Chapter 17 Machines at Work

This crane is a very powerful machine. It uses a device called a pulley. What do you think the pulley does?

Learning Objectives

- Define a machine in relation to doing work.
- Explain how effort force and resistance force affect an object's movement.
- Identify the six simple machines.
- Compare compound machines with simple machines.
- LAB ACTIVITY: Explore how a lever makes work easier.
- SCIENCE IN YOUR LIFE: Show how kitchen tools are based on simple machines.

Words to Know

machine	a tool or device that makes work easier to do
work	what happens when a force moves something through a distance
effort force	a force that is applied when doing work
resistance force	a force that must be overcome when doing work
load	an object to be moved
mechanical advantage	a measure of how helpful a machine is
lever	a simple machine made of a bar or rod that turns on a support
fulcrum	the support on which a lever turns
pulley	a wheel with grooves in its rim through which a rope or chain can run
inclined plane	a slanted surface used for raising objects to another level
wedge	a simple machine made of two inclined planes, back to back
screw	an inclined plane that is wrapped around a nail
wheel and axle	a wheel attached to a rod called an axle; as the axle turns, the wheel also turns

17·1 All Kinds of Work

Words to Know

machine	a tool or device that makes work easier to do
work	what happens when a force moves something through a distance
effort force	a force that is applied when doing work
resistance force	a force that must be overcome when doing work
load	an object to be moved
mechanical advantage	a measure of how helpful a machine is

Science Fact

Granville T. Woods, a 19th century African American, invented electrical machines in his machine shop. Woods sold some of his inventions to Bell Telephone System, General Electric, Westinghouse, and Thomas Edison.

What Is a Machine?

A **machine** is a tool or device that makes work easier to do. In science, **work** is what happens when a force moves something through a distance. In all machines, force and distance are connected.

A machine makes work easier in three ways. First, a machine can increase the amount of force put into a task. Second, a machine can change the direction of the force. Third, a machine can change the speed of the force.

Machines are used to do all kinds of work. Some kinds of work would be impossible or very difficult to do without machines. You could not open a can with your bare hands or cut the lawn in an afternoon's time without a lawn mower. You could not safely get from the United States to Europe without an airplane or a ship.

There are many different kinds of machines. Some have lots of parts. Some have only one or two parts. However, all machines are really made from one or more of the six different *simple machines*.

A simple machine is a machine that changes the size or direction of an applied force. Most simple machines produce work with one movement. In this chapter, you will learn about the six simple machines and how they help people do work.

✓ **How do machines make work easier?**

Effort and Resistance

There are two forces involved in work. One is the **effort force**, which is the force that is applied when doing work. The other is the **resistance force**, which is the force that must be overcome when doing work. The **load** is the object to be moved.

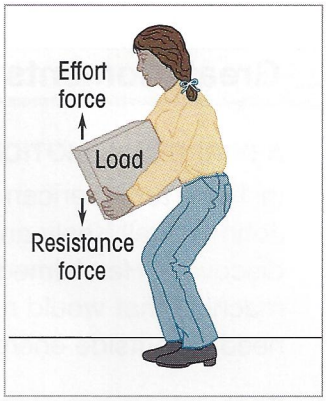


Figure 17-1 *When you lift something, the resistance force is gravity.*

Suppose you had to pick up a heavy sack of grain. The sack of grain is the load. Your lifting is the effort force. Gravity holding the bag down is the resistance force. Now suppose you want to drag the load across the ground. Your pulling is the effort force. Friction on the ground is the resistance force.

Mechanical advantage is a measure of how helpful a machine is. The mechanical advantage of a machine is a number. It is based on the number of times a machine multiplies an effort force.

For example, suppose you are using a crowbar to pry old kitchen cabinets from the wall. You slip one end of the crowbar behind the cabinets and push against the other end. The crowbar has a mechanical advantage of 4. This means the force produced by the crowbar is 4 times greater than the effort force you applied to your end of the crowbar. You only had to apply one-fourth of the force needed to remove the cabinets from the wall. However, you had to push your end of the crowbar 4 times farther than the other end moved.

✓ **What two forces are involved in work?**

Lesson Review

1. What is the purpose of a machine?
2. When you lift a box, what is the effort force? What is the resistance force?
3. **CRITICAL THINKING** Is a machine more useful if its mechanical advantage is higher or lower? Why?

