skydiver, down!) The constant velocity that the skydiver reaches is called terminal velocity. It usually takes a skydiver about 10 seconds to reach terminal velocity.

Forces on Skydivers

It is the forces on skydivers that make them eventually reach terminal velocity. To the

By controlling the amount of the body that is exposed to the drag of the air, a skydiver can change the terminal velocity. Here, a skydiver falls in a spread-eagle position. Since the maximum amount of body is exposed to the air, the air friction is greater and the terminal velocity is smaller than when the body is pointed straight down.

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observer, gravity is the more obvious force. If gravity were the only force acting on skydivers, their velocity would continue to increase at a rate of 9.8 meters per second each second that they fall. Ten seconds into the fall, they would be moving at 98 meters per second if gravity were the only force on them. As they continued to fall, they would continue to go faster and faster.

But gravity isn't the only force on skydivers. Air friction, or drag, pushes up on their bodies as they fall through the air. ("Drag" is another word for the force of friction between the skydiver and the air.) The force of gravity is constant, but drag increases with the skydiver's speed. As skydivers fall, they eventually reach the point where the size of the drag force equals the size of the force of gravity. The drag continues to push up while gravity continues to pull down. But now, the two forces counterbalance each other. As a result, skydivers fall at a constant velocity—terminal velocity.

Controlling Terminal Velocity

Skydivers can make their terminal velocity faster or slower by changing *body position* as

Terminal velocity is a result of the interaction of two forces: gravity and air friction (drag).

AP/WIDE WORLD PHOTOS

Because the terminal velocity of spread-eagle sky-divers is very nearly the same, they can form patterns like the one seen here as they fall.

CORBIS/CHRIS SIMPSON; CORDALY PHOTO LIBRARY LTD.

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Left: *Skydivers leaping from their plane*

Below: *Parachutes are designed to take advantage of air friction, allowing skydivers to land safely.*

they fall. For skydivers falling with their backs or stomachs parallel to the earth, terminal velocity is about 50 meters per second after 10 seconds. If skydivers were going head first, terminal velocity would reach twice that rate, or 100 meters per second.

Why the difference? Because terminal velocity also depends on the surface area of the diver against which the air pushes during the fall. The greater the surface area, the greater the drag. The smaller the surface area, the less the drag and the faster the fall. To understand the comparison, think of swimmers—they feel much more resistance entering the water with a belly flop than with a nosedive.

Falling at terminal velocity without a parachute is still too fast to land safely on the ground. So skydivers do need that parachute. Parachutes help slow skydivers even more by greatly increasing their surface area. Large parachutes are more powerful than small ones. The larger the parachute, the greater the air resistance acting on the diver, and the slower the terminal velocity. The probability of a smooth, safe landing increases proportionately! □

QUESTIONS

1. What forces act on a skydiver to make the diver reach terminal velocity?
2. How is air friction different from the sliding friction studied in this lesson?

Rock Climbing:

Two People, One Powerful Force

CORBIS/GALEN ROWELL

At a time like this, friction comes in handy.

Rock climbing is not usually thought of as a team sport. For most climbers, however, it is. The climber has a partner, called a belayer.

As the climber ascends the slope, the belayer often remains below. The job of the belayer is to keep the climber from falling. The climber or belayer places an anchor at the top of the climb or at some other convenient location. The belayer holds one end of a rope. The other end of the rope is threaded through the anchor and then attached to the climber's waist. As the climber ascends the slope, the belayer holds the rope. If the climber should slip and fall, the belayer would pull on the rope and prevent the climber from falling to the ground below.

Going Up!

Both partners make full use of a powerful force called friction. Climbers use friction to make their way up to the top. While ascending a steep rock face, the climbers constantly look for "holds"—cracks and crevices into which they can wedge their feet, or small rocks or ledges that they can grasp or step on. If the rock face is smooth, climbers have to rely only on the friction between their hands and feet and the rock face to keep from falling.

Climbers also increase the force of friction by wearing shoes with specially designed soles. These soles cover more of the foot than the soles of everyday shoes do. This makes it easier for the climber to get some part of the sole of the shoe on the rock. This is important because the soles are designed to create a lot of friction with the rock.

CORBIS/KARL WEATHERLY

Climbers' shoes are designed to grip the rock surface and to prevent their feet from slipping.

Holding On!

While climbers make their way up the mountain or cliff, belayers keep an eye on their progress. Belayers use one of several methods to increase the friction on the rope and ensure that the climbers will be safe. For example, belayers can wrap the rope around their hips. The friction between their clothing and the rope wrapped around them is far greater than the friction between their hands and the ropes. Should the climbers slip, belayers can control the fall better than they could if the rope were just in their hands. More often belayers thread the rope around special metal devices that increase the friction on the rope and decrease the force the belayer must exert if the climber falls.

Climbers and belayers aren't usually thinking about friction when they're moving up a mountainside. They're focusing on their goal: reaching the top. Friction helps keep them safer and makes the climb easier. And, unlike those special shoes and mountaineering equipment, it's absolutely free! □

Climbers prepare their gear.

Belaying devices for climbing