Chapter 12

Work and Machines

The BIG Idea
Work and Energy

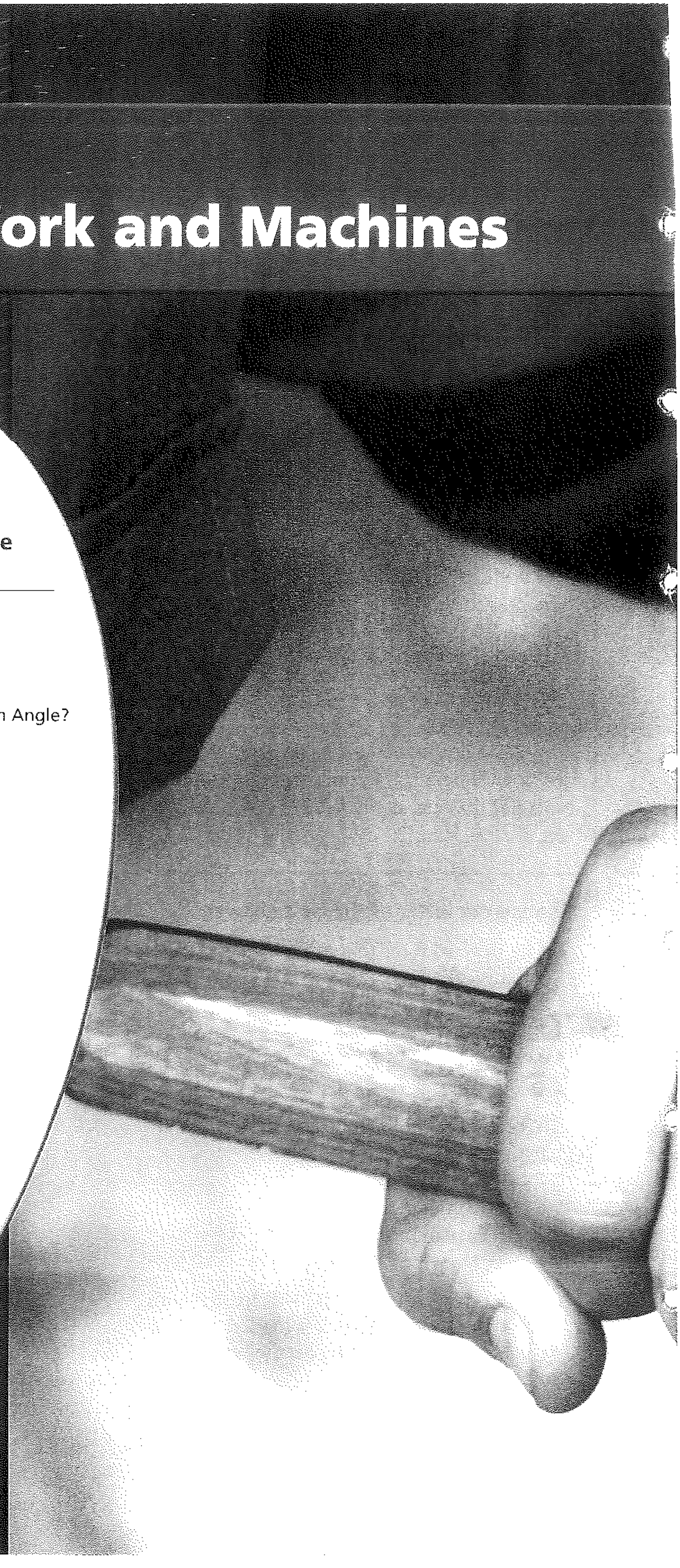
How do simple machines make work easier?

Chapter Preview

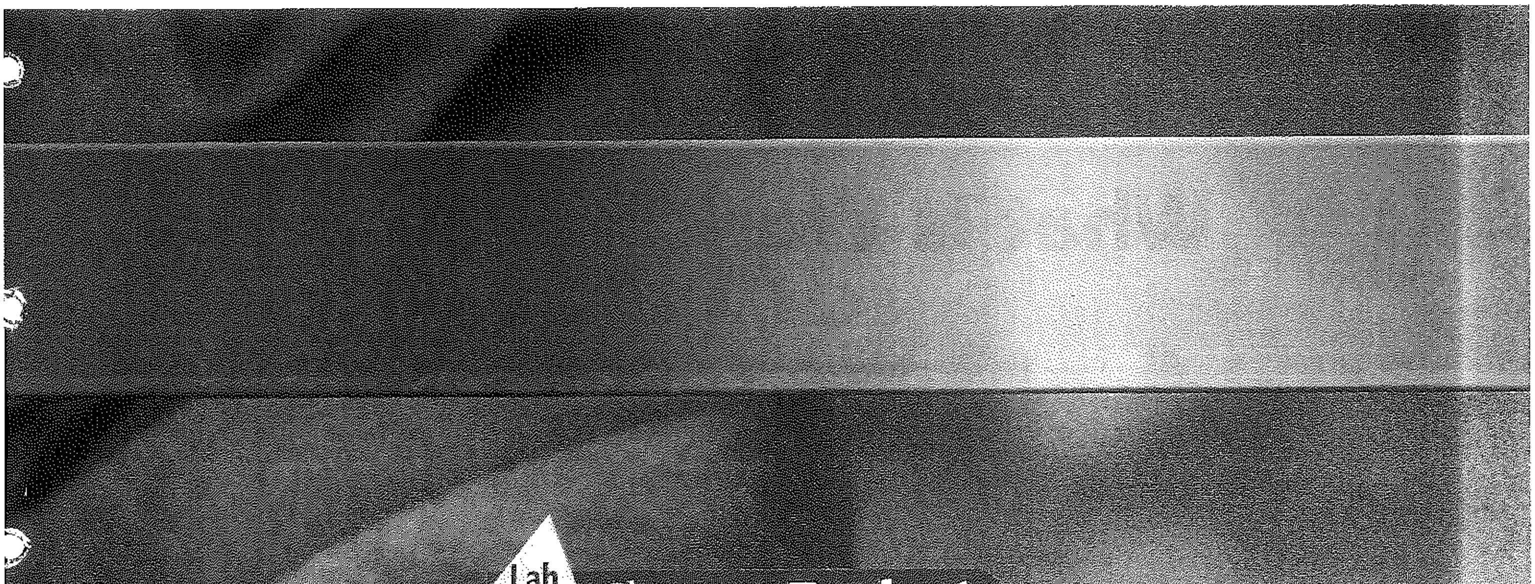
1 What Is Work?
Discover What Happens When You Pull at an Angle?
Try This Is Work Always the Same?