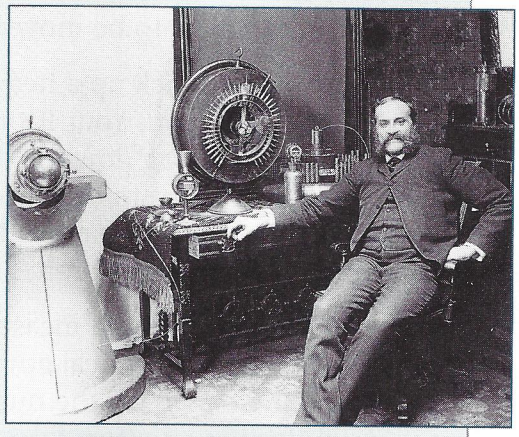
Great Moments in Science

A PERPETUAL MOTION MACHINE

In 1874, an American scientist named John Worrell Keely announced a new discovery. He claimed to have built a machine that would run forever without needing outside energy.

Keely raised more than a million dollars to improve his machine. He claimed he would soon be able to have the machine run trains and do factory work.

Keely worked on his machine for 20 years. When he died, his home was searched. A pump was found under the floorboards. He had used it to power his "perpetual motion machine." The machine was a fake. Today, scientists know that perpetual motion machines are impossible to build. All machines must have energy to work.



John Worrell Keely claimed he had built a perpetual motion machine.

CRITICAL THINKING What are some kinds of energy sources that machines need in order to work?

17-2 Simple and Compound Machines

Words to Know

lever	a simple machine made of a bar or rod that turns on a support
fulcrum	the support on which a lever turns
pulley	a wheel with grooves in its rim through which a rope or chain can run
inclined plane	a slanted surface used for raising objects to another level
wedge	a simple machine made of two inclined planes, back to back
screw	an inclined plane that is wrapped around a nail
wheel and axle	a wheel attached to a rod called an axle; as the axle turns, the wheel also turns

The Six Simple Machines

The six simple machines are levers, pulleys, inclined planes, wedges, screws, and wheels and axles. Each type of simple machine has some mechanical advantage. This means it increases the effort force.

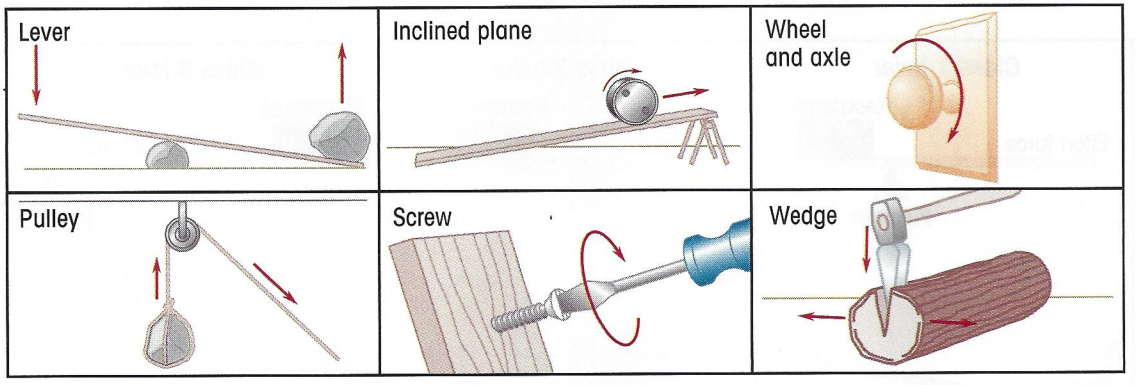


Figure 17-2 *Here are the six different kinds of simple machines.*

✓ **What are the six simple machines?**

Figure 17-3 *This screwdriver is being used as a lever.*

Levers

A **lever** is a simple machine made of a bar or rod that turns on a support. The **fulcrum** is the support on which a lever turns. Some examples of machines that have or act as levers are seesaws, wheelbarrows, nutcrackers, brooms, bottle openers, scissors, screwdrivers, shovels, and crowbars.

There are three types, or classes, of levers. In a Class 1 lever, the fulcrum is between the effort force and the resistance force. A seesaw is an example of a Class 1 lever.

In a Class 2 lever, the resistance force is between the effort force and the fulcrum. A wheelbarrow is an example of a Class 2 lever. The wheel of the wheelbarrow is the fulcrum. The wheel is the support on which the lever sits. The resistance force is in the wheelbarrow. The effort force is in your arms. A nutcracker is another example of a Class 2 lever.

