CHAPTER 5

Work and Machines

Paola Pezzo couldn't have won a gold medal in the 2000 Summer Olympic Games without a machine—her mountain bike. Can you imagine your life without machines? Think of all the machines you use every day—in-line skates, staplers, pencil sharpeners. Machines make work easier. Many machines are simple. Others, such as mountain bikes and automobiles, are combinations of many simple machines. What kinds of machines are in a mountain bike? In this chapter, you will learn about simple and compound machines and how they change forces to make work easier.

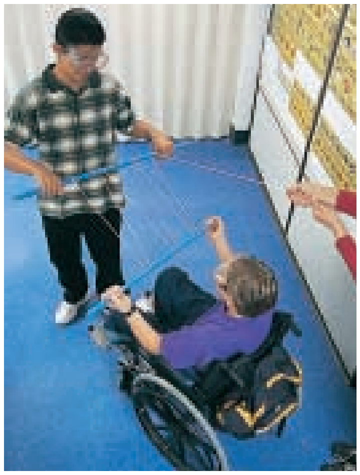
What do you think?

Science Journal Look at the picture below with a classmate. Discuss what you think is happening. Here's a hint: *This makes a carpenter's work easier.* Write your answer or best guess in your Science Journal.

Explore Activity

Before the hydraulic lift, mechanics used a pulley to raise cars off the ground. The pulley had many grooved wheels and a long chain threaded through them. The mechanic had to pull several meters of chain just to raise the car a few centimeters. In this activity, make your own pulley and experience the advantage of using simple machines.

Construct a Pulley



1. Tie a rope several meters in length to the center of a broom handle. Have one student hold both ends of the handle.
2. Have another student hold the ends of a second broom handle and face the first student. The two handles should be parallel, a meter apart.
3. Have a third student loop the free end of the rope around the second handle. Continue wrapping, making six or seven loops.
4. The third student should stand to the side of one of the handles and pull on the free end of the rope. The two students holding the broom handles should prevent the handles from coming together.

Observe

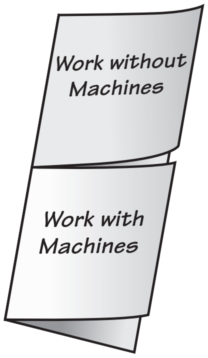
Write a paragraph in your Science Journal describing what happened when the rope was pulled. How far did the rope have to be pulled to bring the handles together?

Before You Read

Foldables Reading & Study Skills

Making a Compare and Contrast Study Fold **Make the following Foldable to see how work and machines are similar and different.**

1. Place a sheet of paper in front of you so the short side is at the top. Fold the paper in half from the left side to the right side and unfold.
2. Through the top thickness of paper, cut along the middle fold line to form two tabs. Label them *Work without Machines* and *Work with Machines*.
3. List examples of work you do without machines under its tab. As you read the chapter, rate the work you did without machines on a scale of 1 (little force) to 10 (great force). Write it next to the work.



SECTION 1

Work

As You Read

What You'll Learn

- **Explain** the meaning of work.
- **Explain** how work and energy are related.
- **Calculate** work.
- **Calculate** power.

Vocabulary

work
power

Why It's Important

Learning the scientific meaning of work is a key to understanding how machines make life easier.

What is work?

Press your hand against the surface of your desk as hard as you can. Although your muscles might start to feel tired, you haven't done any work. Most people feel that they have done work if they push or pull something. However, the scientific meaning of work is more specific. **Work** is the transfer of energy that occurs when a force makes an object move. Recall that a force is a push or a pull. For work to be done, a force must make something move. If you push against the desk and nothing moves, you haven't done any work.

Doing Work Two conditions have to be satisfied for work to be done on an object. One is that the object has to move, and the other is that the motion of the object must be in the same direction as the applied force. For example, if you pick up a pile of books from the floor as in **Figure 1,** you do work on the books. The books move upward in the direction of the force you are applying. If you hold the books in your arms without moving, you are not doing work on the books. You're still applying an upward force to keep the books from falling, but no movement is taking place.

Figure 1
When you lift a stack of books, your arms apply a force upward and the books move upward. Because the force and distance are in the same direction, your arms have done work on the books.

Direction of Motion Now suppose you start walking as in **Figure 2.** The books are moving horizontally, but your arms still do no work on the books. The force exerted by your arms is still upward, and is at right angles to the direction the books are moving. It is your legs that are exerting the force that causes you and the books to move forward. It is your legs, not your arms, that cause work to be done on the books.

Reading Check *What must you ask to determine if work is being done?*

Figure 2
If you hold a stack of books and walk forward, your arms are exerting a force upward. However, the distance the books move is horizontal. Therefore your arms are not doing work on the books. *Does this mean no work is done on the books? Explain.*

Work and Energy

How are work and energy related? When work is done, a transfer of energy always occurs. This is easy to understand when you think about how you feel after carrying a heavy box up a flight of stairs. Remember that when the height of an object above Earth's surface increases, the potential energy of the object increases. You transferred energy from your moving muscles to the box and increased its potential energy by increasing its height.

You may recall that energy is the ability to cause change. Another way to think of energy is that energy is the ability to do work. If something has energy, it can transfer energy to another object by doing work on that object. When you do work on an object, you increase its energy. If you do work, such as the person carrying the box in **Figure 3,** your energy decreases. Energy is always transferred from the object that is doing the work to the object on which the work is done.

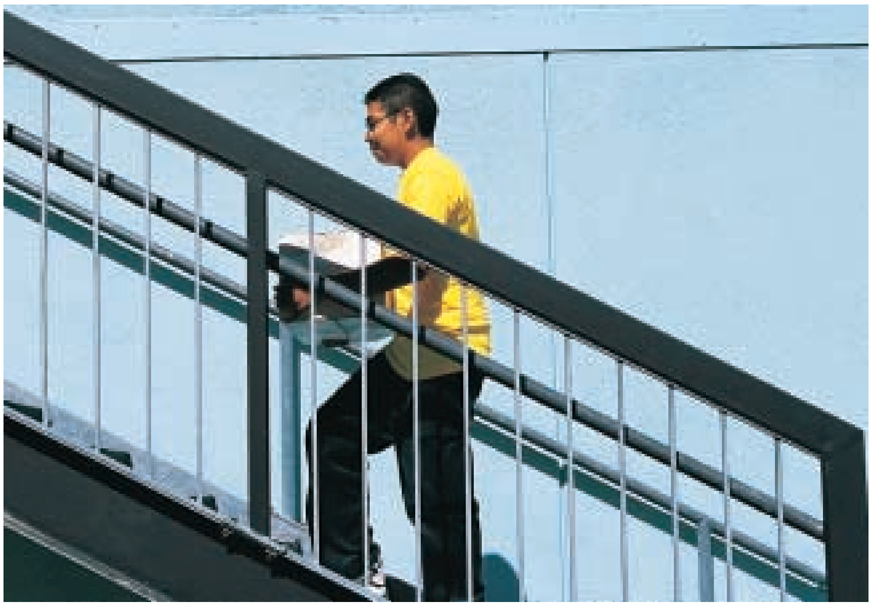


Figure 3
By carrying a box up the stairs, you are doing work. You transfer some of your energy to the box. *How is work done on the box?*

Calculating Work

Which of these tasks would involve more work—lifting a pack of gum or a pile of books from the floor to waist level? Would you do more work if you lifted the books from the floor to your waist or over your head? You probably can guess the answers to these questions. You do more work when you exert more force and when you move an object a greater distance. In fact, the amount of work done depends on two things: the amount of force exerted and the distance over which the force is applied.

When a force is exerted and an object moves in the direction of the force, the amount of work done can be calculated as follows.

$$\textit{Work} = \textit{force} \times \textit{distance}$$
$$W = F \times d$$

In this equation, force is measured in newtons (N) and distance is measured in meters. Work, like energy, is measured in joules. One joule is about the amount of work required to lift a baseball a vertical distance of 0.7 m.

Math Skills Activity

Calculating Work Given Force and Distance

Example Problem

You move a 75-kg refrigerator 35 m. This requires a force of 90 N. How much work, in joules, was done while moving the refrigerator?

Solution

1. *This is what you know:* force: $F = 90$ N; distance: $d = 35$ m; 1 newton-meter (N·m) = 1 joule (J)
2. *This is what you need to find:* Work W
3. *This is the equation you need to use:* $W = F \times d$
4. *Substitute the known values:* $W = (90 \text{ N}) \times (35 \text{ m}) = 3{,}150 \text{ N·m} = 3{,}150 \text{ J}$

Check your answer by dividing the work you calculated by the given distance. Did you calculate the force that was given?

Practice Problem

When you and a friend move a 45-kg couch to another room, you exert a force of 75 N over 5 m. How much work, in joules, did you do?

For more help, refer to the Math Skill Handbook.

Figure 4
A softball pitcher exerts a force on the ball to throw it to the catcher. After the ball leaves her hand, she no longer is exerting any force on the ball. The only work she does on the ball is moving it from the back of the pitch to the release.

When is work done? Suppose you give a book a push and it slides along a table for a distance of 1 m before it comes to a stop. The distance you use to calculate the work you did is how far the object moves while the force is being applied. Even though the book moved 1 m, you do work on the book only while your hand is in contact with it. The distance in the formula for work is the distance the book moved while your hand was pushing on the book. As **Figure 4** shows, work is done on an object only when a force is being applied to the object.

Power

Suppose you and another student are pushing boxes of books up a ramp to load them into a truck. To make the job more fun, you make a game of it, racing to see who can push a box up the ramp faster. The boxes weigh the same, but your friend is able to push a box a little faster than you can. She moves a box up the ramp in 30 s. It takes you 45 s. You both do the same amount of work on the books because the boxes weigh the same and are moved the same distance. The only difference is the time it takes to do the work.

In this game, your friend has more power than you do. **Power** is the amount of work done in a certain amount of time. It is a rate—the rate at which work is done.