2 How Machines Do Work
Discover Is It a Machine?
Try This Going Up
Analyzing Data Mechanical Advantage
Skills Lab Seesaw Science

3 Simple Machines
Discover How Can You Increase Force?
Try This A Paper Screw
Skills Activity Communicating
Active Art Types of Pulleys
At-Home Activity Machines in the Kitchen
Skills Lab Angling for Access



A woodcarver creates a carving. ▶



Lab zone™ Chapter **Project**

The Nifty Lifting Machine

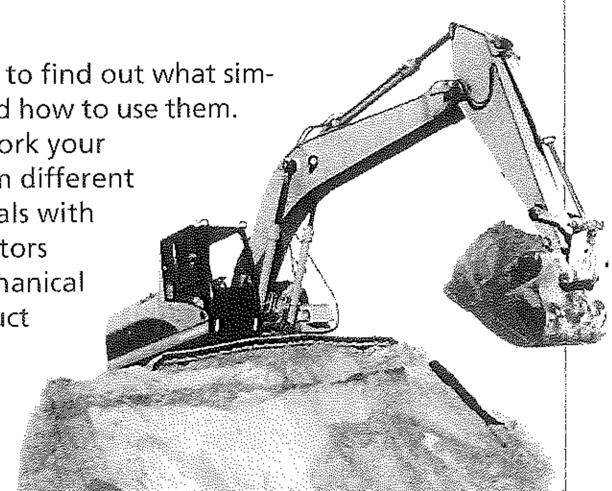
In this Chapter Project, you will design and build a lifting machine and then demonstrate it to the class.

Your Goal To design, build, and test a complex machine that can lift a 600-gram soup can 5 centimeters

Your machine must

- be made of materials that are approved by your teacher
- consist of at least two simple machines working in combination
- be able to lift the soup can to a height of at least 5 centimeters
- be built following the safety guidelines in Appendix A

Plan It! Preview the chapter to find out what simple machines you can use and how to use them. Determine the amount of work your machine must do. Brainstorm different machine designs and materials with your classmates. Analyze factors affecting efficiency and mechanical advantage, and then construct your machine. When your teacher has approved your design, build and test your machine.



Section 1

What Is Work?

Reading Preview

Key Concepts

- When is work done on an object?
- How do you determine the work done on an object?
- What is power?

Key Terms

- work • joule • power

Target Reading Skill

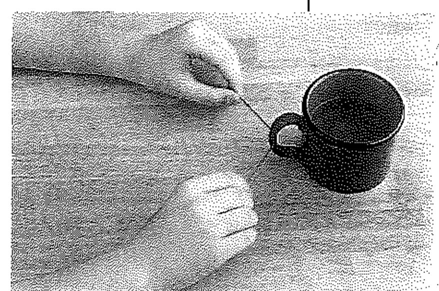
Asking Questions Before you read, preview the red headings. In a graphic organizer like the one below, ask a *what* or *how* question for each heading. As you read, write the answers to your questions.

Question	Answer
What is work?	Work is . . .

Lab zone Discover Activity

What Happens When You Pull at an Angle?

1. Fill a mug half full with water.
2. Cut a medium-weight rubber band to make a strand of elastic. Thread the elastic through a mug handle. By pulling on the elastic, you can move the mug across a table.
3. You can hold the two halves of elastic parallel to each other or at an angle to each other, as shown. Predict which way will be more effective in moving the mug.
4. Pull on the elastic both ways. Describe any differences you observe.



Think It Over

Developing Hypotheses Which of the two pulls was more effective in moving the mug? Explain why.

This morning you probably woke up and went to school with your backpack of books. You lifted the backpack and then carried it with you. If you had a lot of books to bring home, carrying your backpack might have felt like a lot of work. But in the scientific definition of work, after you lifted the backpack, you did no work to carry it at all!

The Meaning of Work

In scientific terms, you do **work** when you exert a force on an object that causes the object to move some distance. **Work is done on an object when the object moves in the same direction in which the force is exerted.** If you push a child on a swing, for example, you are doing work on the child. If you pull your books out of your backpack, you do work on the books. If you lift a bag of groceries out of a shopping cart, you do work on the bag of groceries.

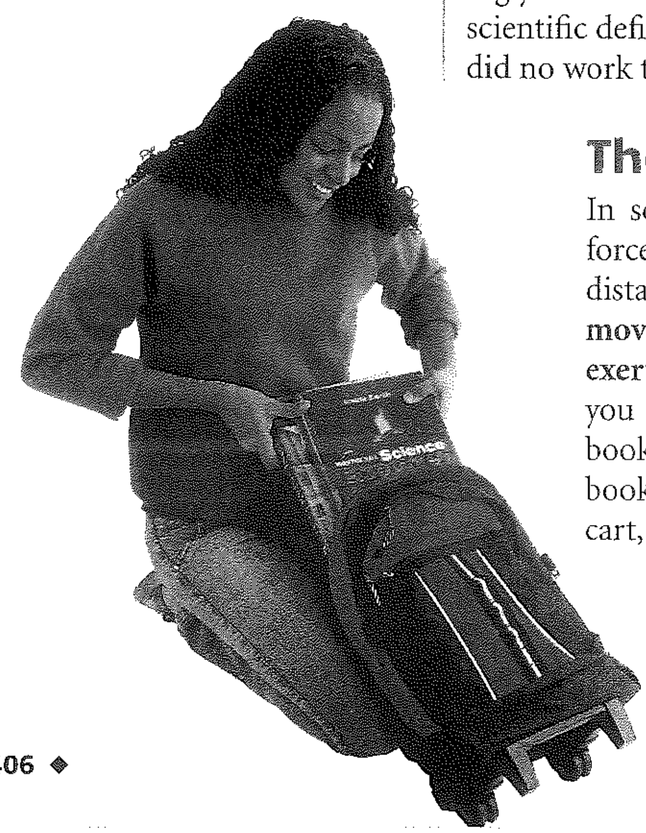


FIGURE 1
Doing Work
Lifting books out of a backpack is work, but carrying them to class is not.

No Work Without Motion To do work on an object, the object must move some distance as a result of your force. If the object does not move, no work is done, no matter how much force is exerted.