In a Class 3 lever, the effort force is between the resistance force and the fulcrum. A broom is an example of a Class 3 lever. The fulcrum is where your hand is at the top of the broom. The resistance force is the floor. The effort force is you pushing the broom handle. Some other examples of Class 3 levers are tongs, fishing poles, fly swatters, tweezers, and baseball bats.

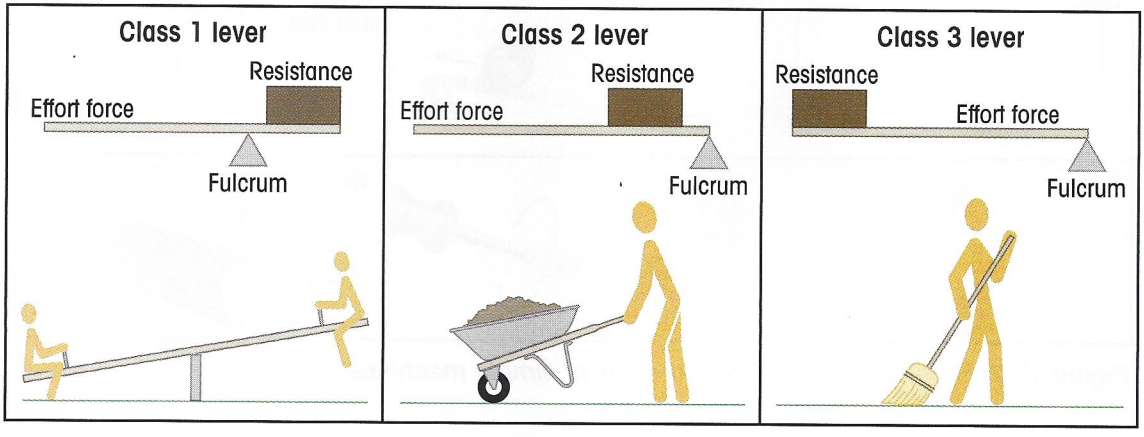


Figure 17-4 *Here are examples of the three classes of levers.*

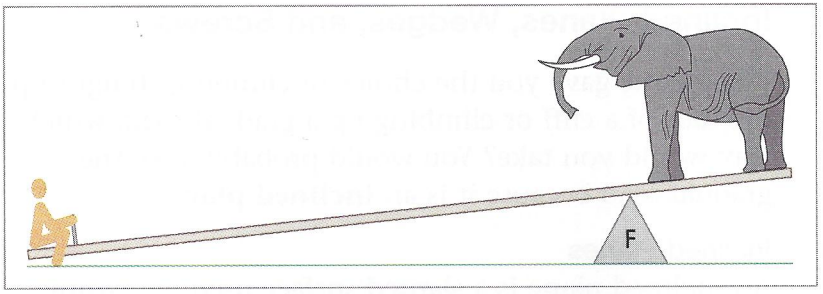


Figure 17-5 *If you have a long enough lever and a strong enough fulcrum, you can lift almost anything.*

Think of the bar of a Class 1 lever as having two parts: the resistance arm and the effort arm. The resistance arm is between the fulcrum and the resistance force. The effort arm is between the fulcrum and the effort force.

By having a long effort arm, the work is spread over a greater distance. By increasing the distance over which the work is spread, you increase the mechanical advantage. So, the longer the effort arm, the greater the mechanical advantage is.

✓ **How are the three classes of levers different?**

Pulleys

A **pulley** is a wheel with grooves in its rim through which a rope or chain can run. A groove is a long cut. The rope or chain fits into the grooves. The load is tied to one end of the rope or chain. The effort force pulls on the other end. Pulleys are used on flagpoles, sails, clotheslines, and elevators.

Suppose you want to lift a bag of cement onto a platform. Lifting the bag by hand would be very difficult. You would be fighting gravity. Instead, you can attach a rope to the load. Then you wind that rope around a pulley hanging above you. The pulley changes the direction of the effort force to help you. Now all you have to do is pull *down* on the free end of the rope. Of course, you are still fighting gravity. But the gravity pulling your body down will help you pull the rope.