Reading Check *How is power related to work?*

Mini LAB

Calculating Your Work and Power

Procedure

1. Find a set of **stairs** that you can safely walk and run up. Measure the total height of the stairs in meters.
2. Record how many seconds it takes you to walk and run up the stairs.
3. Calculate the work you did in walking and running up the stairs using $W = F \times d$. For force, use your weight in newtons (your weight in pounds $\times$ 4.5).
4. Use the formula $P = W/t$ to calculate the power you needed to walk and run up the stairs.

Analysis

1. Is the work you did walking and running the steps the same?
2. Which required more power—walking or running up the steps? Why?

CONTENTS

SCIENCE Online

Research Visit the Glencoe Science Web site at **science.glencoe.com** for more information about energy-efficient devices. Communicate to your class what you learn.

CLICK HERE

Calculating Power To determine the power you deliver by pushing a box up the ramp, you need a way to calculate power. To calculate power, divide the work done by the time that is required to do the work.

$$\text{Power} = \text{work/time}$$
$$P = W/t$$

Power is measured in watts, named for James Watt, who helped develop the steam engine in the eighteenth century. A watt (W) is 1 J/s. A watt is fairly small—about equal to the power needed to raise a glass of water from a table to your mouth in 1 s. Because the watt is such a small unit, large amounts of power often are expressed in kilowatts. One kilowatt (kW) equals 1,000 W. If you were to run up a flight of steps in about 1.5 s, it would take about 1 kW of power.

Math Skills Activity

Calculating Power Given Work and Time

Example Problem

It took five minutes to move a refrigerator. You did 3,150 joules of work in the process. How much power was required to move the refrigerator?

Solution

1. *This is what you know:* Work: $W = 3{,}150$ J
   Time: $t = 5$ min $= 300$ s
   1 J/s = 1 W
2. *This is what you need to find:* Power (P)
3. *This is the equation you need to use:* $P = W/t$
4. *Substitute the known values:* $P = 3{,}150 \text{ J}/300 \text{ s} = 10.5 \text{ J/s} = 10.5 \text{ W}$

Check your answer by multiplying the power you calculated by the time given in the problem. Did you calculate the same work that was given?

Practice Problem

How much power is required to push a car for 10 seconds if the amount of work done during that time is 5,500 joules?

For more help, refer to the Math Skill Handbook.

Power and Energy Doing work is a way of transferring energy from one object to another. Remember that energy can be transferred in other ways that don't involve doing work. For example, a lightbulb like the one in **Figure 5** uses electrical energy to produce heat and light, but no work is done. Power is produced or used any time energy is transferred from one object to another. Power is the energy transferred divided by the time needed for the transfer to occur. Anytime energy is transferred from one object to another, power can be calculated from the following equation.

$$\text{Power} = \text{energy/time}$$
$$P = E/t$$

Changing Energy by Doing Work What happens to the energy of a book when you lift it off your desk? You changed the height of the book, so its potential energy increased. Where did this increase in energy come from? You transferred energy to the book by doing work on the book when you lifted it. You can also increase the kinetic energy of an object by doing work on it, as when you push furniture from one place to another. In another example, think about using sandpaper on a piece of wood. Feel the wood and you will notice that it is warm. The energy of the wood has increased in the form of heat from friction. Anytime you do work on an object, you cause its energy to increase.

Figure 5
This 100 W lightbulb uses energy at 100 J/s, converting electrical energy into light and heat. *Even though energy is being transferred, why is no work done?*

Section 1 Assessment

1. Explain how the scientific definition of work is different from the everyday meaning.
2. How are work and energy related?
3. A person pushed a bowling ball 20 m. The amount of work done was 1,470 J. How much force did the person exert?
4. How are power, work, and time related?
5. **Think Critically** In which of the following situations is work being done? Explain.
   - A person shovels snow off a sidewalk.
   - A worker lifts bricks, one at a time, from the ground to the back of a truck.
   - A roofer's assistant carries a bundle of shingles across a construction site.

Skill Builder Activities

6. **Solving One-Step Equations** A passenger weighing 500 N is inside an elevator weighing 24,500 N that rises 30 m in 1 min. How much power is needed for the elevator's trip? **For more help, refer to the Math Skill Handbook.**
7. **Communicating** In your Science Journal, write down everything you did today that would be considered work in the everyday sense. From this list, choose one task that also fits the scientific description of work. Write a paragraph explaining how the task fits the scientific and the everyday descriptions. **For more help, refer to the Science Skill Handbook.**

SECTION

2 Using Machines

As You Read

What You'll Learn

- **Explain** how machines make work easier.
- **Calculate** mechanical advantage.
- **Calculate** efficiency.

Vocabulary

machine
effort force
resistance force
mechanical advantage
efficiency

Why It's Important

Complex devices are made up of simpler parts called simple machines. Even your body contains simple machines.

What is a machine?

How many machines did you use today? Did you cut your food with a knife? Or maybe you used a pair of scissors? If you did, you used a machine. A **machine** is a device that makes doing work easier. When you think of a machine you may picture a device with an engine and many moving parts. But not all machines are complicated or powered by engines or electric motors. Machines can be simple, and can be powered by a force applied by a person. Some, like knives, scissors, and doorknobs, are used everyday to make doing work easier.

Making Work Easier

Machines can make work easier by increasing the force that can be applied to an object. A bottle opener increases the force you can apply to a bottle cap, causing the cap to bend. A car jack enables you to lift a heavy automobile. A second way that machines can make work easier is by increasing the distance over which a force can be applied. A leaf rake is an example of this type of machine. Machines can also make work easier by changing the direction of an applied force. When you open window blinds by pulling on a cord, the downward force on the cord is changed to an upward force that opens the blinds.

Figure 6
A car jack works by increasing your force.

Increasing Force Nobody could lift a car to change a flat tire without help. A car jack, like the one in **Figure 6,** is an example of a machine that multiplies your force.

Remember that work is the product of force and distance. You can do the same amount of work by applying a small force over a long distance as you can by applying a large force over a short distance. For example, the distance you push the handle of a car jack downward is longer than the distance the car moves upward, and the upward force exerted by the jack is greater than the downward force you exert on the handle. Can you think of other machines that multiply force?

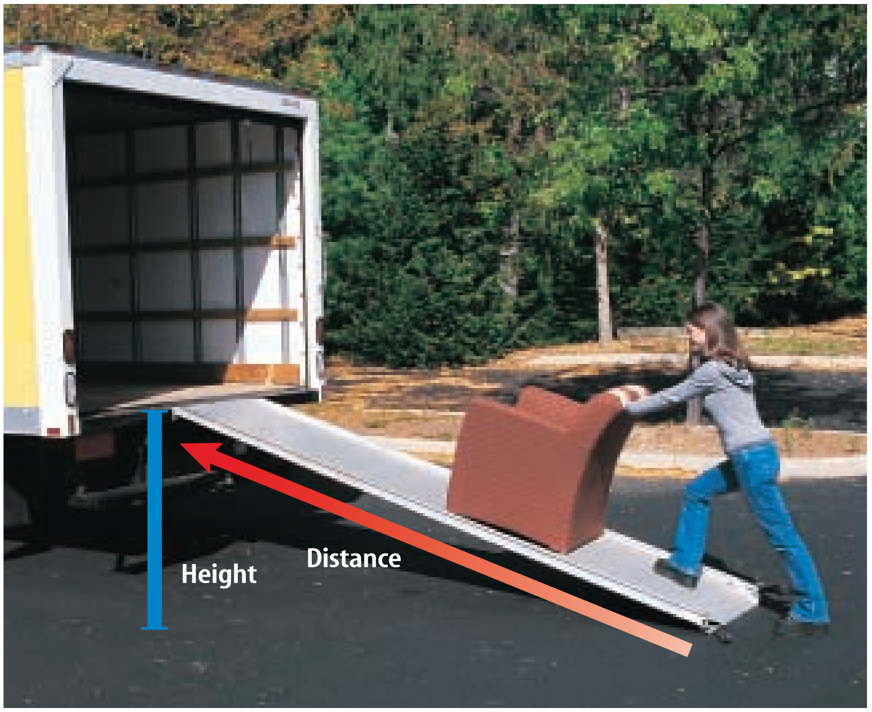


Figure 7
Whether the mover slides the chair up the ramp or lifts it directly into the truck, she will do the same amount of work. Doing the work over a longer distance allows her to use less force.

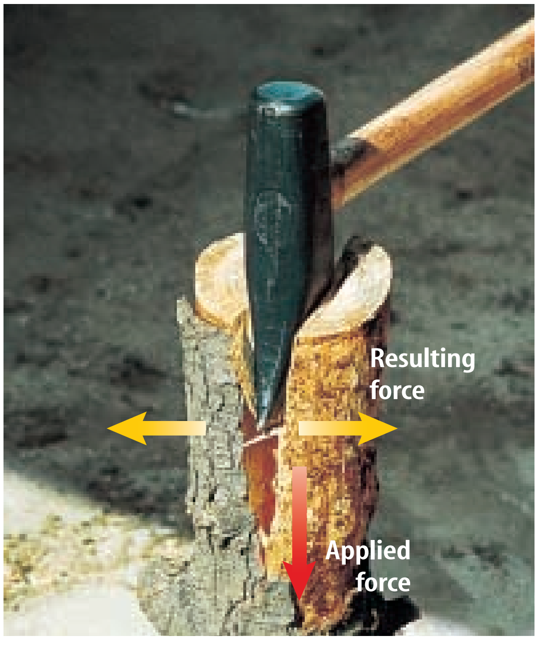
Increasing Distance Why does the mover in **Figure 7** push the heavy furniture up the ramp instead of lifting it directly into the truck? It is easier for her because less force is needed to move the furniture.

The work done in lifting an object depends on the change in height of the object. The same amount of work is done whether the mover pushes the furniture up the long ramp or lifts it straight up. If she uses a ramp to lift the furniture, she moves the furniture a longer distance than if she just raised it straight up. If work stays the same and the distance is increased, then less force will be needed to do the work.