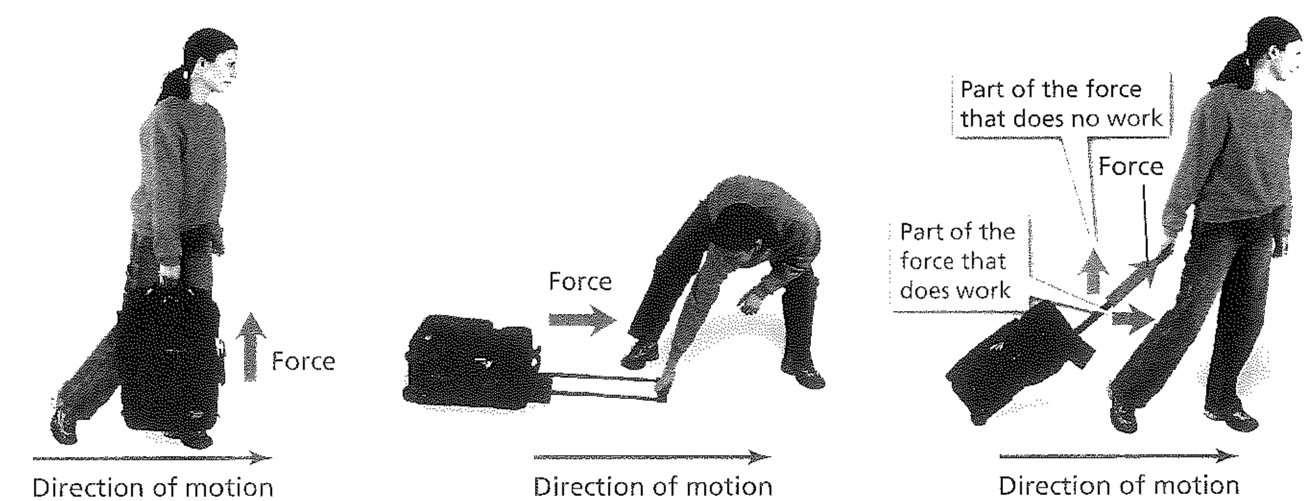
There are many situations in which you exert a force but don't do any work. Suppose, for example, you are pushing a car that is stuck in the snow. You certainly exert a force on the car, so it might seem as if you do work. But if the force you exert does not make the car move, you are not doing any work on it.

Force in the Same Direction So why didn't you do any work when you carried your books to school? To do work on an object, the force you exert must be in the same direction as the object's motion. When you carry an object at constant velocity, you exert an upward force to hold the object so that it doesn't fall to the ground. The motion of the object, however, is in the horizontal direction. Since the force is vertical and the motion is horizontal, you don't do any work on the object as you carry it.

How much work do you do when you pull a suitcase with wheels? When you pull a suitcase, you pull on the handle at an angle to the ground. As you can see in Figure 2, your force has both a horizontal part and a vertical part. When you pull this way, only part of your force does work—the part in the same direction as the motion of the suitcase. The rest of your force does not help pull the suitcase forward.

Reading Checkpoint **If you pull an object horizontally, what part of your force does work?**

FIGURE 2
Force, Motion, and Work
Whether the girl does work on the suitcase depends on the direction of her force and the suitcase's motion. Drawing Conclusions *Why doesn't the girl do work when she carries her suitcase rather than pulling it?*



A The lifting force is not in the direction of the suitcase's motion, so no work is done.

B The force acts in the same direction as the suitcase's motion, so the maximum work is done.

C Only the horizontal part of the force does work to move the suitcase.

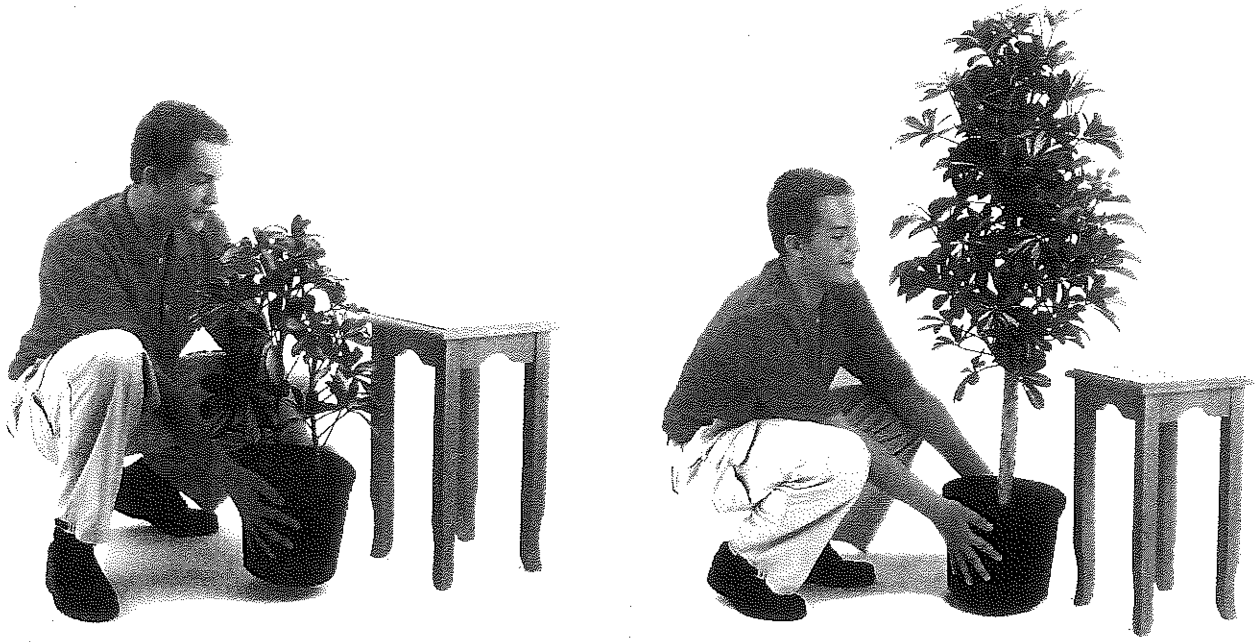


FIGURE 3
Amount of Work
When you lift a plant, you do work. You do more work when you lift a heavier plant the same distance.
Relating Cause and Effect
Why does it take more work to lift the heavier plant?

Calculating Work

Which do you think involves more work: lifting a 50-newton potted plant 0.5 meters off the ground onto a table, or lifting a 100-newton plant onto the same table? Your common sense may suggest that lifting a heavier object requires more work than lifting a lighter object. This is true. Is it more work to lift a plant onto a table or up to the top story of a building? As you might guess, moving an object a greater distance requires more work than moving the same object a shorter distance.

The amount of work you do depends on both the amount of force you exert and the distance the object moves. **The amount of work done on an object can be determined by multiplying force times distance.**

$$\text{Work} = \text{Force} \times \text{Distance}$$

You can use the work formula to calculate the amount of work you do to lift a plant. When you lift an object, the upward force you exert must be at least equal to the object's weight. So, to lift the lighter plant, you would have to exert a force of 50 newtons. The distance you lift the plant is 0.5 meters. The amount of work you do on the plant can be calculated using the work formula.

$$\text{Work} = \text{Force} \times \text{Distance}$$
$$\text{Work} = 50\ \text{N} \times 0.5 = 25\ \text{N}\cdot\text{m}$$

To lift the heavier plant, you would have to exert a force of 100 newtons. So the amount of work you do would be 100 newtons × 0.5 meters, or 50 N·m. As you can see, you do more work to lift the heavier object.