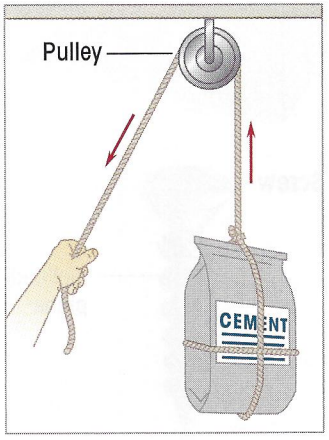


Figure 17-6 *A pulley changes the direction of the effort force.*

✓ **How does a pulley help you lift a load?**

Inclined Planes, Wedges, and Screws

Science Fact

The inclined plane is an interesting type of machine. It has no moving parts.

If someone gave you the choice of climbing straight up the face of a cliff or climbing up a gradual road, which way would you take? You would probably take the gradual road because it is an **inclined plane.**

Inclined Planes

An inclined plane is a slanted surface used for raising objects to another level. Inclined planes make the work of going up easier. The work is spread out over a greater distance. Mountain roads and ramps are both inclined planes.

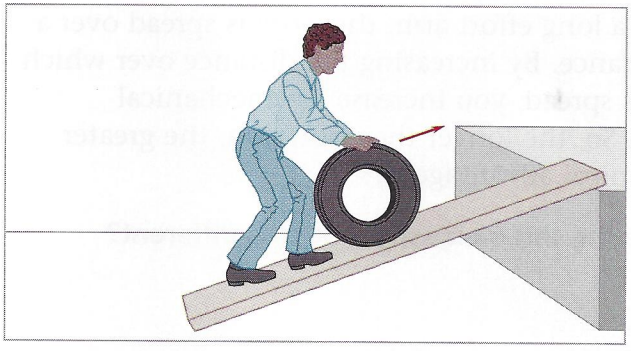


Figure 17-7 *It is easier to raise an object using an inclined plane than to pick it up.*

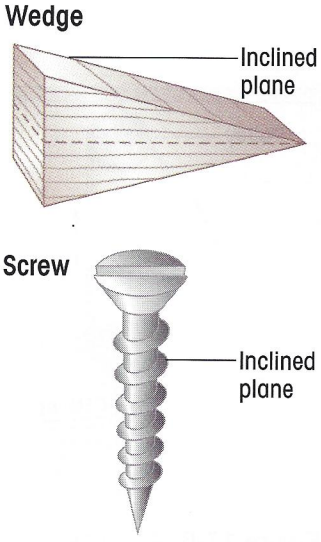


Figure 17-8 *A wedge and a screw are types of inclined planes.*

Wedges

A **wedge** is a simple machine made of two inclined planes, back to back. The wedge is thicker at one edge. Wedges are used to pry things apart. Knives, axes, needles, can openers, and razor blades are all wedges.

Screws

A **screw** is an inclined plane that is wrapped around a nail. Screws are very useful machines. Their mechanical advantage is high. When you turn a screw, a small effort force overcomes a large resistance force.

✓ **How do inclined planes make the work of going up easier?**

Wheels and Axles

To turn a car, you turn its steering wheel. You only turn it a few inches, yet this makes the car turn many feet. Car steering wheels are based on a simple machine called a **wheel and axle.** A wheel and axle is a wheel attached to a rod called an axle. The axle increases the force applied to the wheel. Pencil sharpeners are examples of wheels and axles.

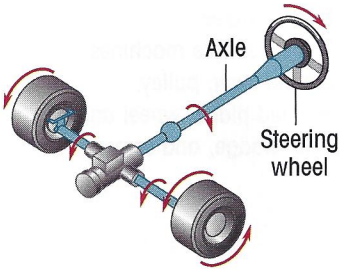


Figure 17-9 *Each set of wheels on a car is attached to an axle.*

Doorknobs are also wheels and axles. The knob is the wheel. The long piece attached to the knob, called the shaft, is the axle. See if you can get permission to remove the knob from a door. Then try to turn the shaft with your fingers. It will be difficult. Now put the knob back on. Since it is much bigger than the shaft, you can turn it easily. It turns the shaft for you and helps open the door.