Reading Check *How does a ramp make lifting an object easier?*

Changing Direction Some machines change the direction of the force you apply. When you use the car jack, you are exerting a force downward on the jack handle. The force exerted by the jack on the car is upward. The direction of the force you applied is changed from downward to upward. Some machines change the direction of the force that is applied to them in another way. The wedge-shaped blade of an ax is one example. When you use an ax to split wood, you exert a downward force as you swing the ax toward the wood. As **Figure 8** shows, the blade changes the downward force into a horizontal force that splits the wood apart.

Figure 8
An ax blade changes the direction of the force from vertical to horizontal.



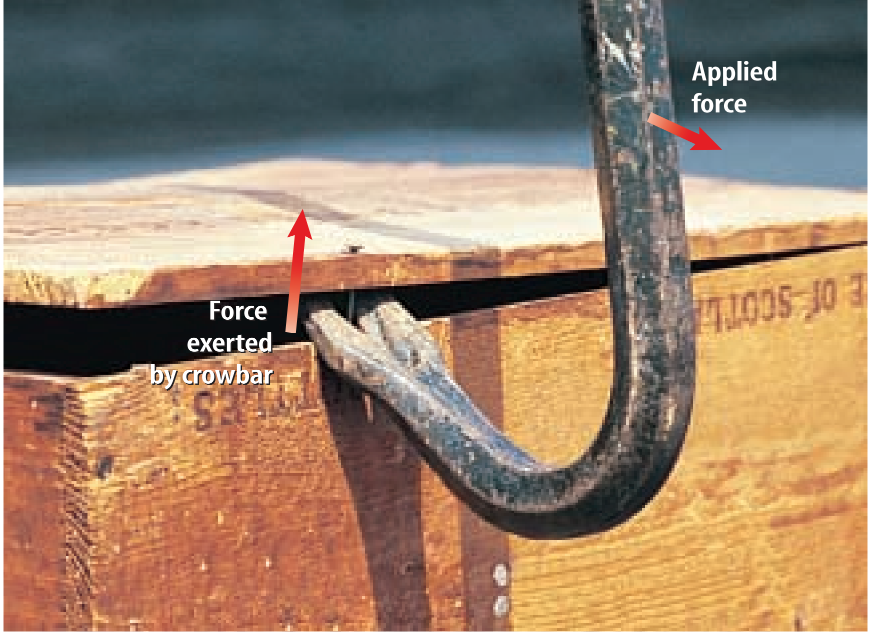


Figure 9
A crowbar increases the force you apply and changes its direction.

TRY AT HOME
Mini LAB

Machines Multiplying Force

Procedure
1. Open a **can of food** using a **manual can opener**. **WARNING:** Do not touch can opener's cutting blades or cut edges of the can's lid.
2. Use a **metric ruler** to measure the diameter of the cutting blade of the can opener.
3. Measure the length of the handle you turn.

Analysis
1. Compare how difficult it is to open the can using the can opener with how difficult it would have been to open the can by turning the cutting blade with a smaller handle.
2. Compare the diameter of the cutting blade with the diameter of the circle formed by turning the can opener's handle.
3. Infer why a can opener makes it easier to open a metal can.

The Work Done by Machines

To pry the lid off a wooden crate with a crowbar, you'd slip the end of the crowbar under the edge of the crate lid and push down on the handle. By moving the handle downward, you do work on the crowbar. As the crowbar moves, it does work on the lid, lifting it up. **Figure 9** shows how the crowbar increases the amount of force being applied and changes the direction of the force.

When you use a machine such as a crowbar, you are trying to move something that resists being moved. For example, if you use a crowbar to pry the lid off a crate, you are working against the friction between the nails in the lid and the crate. You also could use a crowbar to move a large rock. In this case, you would be working against gravity—the weight of the rock.

Effort and Resistance Forces Two forces are involved when a machine is used to do work. You exert a force on the machine, such as a bottle opener, and the machine then exerts a force on the object you are trying to move, such as the bottle cap. The force applied to the machine is called the **effort force.** F_e stands for the effort force. The force applied by the machine to overcome resistance is called the **resistance force,** symbolized by F_r. When you try to pull a nail out with a hammer as in **Figure 10,** you apply the effort force on the handle. The resistance force is the force the claw applies to the nail.

Two kinds of work need to be considered when you use a machine—the work done by you on the machine and the work done by the machine. When you use a crowbar, you do work when you apply force to the crowbar handle and make it move. The work done by you on a machine is called the input work and is symbolized by W_{in}. The work done by the machine is called the output work and is abbreviated W_{out}.

Conserving Energy Remember that energy is always conserved. When you do work on the machine, you transfer energy to the machine. When the machine does work on an object, energy is transferred from the machine to the object. Because energy cannot be created or destroyed, the amount of energy the machine transfers to the object cannot be greater than the amount of energy you transfer to the machine. A machine cannot create energy, so W_{out} is never greater than W_{in}.

However, the machine does not transfer all of the energy it receives to the object. In fact, when a machine is used, some of the energy transferred changes to heat due to friction. The energy that changes to heat cannot be used to do work, so W_{out} is always smaller than W_{in}.

Figure 10
When prying a nail out of a piece of wood with a claw hammer, you exert the effort force on the handle of the hammer, and the claw exerts the resistance force.

Ideal Machines Remember that work is calculated by multiplying force by distance. The input work is the product of the effort force and the distance over which the effort force is exerted. The output work is the product of the resistance force and the distance that force moves the object.

Suppose a perfect machine could be built in which there was no friction. None of the input work or output work would be converted to heat. For such an ideal machine, the input work equals the output work. So for an ideal machine,

$$W_{in} = W_{out}$$

Suppose the ideal machine increases the force applied to it. This means that the resistance force, F_r, is greater than the effort force F_e. Recall that work is equal to force times distance. If F_r is greater than F_e, then W_{in} and W_{out} can be equal only if the effort force is applied over a greater distance than the resistance force is exerted over.

For example, suppose the hammer claw in **Figure 10** moves a distance of 0.10 m to remove a nail. If a resistance force of 1,500 N is exerted by the claw of the hammer, and you move the handle of the hammer 0.5 m, you can find the effort force as follows.

$$\begin{aligned} W_{in} &= W_{out} \\ F_e \times d_e &= F_r \times d_r \\ F_e \times (0.5\ \text{m}) &= (1{,}500\ \text{N}) \times (0.1\ \text{m}) \\ F_e \times (0.5\ \text{m}) &= 150\ \text{N·m} \\ F_e &= 300\ \text{N} \end{aligned}$$

Because the distance you move the hammer is longer than the distance the hammer moves the nail, the effort force is less than the resistance force.

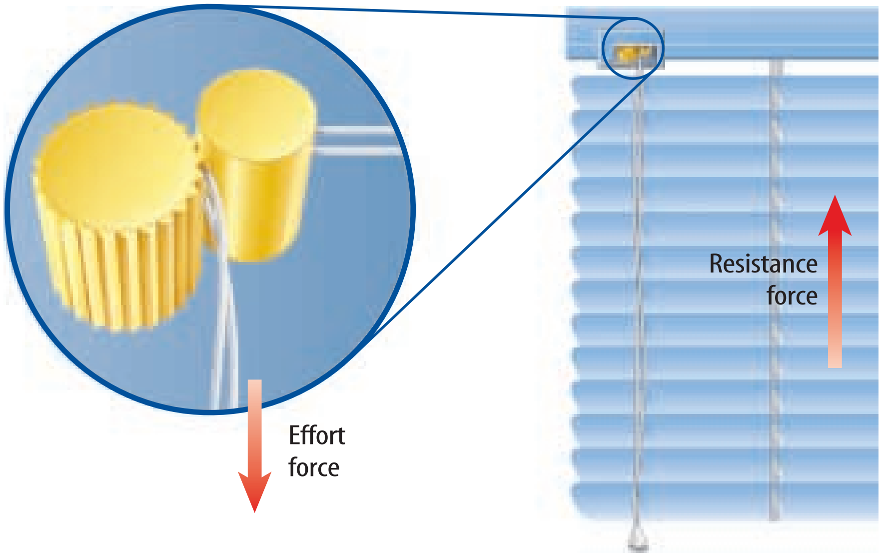


Figure 11
Mini blinds are a familiar example of a simple machine that changes the direction of a force. When you pull down on the cord, the direction of your force is changed to upward. Because the effort force equals the resistance force, the MA of the mini blinds is 1.

Mechanical Advantage

Think again about the crowbar example. The crowbar increases the force you apply, so the force exerted on the crate lid is greater than the force you exert on the handle. In other words, the resistance force is greater than the effort force. However, just as for the hammer, the effort distance you move the crowbar handle is greater than the distance the crowbar moves the lid. The machine multiplies your effort, but you must move the handle a greater distance.

The number of times a machine multiplies the effort force is the **mechanical advantage** (MA) of the machine. To calculate mechanical advantage, you divide the resistance force by the effort force. Some machines simply change the direction of the effort force, such as the window blinds in **Figure 11.** When only the direction of the force changes, the effort force and resistance force are equal, so the mechanical advantage is 1.

Chemistry INTEGRATION

A material called graphite is sometimes used as a lubricant to increase the efficiency of machines. Find out what element graphite is made of and infer why graphite eases the movement of machines.

Efficiency

When you use a hammer to pull a nail out of a piece of wood, the friction between the wood and the nail causes the nail to get warm as it's pulled out. For real machines, some of the energy put into a machine is always lost as heat produced by friction. For that reason, the output work of a machine is always less than the work put into the machine. Machines that lose less energy to friction are said to be more efficient.

Efficiency is a measure of how much of the work put into a machine is changed into useful output work by the machine. A machine with high efficiency produces less heat from friction so more of the input work is changed to useful output work.

Reading Check *What is the efficiency of a machine?*

Calculating Efficiency To calculate the efficiency of a machine, the output work is divided by the input work. Efficiency is usually expressed as a percentage by this equation:

$$\text{efficiency} = \left(\frac{W_{out}}{W_{in}}\right) \times 100\%$$

Because friction causes the output work to always be less than the input work, the efficiency of a real machine is always less than 100 percent. Because no machine is 100 percent efficient, the actual mechanical advantage is always less than the mechanical advantage of an ideal machine.