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When force is measured in newtons and distance in meters, the SI unit of work is the newton × meter (N·m). This unit is also called a joule (JOOL) in honor of James Prescott Joule, a physicist who studied work in the mid-1800s. One **joule** (J) is the amount of work you do when you exert a force of 1 newton to move an object a distance of 1 meter. You would have to exert 25 joules of work to lift the lighter plant and 50 joules of work to lift the heavier plant.

Reading Checkpoint **What is the SI unit for work?**

Power

The amount of work you do on an object is not affected by the time it takes to do the work. For example, if you carry a backpack up a flight of stairs, the work you do is the weight of the backpack times the height of the stairs. Whether you walk or run up the stairs, you do the same amount of work because time is not part of the definition of work.

But time is important when you talk about power. **Power** is the rate at which work is done. **Power equals the amount of work done on an object in a unit of time.** You need more power to run up the stairs with your backpack than to walk because it takes you less time to do the same work.

You can think of power in another way. A device that has more power than another device does more work in the same time. It can also mean doing the same amount of work in less time.

For example, a car's engine does work to accelerate the car from its rest position. The greater a car engine's power, the faster the engine can accelerate the car.

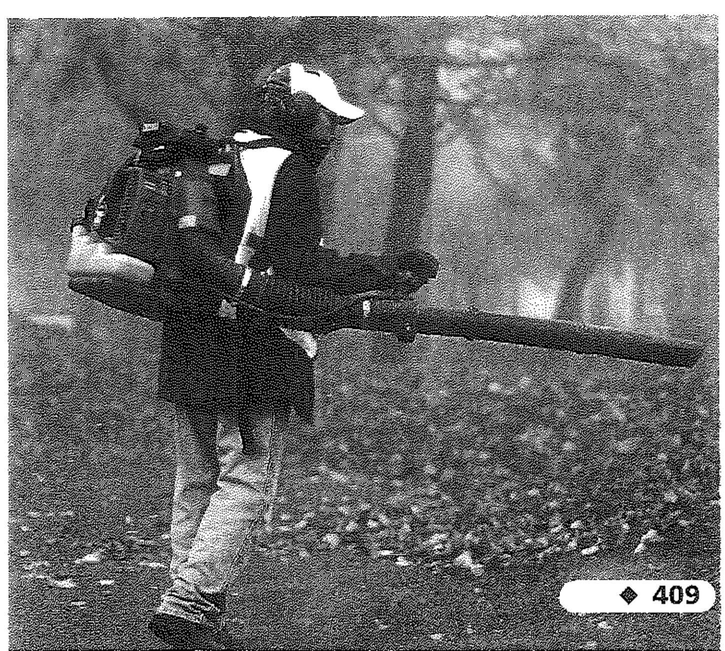
Lab zone **Try This Activity**

Is Work Always the Same?

1. Obtain a pinwheel along with a hair dryer that has at least two power settings.
2. Set the dryer on its lowest setting. Use it to blow the pinwheel. Observe the pinwheel's motion.
3. Set the dryer on its highest setting. Again, blow the pinwheel and observe its motion.

Inferring Explain why work is done on the pinwheel. How are the two situations different? Is the amount of work done greater for the high or low setting? Why?

FIGURE 4
Work and Power
Whether you use a rake or a blower, the same amount of work is done to gather leaves. However, the blower has more power.
Inferring *Will the blower or the rake do the same amount of work in less time?*



Calculating Power Whenever you know how fast work is done, you can calculate power. Power is calculated by dividing the amount of work done by the amount of time it takes to do the work. This can be written as the following formula.

$$\text{Power} = \frac{\text{Work}}{\text{Time}}$$

Since work is equal to force times distance, you can rewrite the equation for power as follows.

$$\text{Power} = \frac{\text{Force} \times \text{Distance}}{\text{Time}}$$

Math Sample Problem

Calculating Power

A tow truck exerts a force of 11,000 N to pull a car out of a ditch. It moves the car a distance of 5 m in 25 seconds. What is the power of the tow truck?

1 Read and Understand

What information are you given?

Force of the tow truck (F) = 11,000 N

Distance (d) = 5.0 m

Time (t) = 25 s

2 Plan and Solve

What quantity are you trying to calculate?

The power (P) of the tow truck =

What formula contains the given quantities and the unknown quantity?

$$\text{Power} = \frac{\text{Force} \times \text{Distance}}{\text{Time}}$$

Perform the calculation.

$$\text{Power} = \frac{11{,}000\ \text{N} \times 5.0\ \text{m}}{25\ \text{s}}$$

$$\text{Power} = \frac{55{,}000\ \text{N}\cdot\text{m}}{25\ \text{s}} \text{ or } \frac{55{,}000\ \text{J}}{25\ \text{s}}$$

$$\text{Power} = 2{,}200\ \text{J/s} = 2{,}200\ \text{W}$$

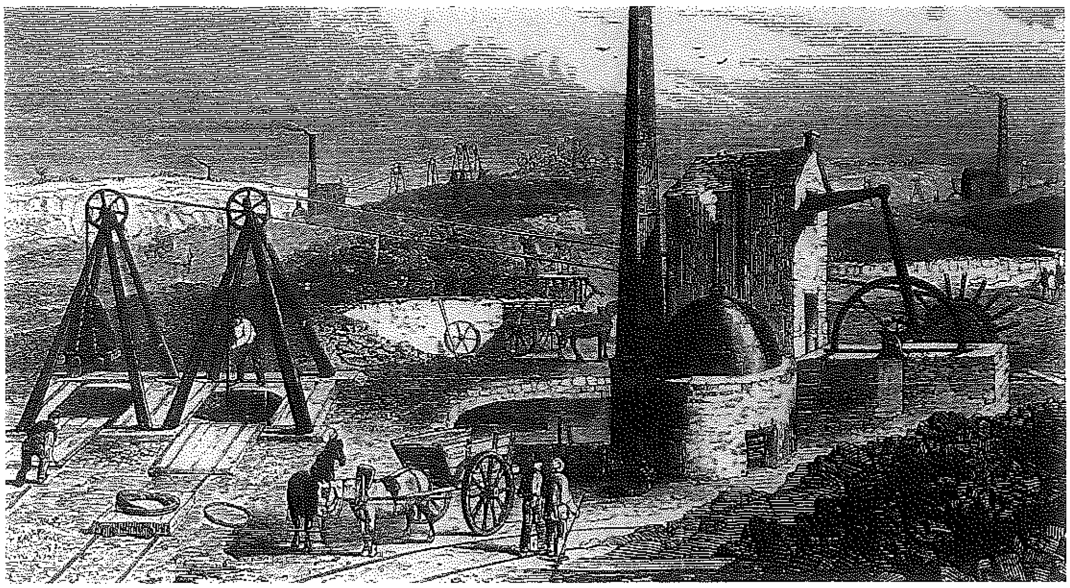
3 Look Back and Check

Does your answer make sense?