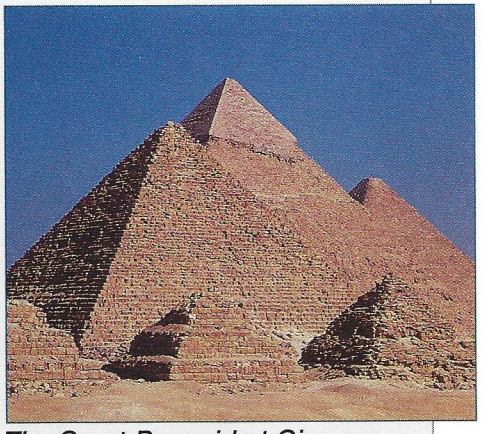
✓ **What part causes an axle to turn easily?**

A Closer Look

THE GREAT PYRAMID AT GIZA

No one knows for sure what simple machines were used to build the Great Pyramid at Giza in Egypt. Each of its 2 million blocks weighs over 2 tons. Some of the blocks are 18 feet (5.5 meters) wide and more than 7 feet (over 2 meters) high. How did people move these blocks without trucks and cranes?

They must have used giant levers to lift up the blocks and inclined planes to reach the top of the pyramid. Perhaps ropes dragged the blocks up the inclined planes or a pulley system was used. No one knows for sure.



The Great Pyramid at Giza was built about 4,500 years ago.

CRITICAL THINKING What simple machine could have been used to shape the blocks?

What Are Compound Machines?

Remember
The six simple machines are the lever, pulley, inclined plane, wheel and axle, wedge, and screw.

A *compound machine* is made of two or more simple machines. Think of a pencil sharpener. The handle is a wheel and axle. The blades that cut the pencil are wedges. Another example is the can opener. A can opener has a lever to force the blade into the can. The blade itself is a wedge. There is also a wheel and axle to turn the opener around the rim of the can.

Most machines are compound machines. Compound machines can do more difficult jobs than simple machines. Scissors, bicycles, cars, CD players, and lawn mowers are all examples of compound machines.

Most simple machines run on people power. Compound machines often use fuels such as gas or oil. Many run on electricity.

A bicycle is a compound machine made of several simple machines.

✓ **How is a compound machine different from a simple machine?**

Lesson Review

1. What are two examples of levers in your classroom?
2. A wedge and a screw are two types of another simple machine. What is it?
3. What is one example of a compound machine in your classroom? What simple machines does it include?
4. **CRITICAL THINKING** Some furniture movers use wooden platforms on wheels. How does this help?

On the Cutting Edge

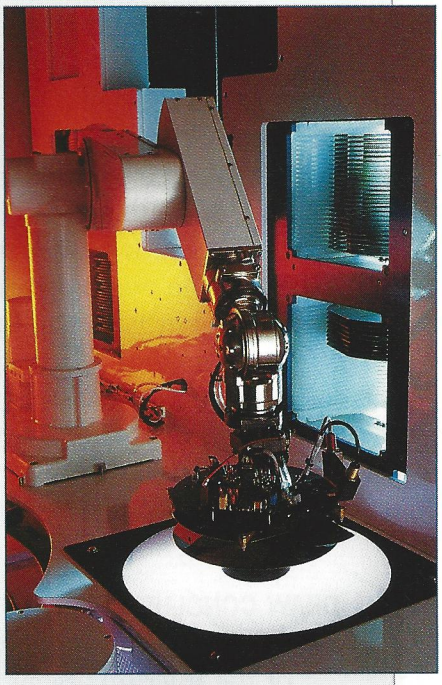
ROBOTS AT WORK

It might be nice to have compound machines known as robots doing chores in our homes. However, most of them are too clumsy to perform ordinary household tasks. Most robots today are used in factories. Robots often perform jobs that are too boring or too dangerous for humans to do.

Robots are very good at putting large products such as cars together. They can handle dangerous materials, spray finishes on items, and inspect parts. They can also cut and polish things.

Scientists today are trying to make tiny robots to do more delicate jobs in factories. These robots would put together small products such as cameras. The tiny robots would fit in a factory the size of a table top.

CRITICAL THINKING What are some possible disadvantages of using robots in factories?



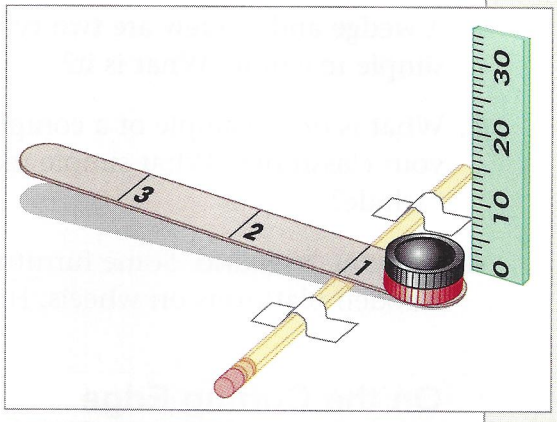
This robotic arm is making computer chips.