Machines can be made more efficient by reducing friction. This usually is done by adding a lubricant, such as oil or grease, to surfaces that rub together, as shown in **Figure 12.** When a lubricant is used in a machine, it fills in the gaps between the surfaces. This allows the two surfaces to slide more easily across each other, reducing friction and increasing efficiency. Sometimes, dirt will build up on the lubricant, and it will lose its effectiveness. The dirty lubricant should be wiped off and replaced with clean oil or grease.

You might have heard some household appliances or automobiles described as being energy efficient. By using less energy to do work, these machines cost less to operate. They also help conserve resources, such as coal, oil, and natural gas, that are used to produce electricity.

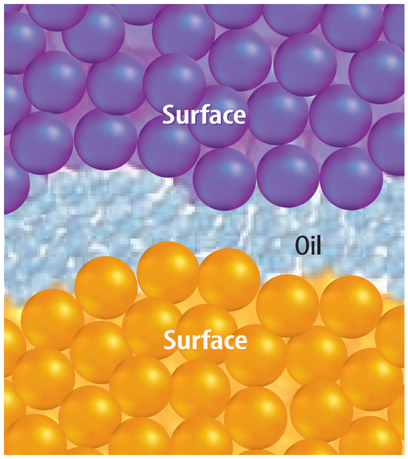


Figure 12
Oil reduces the friction between two surfaces. Oil fills the space between the surfaces so high spots don't rub against each other.

Section 2 Assessment

1. Explain how machines can make work easier without violating the law of conservation of energy.
2. A claw hammer is used to pull a nail from a board. If the claw exerts a resistance of 2,500 N to the applied effort force of 125 N, what is the MA of the hammer?
3. Explain why W_{out} is always less than W_{in}.
4. How would you calculate the efficiency of a machine?
5. **Think Critically** Give an example of a machine you've used recently. How did you apply effort force? How did the machine apply resistance force?

Skill Builder Activities

6. **Recognizing Cause and Effect** When you operate a machine, it's often easy to observe cause and effect. For example, when you turn a doorknob, the latch in the door moves. Give five examples of machines and describe one cause-and-effect pair in the action of each machine. **For more help, refer to the Science Skill Handbook.**
7. **Solving One-Step Equations** Suppose you want to use a machine to lift a 6,000-N log. What effort force will you need if your machine has a mechanical advantage of 25? 15? 1? Show your calculations. **For more help, refer to the Math Skill Handbook.**

SECTION 3

Simple Machines

As You Read

What You'll Learn

- **Describe** the six types of simple machines.
- **Calculate** the ideal mechanical advantage for different types of simple machines.

Vocabulary

simple machine, lever, pulley, wheel and axle, inclined plane, screw, wedge, compound machine

Why It's Important

If you know the principles behind simple machines, you'll make better use of everyday tools.

Types of Simple Machines

Without realizing it, you use many simple machines every day. A **simple machine** is a machine that does work with only one movement. The six types of simple machines are: lever, pulley, wheel and axle, inclined plane, screw, and wedge. As you'll see, the pulley and wheel and axle are modified forms of the lever, and the screw and wedge are modified forms of the inclined plane.

Reading Check *All simple machines are variations of which two basic machines?*

Levers

You probably won't try to pry the cap off a soft drink bottle with your fingers. Instead you would use a bottle opener to remove the cap. A bottle opener like the one in **Figure 13** is an example of a lever. A **lever** is a bar that is free to pivot, or turn, about a fixed point. The fixed point on the lever is called the fulcrum. The distance from the fulcrum to where the effort force is applied is called the effort arm. The distance from the fulcrum to where the resistance force is applied is called the resistance arm.

There are three different classes of levers. The differences are based upon the positions of the effort force, resistance force, and fulcrum.

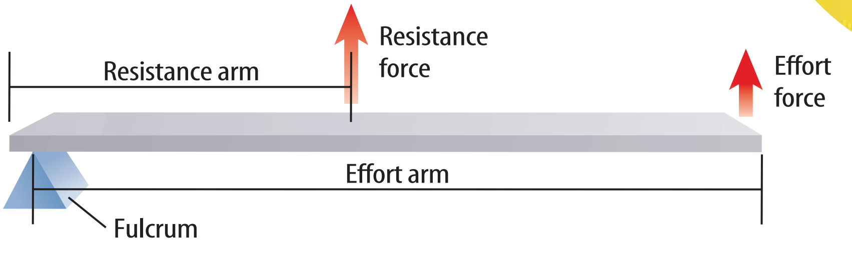
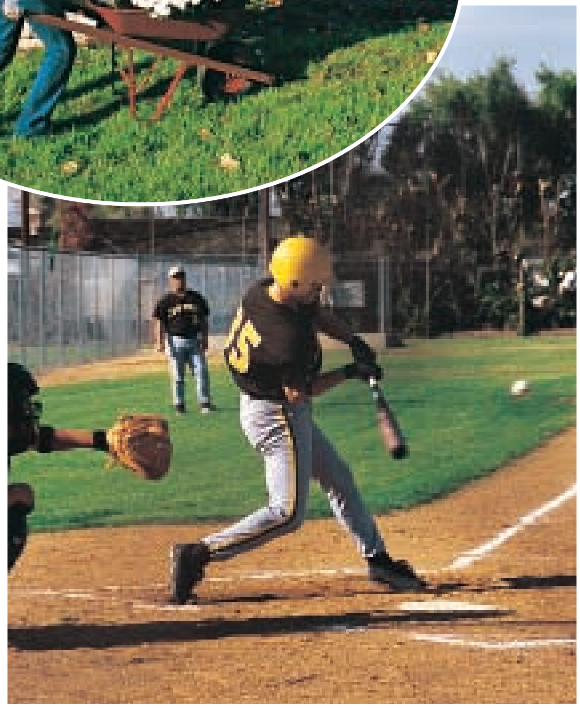


Figure 13
When you push up on the bottle opener (effort force), the opener bends the cap up (resistance force). *What acts as the fulcrum in a bottle opener?*

Figure 14
Levers are classified by the location of the effort force, resistance force, and the fulcrum.

A **For a first-class lever, the fulcrum is between the effort force and resistance force.**

B **For a second-class lever, the resistance force is between the effort force and the fulcrum.**



C **For a third-class lever, the effort force is between the resistance force and the fulcrum.**

Types of Levers To determine the class of a lever, you need to know where the effort and resistance forces are exerted relative to the fulcrum. The screwdriver used to open the can of paint in **Figure 14A** is an example of a first-class lever. In a first-class lever, the fulcrum is located between the effort and resistance forces. A first-class lever is used to multiply force, and it always changes the direction of the applied force.

In a second-class lever, the resistance force is located between the effort force and fulcrum. Look at the wheelbarrow in **Figure 14B.** You provide the effort force at the end, and the wheel acts as the fulcrum. The load you are lifting, the resistance force, is located in between. Second-class levers always multiply force.

Many pieces of sports equipment are examples of third-class levers. In a third-class lever, the effort force is located between the resistance force and fulcrum. Think about swinging a baseball bat like the one in **Figure 14C.** If you are right-handed, you hold the base of the bat with your left hand—the fulcrum. You use your right hand to apply the effort force and swing the bat. The resistance force is provided by the baseball when it hits the bat. Third-class levers cannot multiply force because the effort arm is always smaller than the resistance arm. Instead they increase the distance over which the resistance force is applied.

Every lever can be placed into one of these classes. Each class can be found in your body, as shown in **Figure 15** on the next page.

NATIONAL GEOGRAPHIC

VISUALIZING LEVERS IN THE HUMAN BODY

Figure 15

Fulcrum
Effort force
Resistance force

All three types of levers—first-class, second-class, and third-class—are found in the human body. The forces exerted by muscles in your body can be increased by first-class and second-class levers, while third-class levers increase the range of movement of a body part. Examples of how the body uses levers to help it move are shown here.

FIRST-CLASS LEVER The fulcrum lies between the effort force and the resistance force. Your head acts like a first-class lever. Your neck muscles provide the effort force to support the weight of your head.

SECOND-CLASS LEVER The resistance force is between the fulcrum and the effort force. Your foot becomes a second-class lever when you stand on your toes.

THIRD-CLASS LEVER The effort force is between the fulcrum and the resistance force. A third class lever increases the range of motion of the resistance force. When you do a curl with a dumbbell, your forearm is a third-class lever.

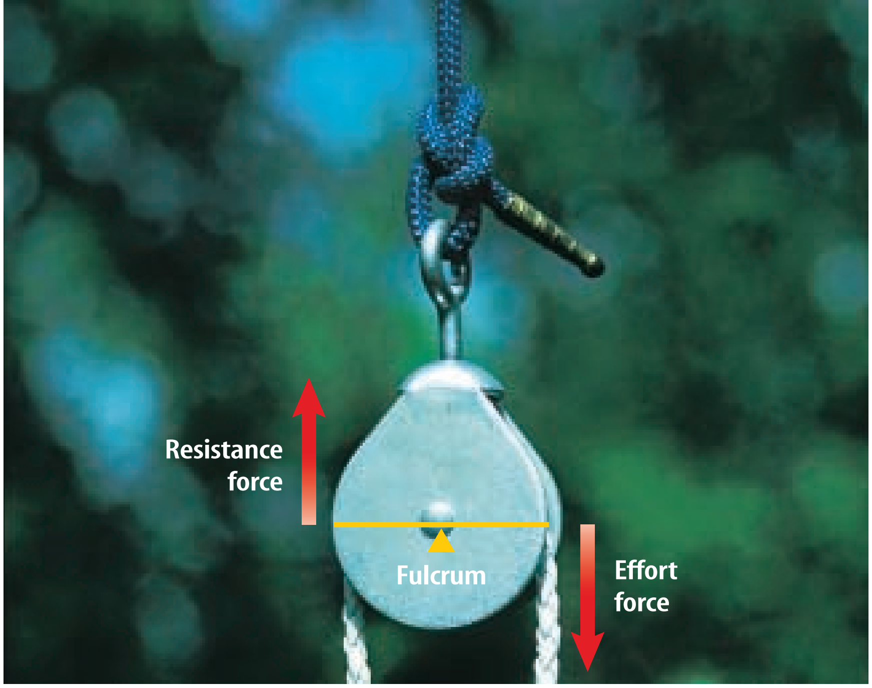


Figure 16
A fixed pulley is another form of the lever. *What are the lengths of the effort arm and resistance arm in a pulley?*

Mechanical Advantage of a Lever The bottle opener makes work easier by multiplying your effort force and changing the direction of your force. To calculate the ideal mechanical advantage (IMA) of the lever, you can use the lengths of the arms of the lever. The distance from the fulcrum to the place you exert your force is the effort arm. The resistance arm is the distance from the fulcrum to the point the resistance force is applied. Assuming no friction, the IMA is as follows:

$$\text{IMA} = \frac{\text{length of effort arm}}{\text{length of resistance arm}} = \frac{L_e}{L_r}$$

Making the effort arm longer increases the ideal mechanical advantage.