The answer tells you that the tow truck pulls the car with a power of 2,200 W. This value is about the same as the power of three horses, so the answer is reasonable.

Math Practice

1. Calculating Power A motor exerts a force of 12,000 N to lift an elevator 8.0 m in 6.0 seconds. What is the power of the motor?
2. Calculating Power A crane lifts an 8,000-N beam 75 m to the top of a building in 30 seconds. What is the crane's power?



Power Units When work is measured in joules and time in seconds, the SI unit of power is the joule per second (J/s). This unit is also known as the watt (W), in honor of James Watt, who made great improvements to the steam engine. One joule of work done in one second is one watt of power. In other words, 1 J/s = 1 W.

A watt is a relatively small unit of power. Because a watt is so small, power is often measured in larger units. One kilowatt (kW) equals 1,000 watts.

When people talk about engines for vehicles, they use another power unit instead of the watt. This unit is the horsepower. One horsepower equals 746 watts. (The horsepower is not an SI unit.)

FIGURE 5
Horsepower
James Watt used the word *horsepower* to advertise the advantages of his improved steam engine (next to the chimney) of 1769.

Reading Checkpoint **What is a kilowatt?**

Section 1 Assessment

Target Reading Skill Asking Questions Use the answers to the questions you wrote about the headings to help you answer the questions below.

Reviewing Key Concepts

1. a. Reviewing What is work?
   b. Describing In order for work to be done on an object, what must happen to the object?
   c. Applying Concepts In which of the following situations is work being done: rolling a bowling ball, pushing on a tree for ten minutes, kicking a football?
2. a. Identifying What is a joule?
   b. Explaining How can you determine the amount of work done on an object?
   c. Problem Solving Is more work done when a force of 2 N moves an object 3 m or when a force of 3 N moves an object 2 m? Explain.
3. a. Defining What is power?
   b. Summarizing How are power and work related?

Math Practice

4. Calculating Power Your laundry basket weighs 22 N and your room is 3.0 m above you on the second floor. It takes you 6.0 seconds to carry the laundry basket up. What is your power?
5. Calculating Power If you take only 4.4 seconds to carry the basket upstairs, what is your power?

Section 2

Integrating Mathematics

How Machines Do Work

Reading Preview

Key Concepts

- How do machines make work easier?
- What is a machine's mechanical advantage?
- How can you calculate the efficiency of a machine?

Key Terms

- machine
- input force
- output force
- input work
- output work
- mechanical advantage
- efficiency

Target Reading Skill

Identifying Main Ideas As you read the What Is a Machine? section, write the main idea in a graphic organizer like the one below. Then write three supporting details.

Main Idea

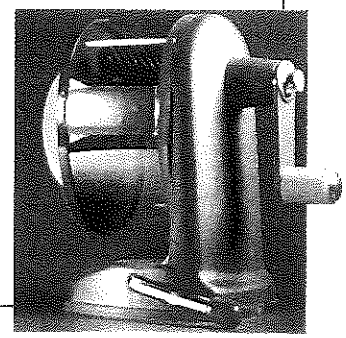
The mechanical advantage of a machine helps by . . .

Detail	Detail	Detail

Lab zone Discover Activity

Is It a Machine?

1. Examine the objects that your teacher gives you.
2. Sort the objects into those that are machines and those that are not machines.
3. Determine how each object that you classified as a machine functions. Explain each object to another student.



Think It Over

Forming Operational Definitions Why did you decide certain objects were machines while other objects were not?

A load of soil for your school garden has been dumped 10 meters from the garden. How can you move the soil easily and quickly? You could move the soil by handfuls, but that would take a long time. Using a shovel would make the job easier. If you had a wheelbarrow, that would make the job easier still! But be careful what you think. Using a machine may make work go faster, but it doesn't mean you do less work.

FIGURE 6
Using Machines
Shovels and rakes make the work of these gardeners easier.

What Is a Machine?

Shovels and wheelbarrows are two examples of machines. A **machine** is a device that allows you to do work in a way that is easier. You may think of machines as complex gadgets with motors, but a machine can be quite simple. For example, think about using a shovel. A shovel makes the work of moving soil easier, so a shovel is a machine.

Moving a pile of soil will involve the same amount of work whether you use your hands or a shovel. What a shovel or any other machine does is change the way in which work is done. **A machine makes work easier by changing at least one of three factors. A machine may change the amount of force you exert, the distance over which you exert your force, or the direction in which you exert your force.** In other words, a machine makes work easier by changing either force, distance, or direction.

Input and Output Forces When you use a machine to do work, you exert a force over some distance. For example, you exert a force on the shovel when you use it to lift soil. The force you exert on the machine is called the **input force.** The input force moves the machine a certain distance, called the input distance. The machine does work by exerting a force over another distance, called the output distance. The force the machine exerts on an object is called the **output force.**

Input and Output Work The input force times the input distance is called the **input work.** The output force times the output distance is called the **output work.** When you use a machine, the amount of output work can never be greater than the amount of input work.