LAB ACTIVITY
Working With Levers

BACKGROUND
A lever is just a bar and a fulcrum. But the place you put the fulcrum makes a big difference in how useful the lever is.

PURPOSE
You will find out how the position of the fulcrum affects how a lever works.

MATERIALS
paper, pen, tape, pencil, flat stick, metric ruler, 2 checkers



Set up your experiment as shown above.

WHAT TO DO
1. Copy the chart to the right.
2. Tape a pencil to a flat surface as shown in the picture.
3. Divide the flat stick into four equal parts. Mark three of the parts 1, 2, 3 as shown.
4. Put the flat stick on the pencil so that the Line 1 mark is over the pencil.
5. Place the two checkers as shown.
6. Push gently on the other end of the stick.
7. Measure and record how high the checkers were lifted.
8. Repeat Steps 4–7 with the fulcrum at Lines 2 and 3.
9. Compare the forces used for all three lines. Record your answers in the chart.

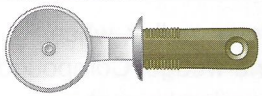
Fulcrum	Line 1	Line 2	Line 3
Height from desk top to end of stick			
Force (easiest, harder, hardest)			

DRAW CONCLUSIONS
- What can you conclude about how the position of the fulcrum affects how a lever works?

SCIENCE IN YOUR LIFE
Machines as Tools

Did you know that there are more simple machines in the kitchen than in any other room in a home? If you look at a kitchen tool catalog, you will see a great many gadgets. Some of the items have been around for a long time, while others are new inventions.

Here are some tools listed in a kitchen tool catalog:

	**Pastry Brush** This lets you spread milk, egg yolk, and cream.
	**Apple Corer** This cores fruit easily.
	**Pizza Cutter** This makes a clean cut through the crust and topping.
	**Tongs** These let you safely lift, turn, and carry food.
	**Pastry Scraper** This helps you pry rolled dough off a work surface.
	**Slotted Spoon** This lets you drain foods cooked in liquids.

Based on the information in the chart above, answer these questions.

1. Which tools are levers?
2. Which tool has a wheel and axle?
3. Which tools have wedges?
4. Which tool is a compound machine? Explain.

Critical Thinking

What four kitchen tools that are simple machines can you add to the list? Describe each tool.

Chapter

17 Review

Summary

Work is moving something through a distance, using force. A machine makes work easier by changing the speed, direction, or amount of force.

Lesson 17.1

There are two forces involved in work. Effort force is the force applied to do the work. Resistance force is the force that must be overcome if the work is to be done. The load is the object that work moves. Mechanical advantage is the number of times a machine multiplies an effort force.

Lesson 17.2

The six simple machines are the lever, pulley, wheel and axle, inclined plane, screw, and wedge. Compound machines are made of two or more simple machines put together.

Vocabulary Review

Match each definition with a term from the list.

- lever
- work
- pulley
- fulcrum
- inclined plane
- mechanical advantage
- wedge
- load

1. A slanted surface used for raising objects to another level
2. A simple machine made of two inclined planes
3. A simple machine made of a bar or rod that turns on a support
4. A measure of how helpful a machine is
5. An object to be moved
6. What happens when a force moves something through a distance
7. A support on which a lever turns
8. A wheel with grooves in its rim through which a rope or chain can run

Chapter Quiz

Write your answers on a separate sheet of paper.

1. How does a machine make work easier?
2. What is the force that must be defeated in work?
3. What force is put into a machine to do work?
4. Where is the fulcrum in a Class 1 lever?
5. Where would you place the fulcrum of a lever to lift a heavy load most easily?
6. What simple machine lets you raise a load by pulling down on a rope?
7. What two simple machines are types of inclined planes?
8. What kind of simple machine is a doorknob?
9. What kind of machines are most machines?
10. A pencil sharpener is a compound machine. What two simple machines is it made up of?

Test Tip
To prepare for a test, be sure you can do all the Learning Objectives given at the beginning of the chapter.

Research Project

Most machines were invented to make everyday tasks easier. Research information about three of these machines in encyclopedias or on the Internet. Make a chart that shows the following information about each machine: description, job, inventor's name, date invented, and use.