Pulleys

What causes an elevator to rise? A cable attached to the elevator is wrapped around a pulley, allowing the elevator to be raised and lowered. A **pulley** is a grooved wheel with a rope, chain, or cable running along the groove. A fixed pulley is a modified first-class lever, as shown in **Figure 16.** The axle of the pulley acts as the fulcrum. The two sides of the pulley are the effort arm and resistance arm. A pulley can multiply the effort force, but all pulleys can change the direction of the effort force.

Fixed Pulleys The cable attached to an elevator passes over a fixed pulley at the top of the elevator shaft. A fixed pulley, such as the one in **Figure 17,** is attached to something that doesn't move, such as a ceiling or wall. Because a fixed pulley changes only the direction of force, the effort force is not multiplied and the IMA is 1.

Figure 17
A fixed pulley changes only the direction of your force. You still need to apply 4 N of force to lift the weight.

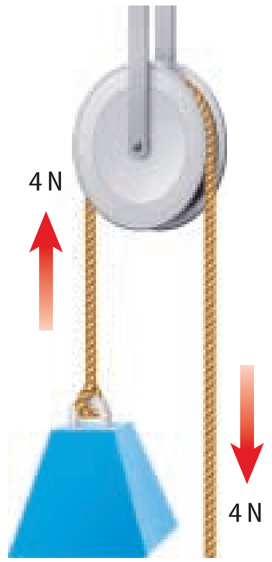
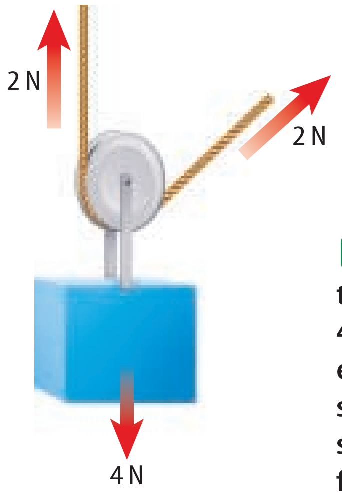
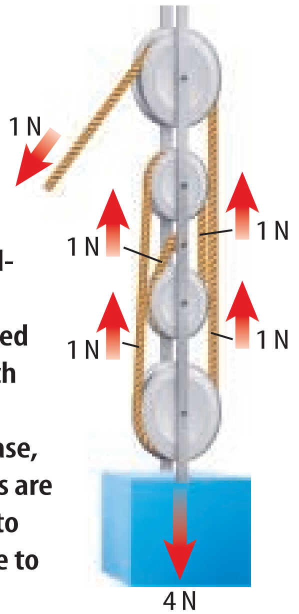


Figure 18
The fixed pulley does not multiply force, while a movable pulley and block and tackle do.



A **With a movable pulley, the attached side of the rope supports half of the 4-N weight.**



B **In a block-and-tackle system, the 4-N weight is divided equally among each supporting rope segment. In this case, four rope segments are used, so you have to use only a 1-N force to lift the weight.**

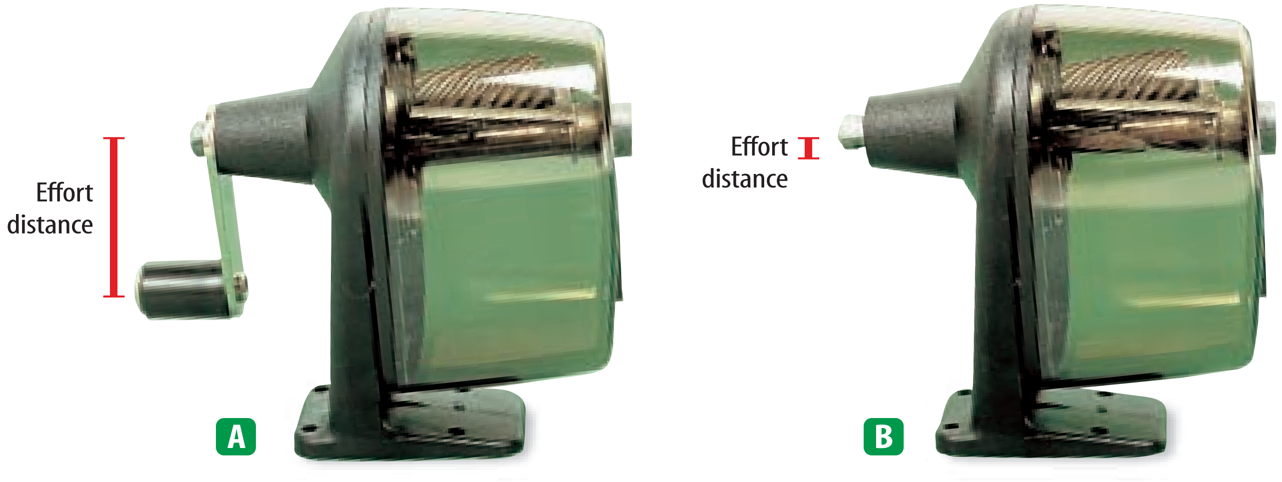
Movable Pulleys A pulley in which one end of the rope is fixed and the wheel is free to move is called a movable pulley. Unlike a fixed pulley, a movable pulley does multiply force. Suppose a 4-N weight is hung from the movable pulley in **Figure 18A.** The ceiling acts like someone helping you to lift the weight. The string attached to the ceiling will support half of the weight—2 N. You need to exert only the other half of the weight—2 N—in order to support and lift the weight. Since the resistance force is 4 N and your effort force is 2 N, the IMA of the movable pulley will be 2.

Because the movable pulley increases your effort force, the distance must increase to conserve energy. The IMA is 2, so the distance you pull must be twice as large as the resistance distance.

Reading Check *How does a movable pulley multiply the effort force?*

The Block and Tackle A system of pulleys consisting of fixed and movable pulleys is called a block and tackle. **Figure 18B** shows a block and tackle made up of two fixed pulleys and two movable pulleys. If a 4-N weight is suspended from the movable pulley, each rope segment supports one fourth of the weight, reducing the effort force to 1 N. The IMA of a pulley system is equal to the number of rope segments that support the resistance weight. A block and tackle can have a large mechanical advantage. When designing a block and tackle you must keep in mind that the more pulleys that are involved, the effects of friction are greater, which will reduce the overall mechanical advantage.

Figure 19
If the handle on the pencil sharpener were removed, you would be unable to sharpen your pencil.



Wheel and Axle

Could you use the pencil sharpener in **Figure 19** if the handle weren't attached? The handle on the pencil sharpener is an example of a wheel and axle. A **wheel and axle** is a machine consisting of two wheels of different sizes that rotate together.

When you think of a wheel and axle, you might picture something like a bicycle tire. Both parts of a wheel and axle move in a circle. Even though the handle of a pencil sharpener doesn't roll, it moves in a circular path just as the bicycle wheel does. Usually, effort force is exerted on the larger wheel. The smaller wheel, the axle, usually exerts the resistance force. Doorknobs and faucet handles are machines that use a wheel and axle.

The wheel and axle is another modified form of a lever. On the pencil sharpener, the point where the handle connects to the sharpening mechanism acts as the fulcrum. The length of the handle is the effort arm, or the wheel. The radius of the wheel inside is the resistance arm, or the axle.

Mechanical Advantage of the Wheel and Axle

Remember that the IMA of a lever can be calculated by dividing the effort arm by the resistance arm. In a wheel and axle, each travels in a circular path, so the effort arm is the same as the radius of the wheel. Likewise, the resistance arm is the same as the radius of the axle. Thus, the IMA can be calculated as follows.

$$\text{IMA} = \frac{\text{radius of wheel}}{\text{radius of axle}} = \frac{r_w}{r_a}$$

The mechanical advantage of a wheel and axle can be increased by making the radius of the wheel larger.

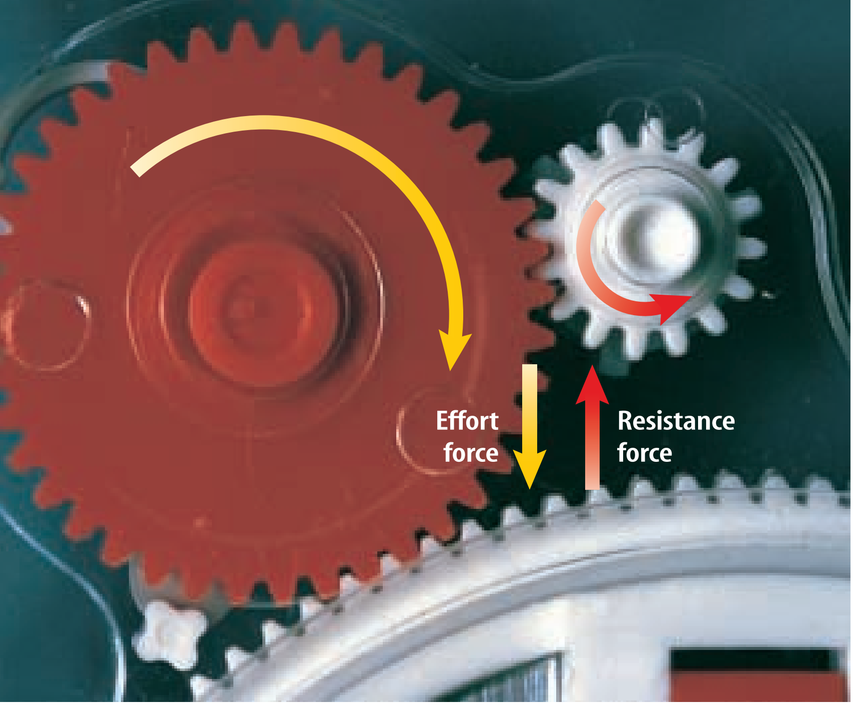


Figure 20
When one gear turns, the teeth that are interlocked with the other gear make it turn.