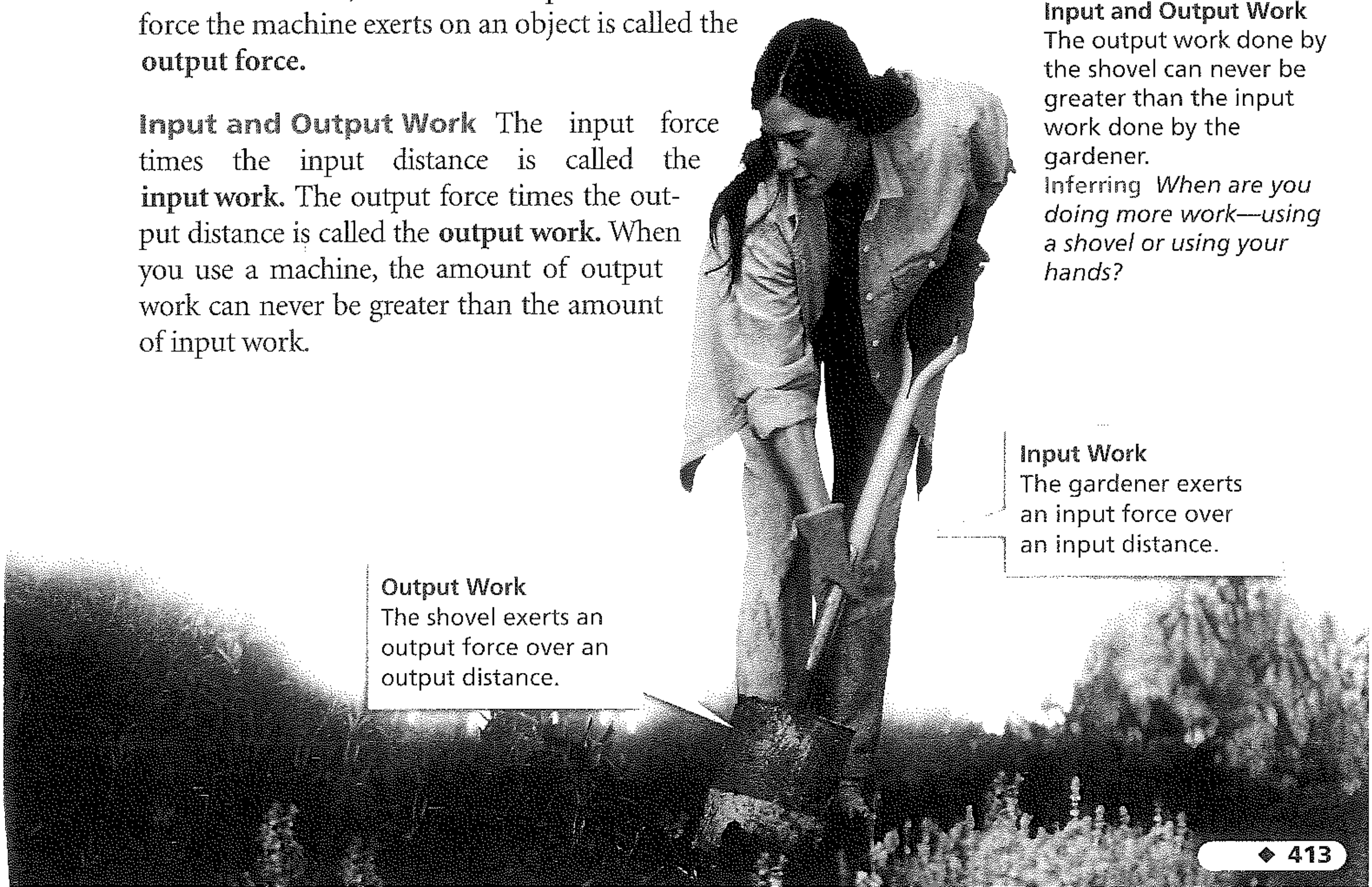
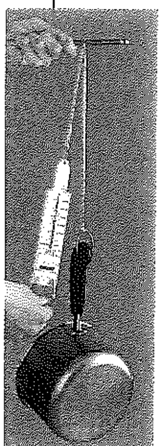


FIGURE 7
Input and Output Work
The output work done by the shovel can never be greater than the input work done by the gardener.
Inferring *When are you doing more work—using a shovel or using your hands?*

Lab zone **Try This Activity**

Going Up

Does a rope simply turn your force upside down? Find out!



1. Tie a piece of string about 50 cm long to an object, such as an empty cooking pot. Make a small loop on the other end of the string.
2. Using a spring scale, slowly lift the pot 20 cm. Note the reading on the scale.
3. Now loop the string over a pencil and pull down on the spring scale to lift the pot 20 cm. Note the reading on the scale.

Developing Hypotheses How did the readings on the spring scale compare? If the readings were different, suggest a reason why. What might be an advantage to using this system?

Changing Force In some machines, the output force is greater than the input force. How can this happen? Recall the formula for work: Work = Force × Distance. If the amount of work stays the same, a decrease in force must mean an increase in distance. So if a machine allows you to use less input force to do the same amount of work, you must apply that input force over a greater distance.

What kind of machine allows you to exert a smaller input force? Think about a ramp. Suppose you have to lift a heavy box onto a stage. Instead of lifting the box, you could push it up a ramp. Because the length of the ramp is greater than the height of the stage, you exert your input force over a greater distance. However, when you use the ramp, the work is easier because you can exert a smaller input force. The faucet knob in Figure 8 changes force in the same way.

Changing Distance In some machines, the output force is less than the input force. Why would you want to use a machine like this? This kind of machine allows you to exert your input force over a shorter distance. In order to apply a force over a shorter distance, you need to apply a greater input force.

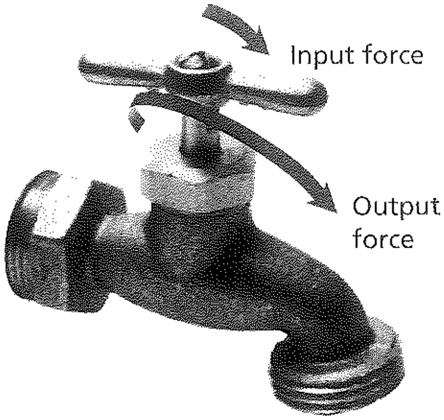
When do you use this kind of machine? Think about taking a shot with a hockey stick. You move your hands a short distance, but the other end of the stick moves a greater distance to hit the puck. When you use chopsticks to eat your food, you move the hand holding the chopsticks a short distance. The other end of the chopsticks moves a greater distance, allowing you to pick up and eat food. When you ride a bicycle in high gear, you apply a force to the pedals over a short distance. The bicycle, meanwhile, travels a much longer distance.

Changing Direction Some machines don't change either force or distance. What could be the advantage of these machines? Well, think about a weight machine. You could stand and lift the weights. But it is much easier to sit on the machine and pull down than to lift up. By running a steel cable over a small wheel at the top of the machine, as shown in Figure 8, you can raise the weights by pulling down on the cable. This cable system is a machine that makes your job easier by changing the direction in which you exert your force.

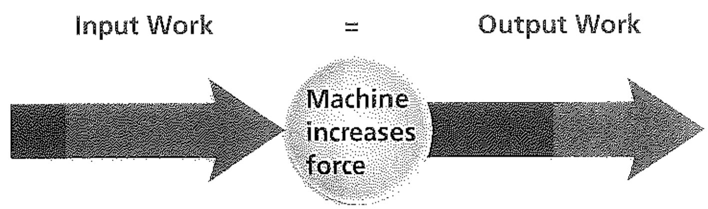
Reading Checkpoint **How does the cable system on a weight machine make raising the weights easier?**

FIGURE 8
Making Work Easier

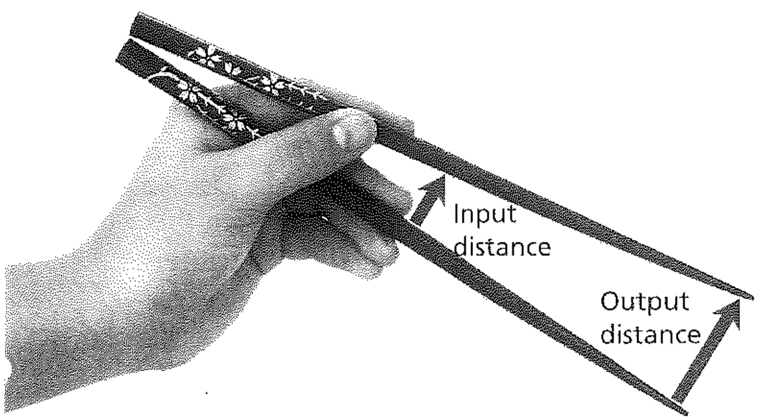
A machine can make work easier in one of three ways.