Gears A modified form of the wheel and axle that you may be familiar with is a gear. A gear usually consists of two wheels of different sizes with interlocking teeth along their circumferences. When one of the wheels is turned, the teeth force the other wheel to turn.

If the larger wheel is the effort gear one turn of the effort gear can result in many turns of the resistance gear, because it has more teeth than the smaller wheel. A system of gears in which the effort gear is larger reduces the effort force.

Gears also may change the direction of the force. Notice that when the effort gear in **Figure 20** is rotated clockwise, the resistance gear rotates counterclockwise. You may have noticed this when you use a can opener. As you twist the handle in one direction, the can revolves in the opposite direction.

Inclined Planes

Why do the roads and paths on mountains zigzag? Would it be easier to climb directly up a steep incline or walk a longer path gently sloped around the mountain? You have learned that it takes less force to lift something if you use a ramp. A sloping surface, such as a ramp that reduces the amount of force required to do work, is called an **inclined plane**.

Mechanical Advantage of an Inclined Plane You do the same work by lifting a box straight up or sliding it up a ramp. But the ramp, an inclined plane, reduces the amount of force required by increasing the distance over which the force is applied. You can calculate the IMA of an inclined plane by dividing the length of the ramp by the height of the ramp.

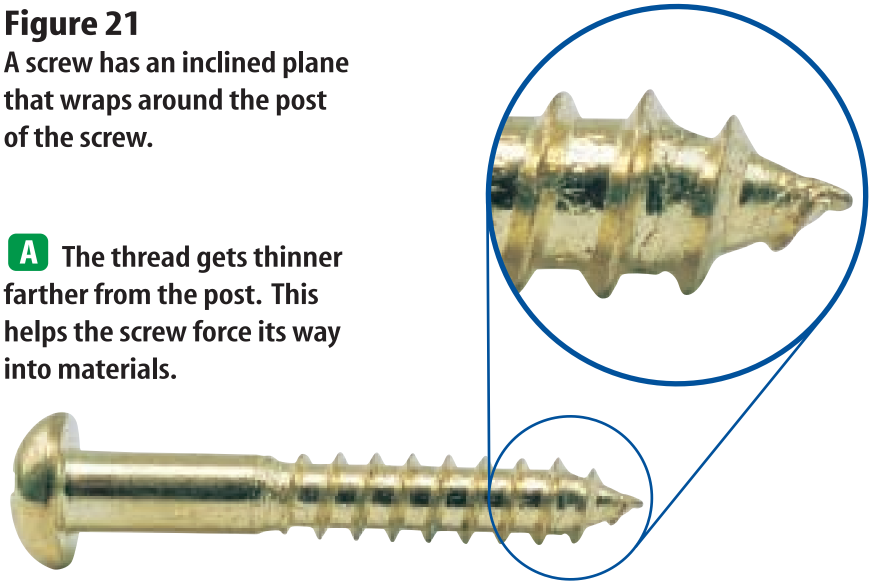
$$\text{IMA} = \frac{\text{effort distance}}{\text{resistance distance}} = \frac{\text{length of slope}}{\text{height of slope}} = \frac{l}{h}$$

As the ramp is made longer and less steep, less force is required to push the object up the ramp.

When you think of an inclined plane, you normally think of moving an object up a ramp—you move and the inclined plane remains stationary. The screw and the wedge, however, are variations of the inclined plane in which the inclined plane moves and the object remains stationary.

Figure 21
A screw has an inclined plane that wraps around the post of the screw.

A **The thread gets thinner farther from the post. This helps the screw force its way into materials.**



B **Many lids, such as those on peanut butter jars, also contain threads.**

The Screw

You normally think of a screw as a carpenter's tool like the one in **Figure 21A.** A **screw** is an inclined plane wrapped in a spiral around a cylindrical post. If you look closely at the screw in **Figure 21A,** you'll see that the threads form a tiny ramp that runs upward from its tip. As you turn the screw, the threads seem to pull the screw into the wood. The wood seems to slide up the inclined plane. Actually, the plane slides through the wood.

There are many other examples of the screw that you encounter every day. How do you remove the lid off a jar of peanut butter, like in **Figure 21B?** If you look closely, you see the threads similar to the ones in **Figure 21A.** Where else can you find examples of a screw?

Figure 22
A knife blade is an example of a sharp wedge. As you cut through the apple, it pushes the halves of the apple apart.

The Wedge

Like the screw, the wedge is also a simple machine where the inclined plane moves through an object or material. A **wedge** is an inclined plane with one or two sloping sides. It changes the direction of the effort force.

Look closely at the knife in **Figure 22.** One edge is extremely sharp, and it slopes outward at both sides, forming an inclined plane. As it moves through the apple in a downward motion, the force is changed to a horizontal motion, forcing the apple apart.

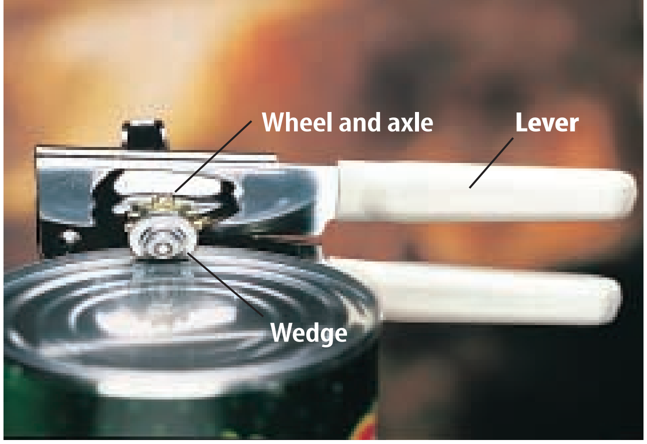


Figure 23
A compound machine, such as a can opener, is made up of simple machines.

Compound Machines

Some of the machines you use every day are made up of several simple machines. When two or more simple machines are used together, it is called a **compound machine.**

Look at the can opener in **Figure 23.** To open the can you first squeeze the handles together. The handles act as a lever and increase the force applied on a wedge, which then pierces the can. You then turn the handle, a wheel and axle, to open the can. The overall mechanical advantage of a compound machine is related to the mechanical advantages of all the machines involved.

A car is also a compound machine. Burning fuel in the cylinders of the engine causes the pistons to move up and down. This up-and-down motion makes the crankshaft rotate. The force exerted by the rotating crankshaft is transmitted to the wheels through other parts of the car, such as the transmission and the differential. Both of these parts contain gears, which are simple machines. When a large and a small gear are in contact, the larger gear rotates a shorter distance, but the force it exerts is increased. In this way, these gears can change the rate at which the wheels rotate, the force exerted by the wheels, and even reverse the direction of rotation.

Section 3 Assessment

1. Give one example of each kind of simple machine. Use examples different from the ones in the text.
2. Explain why the six kinds of simple machines are variations of two basic machines.
3. Suppose you are using a screwdriver to pry the lid off a paint can. Identify the fulcrum, the effort arm, and the resistance arm.
4. A 6-m ramp runs from a ground-level sidewalk to a porch. The porch is 2 m off the ground. What is the ideal mechanical advantage of the ramp?
5. **Think Critically** When would the friction of an inclined plane be useful?

Skill Builder Activities

6. **Making and Using Tables** Organize information about the six kinds of simple machines into a table. Include the type of machine, an example of each type, and a brief description of how it works. You may include other information, such as mechanical advantage, if you wish. **For more help, refer to the Science Skill Handbook.**
7. **Using a Word Processor** Using a word processor, write a separate paragraph about each class of lever. Describe at least two examples of each class, identifying the effort force, resistance force, and fulcrum for each. Use **Figure 15** for reference. **For more help, refer to the Technology Skill Handbook.**

Activity

Levers

Did you ever play on a seesaw? Wasn't it much easier to balance your friend on the other end if you both weighed the same? If your friend was lighter, you had to move toward the fulcrum to balance the seesaw. In this activity, you will use a lever to determine the mass of a coin.

What You'll Investigate

How can a lever measure mass?

Materials

$8\frac{1}{2}$" × 11" sheet of paper
coins (one quarter, one dime, one nickel)
balance
metric ruler

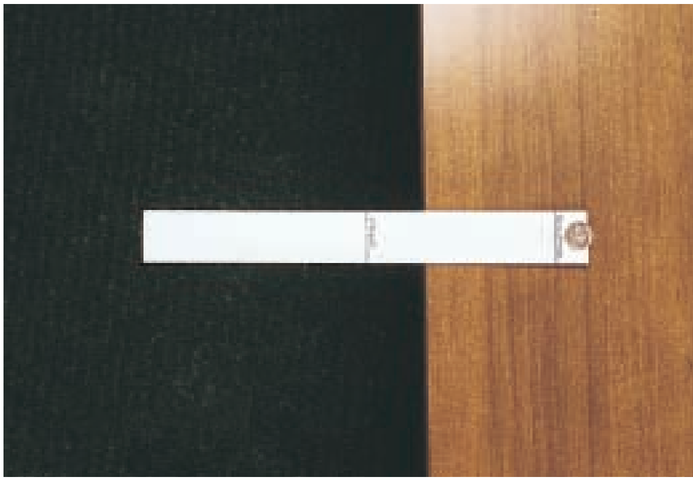
Goals

- **Measure** effort arm and resistance arm.
- **Observe** how mass can affect the fulcrum.

Safety Precautions

Procedure

1. Make a lever by folding the paper into a strip 3 cm wide by 28 cm long.
2. Mark a line 2 cm from one end of the paper strip. Label this line Resistance.
3. Slide the other end of the paper strip over the edge of a table until the strip begins to tip. Mark a line across the paper at the table edge and label this line Effort.
4. **Measure** the mass of the paper to the nearest 0.1 g. Write this mass on the Effort line.
5. Center a dime on the Resistance line. Locate the fulcrum by sliding the paper strip until it begins to tip. Mark the balance line. Label it Fulcrum #1.



6. **Measure** the lengths of the resistance and effort arms to the nearest 0.1 cm.
7. Calculate the IMA of the lever. Multiply the IMA by the mass of the lever to find the approximate mass of the coin.
8. Repeat steps 5 through 7 with the nickel and the quarter. Mark the fulcrum line #2 for the nickel and #3 for the quarter.

Conclude and Apply

1. What provides the effort force?
2. What does it mean if the IMA is less than 1.0?
3. The calculations are done as if the entire weight of the paper is located at what point?
4. **Infer** why mass units can be used in place of force units in this kind of problem.

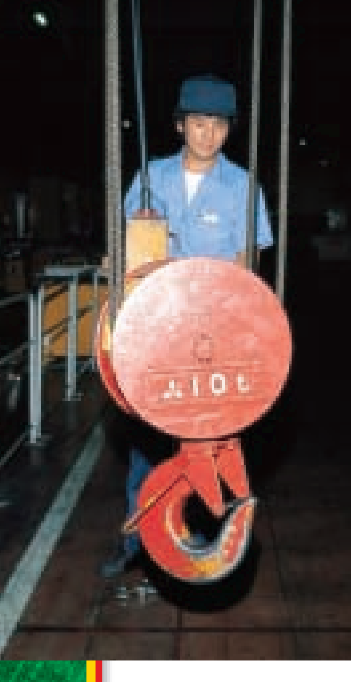
Communicating Your Data

Compare your results with those of other students in your class. **For more help, refer to the Science Skill Handbook.**

Activity

Model and Invent

Work Smarter



You are the contractor on a one-story building with a large air-conditioner. The lower the force, the easier the job for your crew. What ways can you think of to get the air conditioner to the roof?

Recognize the Problem

How can you minimize the force needed to lift an object? What machines could you use?

Thinking Critically

Is a lever practical for this job? Why? Consider a fixed pulley with ideal mechanical advantage (*IMA*) = 1, a movable pulley with *IMA* = 2, a block and tackle with one fixed double pulley and one movable double pulley with *IMA* = 4, and an inclined plane with *IMA* = slope / height = 4. The latter two machines may differ in efficiency. How can you find the efficiency of machines?

Goals

- **Model** lifting devices based on a block and tackle and on an inclined plane.
- **Calculate** the output work that will be accomplished.
- **Measure** the force needed by each machine to lift a weight.
- **Calculate** the input work and efficiency for each model machine.
- **Select** the best machine for your job based on force required.

Possible Materials

Spring scale, 0 – 10 N range
9.8 N weight (1 kg mass)
Two double pulleys
String for pulleys
Stand or support for the pulleys
Wooden board, 40 cm long
Support for board, 10 cm high

Problem Data

	Control	Inclined Plane	Block and Tackle
Ideal Mechanical Advantage, *IMA*	1	4	4
Effort Force, F_e, N			
Effort Distance, d_e, m	0.10		
Resistance Force, F_r, N	9.8	9.8	9.8
Resistance Distance, d_r, m	0.10	0.10	0.10
$Work_{in} = F_e \times d_e$, Joules			
$Work_{out} = F_r \times d_r$, Joules	0.98	0.98	0.98
% Efficiency, $(Work_{out} / Work_{in}) \times 100$			

Planning the Model

1. Work in teams of at least two. **Collect** all the needed equipment.
2. Sketch a model for each lifting machine. **Model** the inclined plane with a board 40 cm long and raised 10 cm at one end. Include a control in which the weight is lifted while being suspended directly from the spring scale.
3. Make a table for data.

Check the Model Plans

1. Is the pulley support high enough that the block and tackle can lift a weight 10 cm?
2. Obtain your teacher's approval of your sketches and data table before proceeding.

Making the Model

1. Tie the weight to the spring scale and measure the force required to lift it. Record the effort force in your data table under Control, along with the 10-cm effort distance.
2. Assemble the inclined plane so that the weight can be pulled up the ramp at a constant rate. The 40-cm board should be supported so that one end is 10 cm higher.
3. Tie the string to the spring scale and measure the force required to move the weight up the ramp at a constant speed. Record this effort force under inclined plane in your data table. Record 40 cm as the effort distance for the inclined plane.
4. Assemble the block and tackle using one fixed double pulley and one movable double pulley.
5. Tie the weight to the lower pulley and tie the spring scale to the string at the top of the upper pulley.
6. **Measure** the force required to lift the weight with the block and tackle. Record this effort force.
7. **Measure** the length of string that must be pulled to raise the weight 10 cm. Record this effort distance.

Analyzing and Applying Results

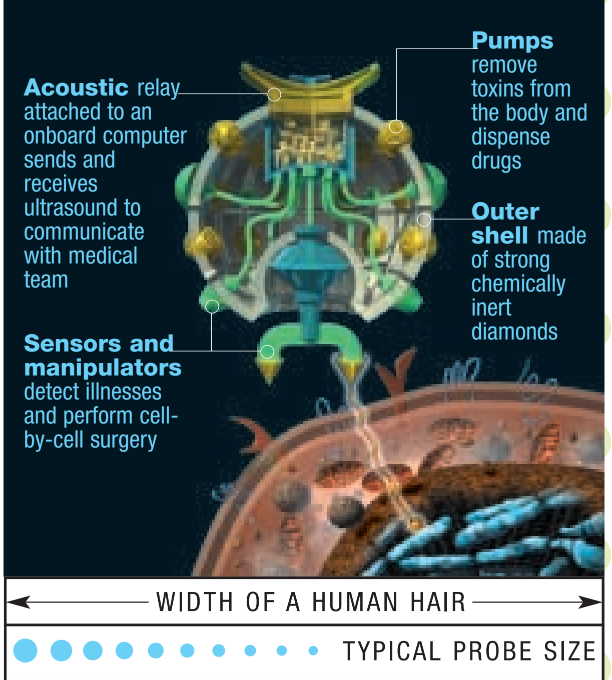
1. **Calculate** the output work for all three methods of lifting the 9.8 N weight 10 cm.
2. **Calculate** the input work and the efficiency for the control, the inclined plane, and the block and tackle.
3. Which machine used the lowest force to raise the weight? How do you account for the observed differences in efficiencies? How could you improve the efficiency for each?

Communicating Your Data

Make a poster showing how the best machine would be used to lift the air conditioner to the roof of your building.

THE SCIENCE

ANATOMY OF A NANOPROBE

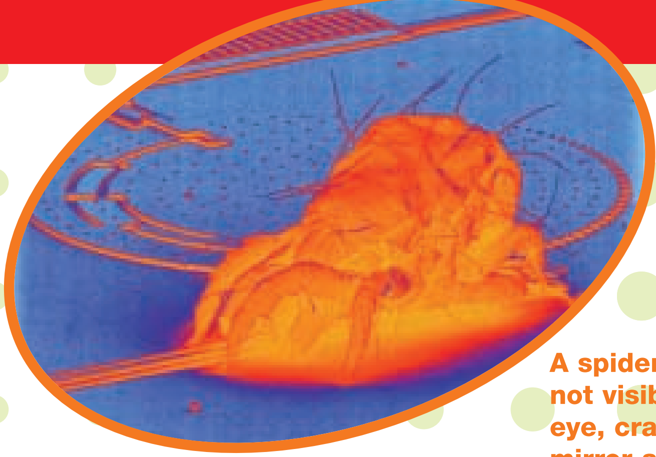


Up to 10 trillion nanorobots, each as small as 1/200th the width of a human hair, might be injected at once

Imagine an army of tiny robots, each no bigger than a bacterium, swimming through your bloodstream. One type of robot takes continuous readings of blood pressure in different parts of your body. Another type monitors cholesterol. Still others measure your blood sugar, the beginnings of possible blockages in arteries leading to your heart, and your general health.

Welcome to the world of nanotechnology—the science of creating molecular-sized machines. The machines, called nanobots, are each about one one billionth of a meter in size. The prefix *nano* refers to a billionth part of a unit, and comes from *nanos*, the Greek word for "dwarf." These machines are so small they can skillfully control matter one atom at a time.

Nanotechnology uses microscopic machines to do microscopic work. By combining engineering and biology, scientists might actually be able to reorganize atoms and molecules to create new objects. For example, nanobots could create diamonds from coal—all they'd need to do is rearrange a few atoms.



A spider mite, which is not visible to the human eye, crawls across a mirror assembly, a part used in micromachines.

OF VERY, VERY SMALL

One day you might have robots swimming through your bloodstream

This is the smallest guitar in the world. It is about as big as a human white blood cell. Each of its six silicon strings is 100 atoms wide. You can see the guitar only with an electron microscope.

Nanobots also could be used to clean up oil spills and toxic waste sites. Toxic wastes usually are made up of atoms that are arranged into noxious molecules. Nanobots will be able to break down these poisonous molecules, converting dangerous waste into harmless forms. Nanobots will have all sorts of uses in nature, in the body, and in the workplace.

Small, Smaller, Smallest

Nanotechnologists are predicting that within a few decades they will be creating machines that can do just about anything, as long as it's small. Already, nanotechnologists have built gears 10,000 times thinner than a human hair. They've also built tiny molecular "motors" only 50 atoms long. At Cornell University, nanotechnologists created the world's smallest guitar. It is appoximately the size of a white blood cell and it even has six strings.

Of course, the tiny guitar isn't meant to be played—only to illustrate the reality of the "science of the small," and to give us a glimpse into what lies ahead.

And getting back to those nanobots in your body—in the future, they might transmit your internal vital signs to a nanocomputer, which might be implanted under your skin. There the data could be analyzed for signs of disease.

Nanomachines then could be sent to scrub your arteries clean of dangerous blockages, or mop up cancer cells, or even vaporize blood clots with tiny lasers. These are just some of the possibilities in the imaginations of those studying the new science of nanotechnology.