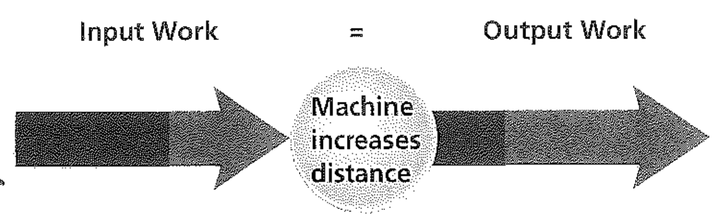
When a machine increases force, you must exert the input force over a greater distance.



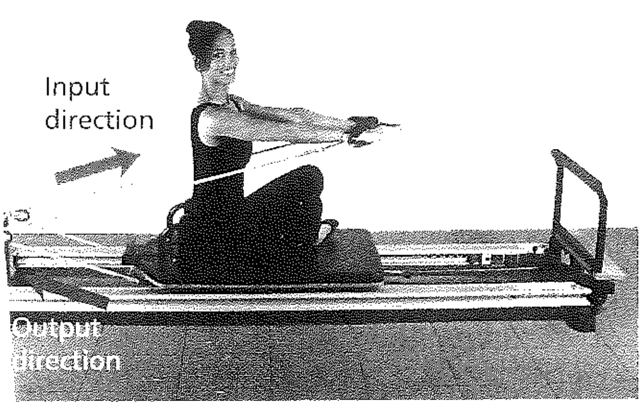
Small input force × Large input distance = Large output force × Small output distance



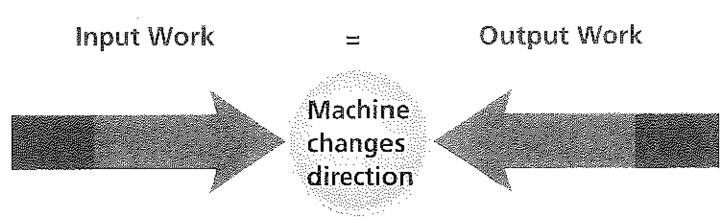
When a machine increases distance, you must apply a greater input force.



Large input force × Small input distance = Small output force × Large output distance



When a machine changes the direction of the input force, the amount of force and the distance remain the same.



Small input force × Large input distance = Large output distance × Small output force

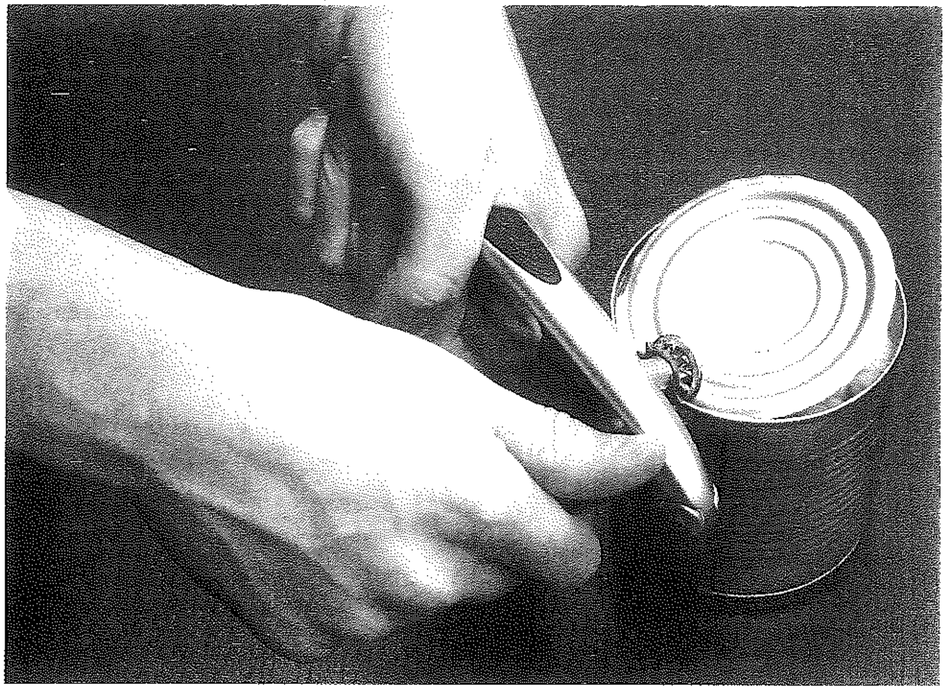


FIGURE 9
Mechanical Advantage
Without the mechanical advantage of the can opener, opening the can would be very difficult.

Mechanical Advantage

If you compare the input force to the output force, you can find the advantage of using a machine. **A machine's mechanical advantage is the number of times a machine increases a force exerted on it.** Finding the ratio of output force to input force gives you the **mechanical advantage** of a machine.

$$\text{Mechanical advantage} = \frac{\text{Output force}}{\text{Input force}}$$

Increasing Force When the output force is greater than the input force, the mechanical advantage of a machine is greater than 1. Suppose you exert an input force of 10 newtons on a hand-held can opener, and the opener exerts an output force of 30 newtons on a can. The mechanical advantage of the can opener is

$$\frac{\text{Output force}}{\text{Input force}} = \frac{30 \text{ N}}{10 \text{ N}} = 3$$

The can opener triples your input force!

Increasing Distance For a machine that increases distance, the output force is less than the input force. So in this case, the mechanical advantage is less than 1. For example, suppose your input force is 20 newtons and the machine's output force is 10 newtons. The mechanical advantage is

$$\frac{\text{Output force}}{\text{Input force}} = \frac{10 \text{ N}}{20 \text{ N}} = 0.5$$

The output force of the machine is half your input force, but the machine exerts that force over a longer distance.