CONNECTIONS Design Think up a very small simple or complex machine that could go inside the body and do something. What would the machine do? Where would it go? Share your diagram or design with your classmates.

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CONTENTS

Chapter 5 Study Guide

Reviewing Main Ideas

Section 1 Work

1. Work is the transfer of energy when a force makes an object move.
2. Work is done only when force produces motion in the direction of the force. *Does this forklift do work by lifting these crates? Explain.*

3. Power is the amount of work, or the amount of energy transferred, in a certain amount of time.

Section 2 Using Machines

1. A machine makes work easier by changing the size of the force applied, by increasing the distance an object is moved, or by changing the direction of the applied force. *How is work made easier for the person pulling the nail from a board?*

2. The number of times a machine multiplies the force applied to it is the mechanical advantage of the machine. The actual mechanical advantage is always less than the ideal mechanical advantage.
3. The efficiency of any machine is a ratio of the work done by the machine to the work put into the machine. No machine can be 100 percent efficient.

Section 3 Simple Machines

1. A simple machine is a machine that can do work with a single movement.
2. A simple machine can increase an applied force, change its direction, or both.
3. A lever is a bar that is free to pivot about a fixed point called a fulcrum. A pulley is a grooved wheel with a rope running along the groove. A wheel and axle consists of two different-sized wheels that rotate together. An inclined plane is a sloping surface used to raise objects. The screw and wedge are special types of inclined planes.
4. A combination of two or more simple machines is called a compound machine. *What simple machines make up a pair of scissors?*

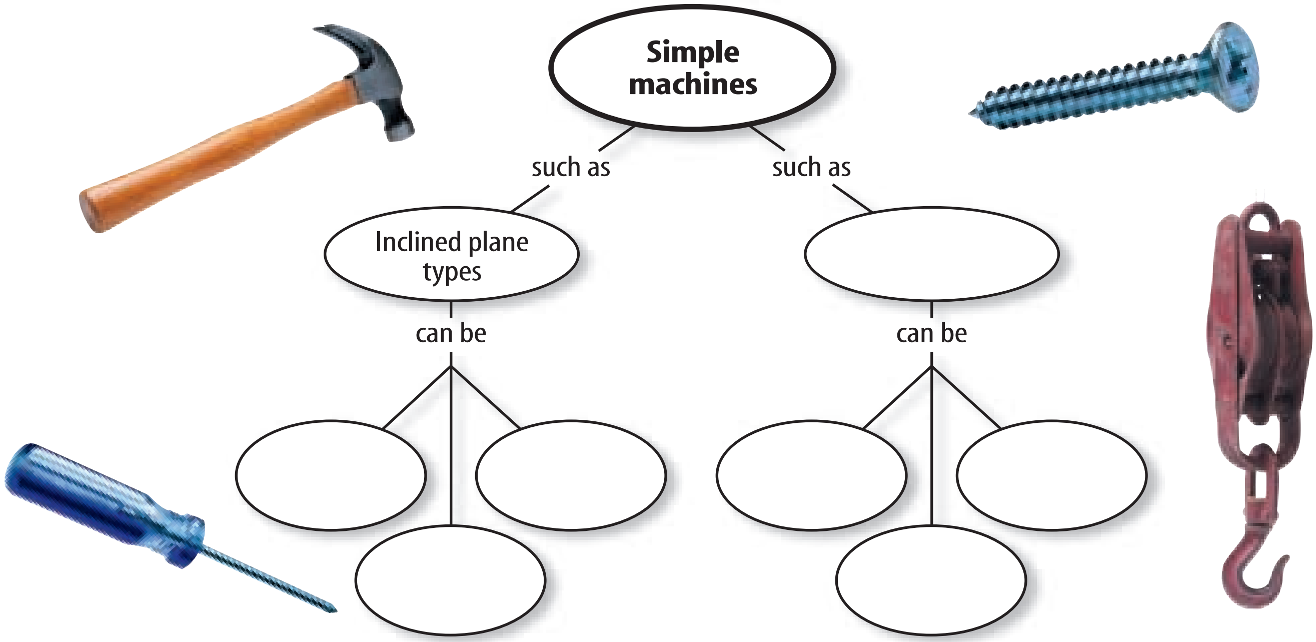
After You Read

FOLDABLES Reading & Study Skills

On your Foldable, list work you would do with machines under its tab. Now compare and contrast work with and without machines.

Visualizing Main Ideas

Complete the concept map for simple machines using the following terms: inclined plane, lever, lever types, pulley, screw, wedge, and wheel and axle.



Vocabulary Review

Vocabulary Words

a. compound machine
b. efficiency
c. effort force
d. inclined plane
e. lever
f. machine
g. mechanical advantage
h. power
i. pulley
j. resistance force
k. screw
l. simple machine
m. wedge
n. wheel and axle
o. work

THE PRINCETON REVIEW Study Tip

When you encounter new vocabulary, write it down in a sentence. This will help you understand, remember, and use new vocabulary words.

Using Vocabulary

Replace the underlined words with the correct vocabulary word(s).

1. A combination of two or more simple machines is a(n) <u>ideal machine</u>.
2. A wedge is another form of a <u>wheel and axle</u>.
3. The amount by which a machine multiplies your force is called <u>efficiency</u>.
4. The force that you exert on a lever is called the <u>resistance force</u>.
5. A(n) <u>inclined plane</u> is a grooved wheel with a rope or chain running through it.
6. <u>Efficiency</u> is the rate at which work is done.
7. <u>Power</u> is when a force causes an object to move in the direction of the force.

Chapter 5 Assessment

Checking Concepts

Choose the word or phrase that best answers the question.

1. Using the scientific definition, which of the following is true of work?
   A) It must be difficult.
   B) It must involve levers.
   C) It must involve the transfer of energy.
   D) It must be done with a machine.

2. How many types of simple machines exist?
   A) three **C)** eight
   B) six **D)** ten

3. In an ideal machine, which of the following is true?
   A) Work input is equal to work output.
   B) Work input is greater than work output.
   C) Work input is less than work output.
   D) Work input is independent of work output.

4. Which of these cannot be done by a machine?
   A) multiply force
   B) multiply energy
   C) change direction of a force
   D) work

5. What term indicates the number of times a machine multiplies the effort force?
   A) efficiency
   B) power
   C) mechanical advantage
   D) resistance

6. How could you increase the IMA of an inclined plane?
   A) increase its length
   B) increase its height
   C) decrease its length
   D) make its surface smoother

7. How far must the effort rope of a single fixed pulley move to raise a resistance 4 m?
   A) 1 m **C)** 4 m
   B) 2 m **D)** 8 m

8. In a wheel and axle, which of the following usually exerts the resistance force?
   A) the axle **C)** the gear ratio
   B) the larger wheel **D)** the pedals

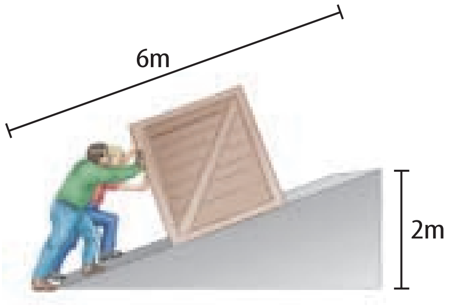
9. What is the IMA of an inclined plane 8 m long and 2 m high?
   A) 2 **C)** 8
   B) 4 **D)** 16

10. Which of the following increases as the efficiency of a machine increases?
    A) work input **C)** friction
    B) work output **D)** IMA

Thinking Critically

11. An adult and a small child get on a seesaw that has a movable fulcrum. When the fulcrum is in the middle, the child can't lift the adult. How should the fulcrum be moved so the two can seesaw? Explain.

12. Using a ramp 6 m long, workers apply an effort force of 1,250 N to move a 2,000-N crate onto a platform 2 m high. What is the efficiency of the ramp?

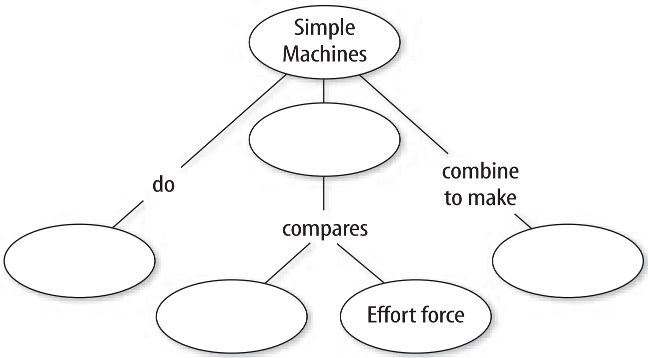


13. How much power does a person weighing 500 N need to climb a 3-m ladder in 5 s?

14. You have two screwdrivers. One is long with a thin handle, and the other is short with a fat handle. Which would you use to drive a screw into a board? Explain.

Developing Skills

15. Concept Mapping Complete the concept map of simple machines using the following terms: *compound machines, mechanical advantage, resistance force, work.*



16. Communicating A pair of scissors is a compound machine. Draw a diagram of a pair of scissors and label the simple machines you can identify. Explain to a classmate the purpose of each simple machine in this device.

Performance Assessment

17. Invention Design a human-powered machine of some kind. Describe the simple machines used in your design, and tell what each of these machines does.

Technology

Go to the Glencoe Science Web site at **science.glencoe.com** or use the **Glencoe Science CD-ROM** for additional chapter assessment.

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THE PRINCETON REVIEW Test Practice

Maria went to the library to do some research on inventions that made it easier to perform everyday tasks. Some of the pictures that she photocopied are shown in the diagram below.

Study the diagram and answer the following questions.

1. What do these simple machines have in common?

A) They are all wedges.
B) They are all levers.
C) All were invented in the United States.
D) They are all recent inventions.

2. The larger scissors can cut through a thick object because _____ .

F) levers with longer effort arms are easier to hold
G) levers with longer effort arms multiply force more
H) levers with longer effort arms multiply her force less
J) levers with longer effort arms are made of stronger materials

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