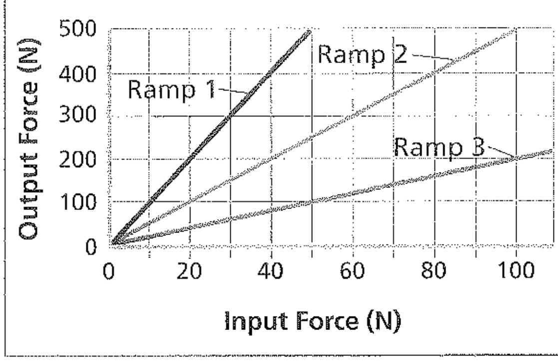
Math Analyzing Data

Mechanical Advantage

The input force and output force for three different ramps are shown in the graph.

1. Reading Graphs What variable is plotted on the horizontal axis?
2. Interpreting Data If an 80-N input force is exerted on Ramp 2, what is the output force?
3. Interpreting Data Find the slope of the line for each ramp.
4. Drawing Conclusions Why does the slope represent each ramp's mechanical advantage? Which ramp has the greatest mechanical advantage?

Mechanical Advantages of Ramps



Changing Direction What can you predict about the mechanical advantage of a machine that changes the direction of the force? If only the direction changes, the input force will be the same as the output force. The mechanical advantage will always be 1.

Efficiency of Machines

So far, you have learned that the work you put into a machine is exactly equal to the work done by the machine. In an ideal situation, this equation is true. In real situations, however, the output work is always less than the input work.

Friction and Efficiency If you have ever tried to cut something with scissors that barely open and close, you know that a large part of your work is wasted overcoming the tightness, or friction, between the parts of the scissors.

In every machine, some work is wasted overcoming the force of friction. The less friction there is, the closer the output work is to the input work. The **efficiency** of a machine compares the output work to the input work. Efficiency is expressed as a percent. The higher the percent, the more efficient the machine is. If you know the input work and output work for a machine, you can calculate a machine's efficiency.

Reading Checkpoint **Why is output work always less than input work in real situations?**

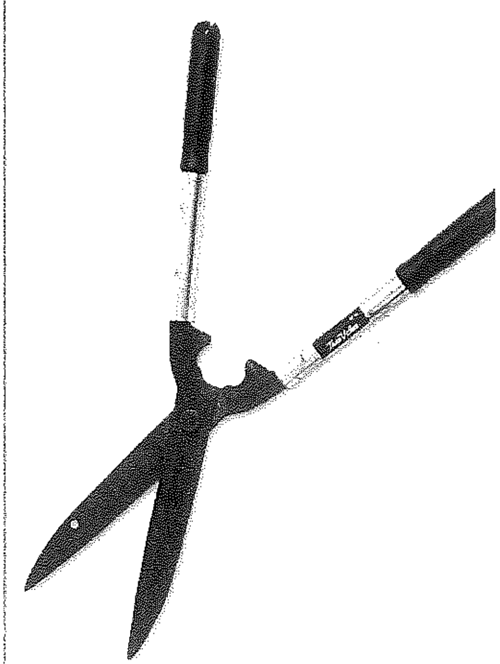


FIGURE 10
Efficiency
A rusty pair of shears is less efficient than a new pair of shears.
Applying Concepts *What force reduces the efficiency of the shears?*

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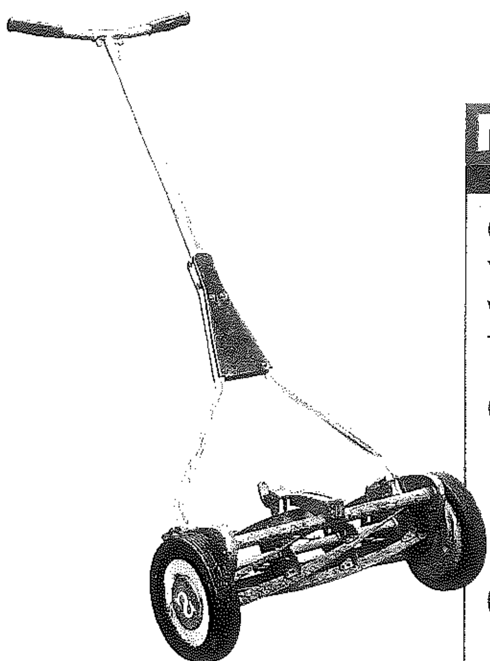
For: Links on mechanical efficiency
Visit: www.SciLinks.org
Web Code: scn-1342

Calculating Efficiency To calculate the efficiency of a machine, **divide the output work by the input work and multiply the result by 100 percent.** This is summarized by the following formula.

$$\text{Efficiency} = \frac{\text{Output work}}{\text{Input work}} \times 100\%$$

If the tight scissors described on the previous page have an efficiency of 60%, only a little more than half of the work you do goes into cutting the paper. The rest is wasted overcoming the friction in the scissors.



Math Sample Problem

Calculating Efficiency

You do 250,000 J of work to cut a lawn with a hand mower. If the work done by the mower is 200,000 J, what is the efficiency of the lawn mower?

1 Read and Understand.

What information are you given?

Input work (W_{input}) = 250,000 J

Output work (W_{output}) = 200,000 J

2 Plan and Solve

What quantity are you trying to calculate?

The efficiency of the lawn mower = ■

What formula contains the given quantities and the unknown quantity?

$$\text{Efficiency} = \frac{\text{Output work}}{\text{Input work}} \times 100\%$$

Perform the calculation.

$$\text{Efficiency} = \frac{200{,}000 \text{ J}}{250{,}000 \text{ J}} \times 100\%$$

$$\text{Efficiency} = 0.8 \times 100\% = 80\%$$

The efficiency of the lawn mower is 80%.

3 Look Back and Check

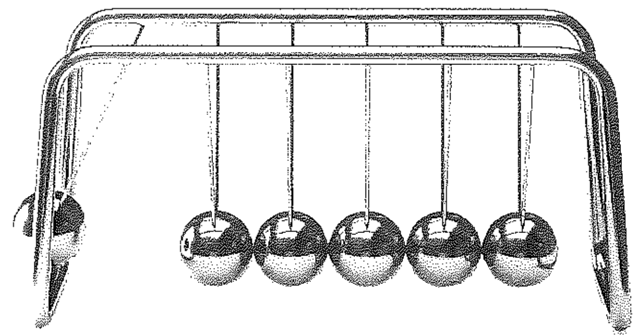
Does your answer make sense?

An efficiency of 80% means that 80 out of every 100 J of work went into cutting the lawn. This answer makes sense because most of the input work is converted to output work.

Math Practice

1. Calculating Efficiency You do 20 J of work while using a hammer. The hammer does 18 J of work on a nail. What is the efficiency of the hammer?
2. Calculating Efficiency Suppose you left your lawn mower outdoors all winter. Now it's rusty. Of your 250,000 J of work, only 100,000 J go to cutting the lawn. What is the efficiency of the lawn mower now?

FIGURE 11
An Ideal Machine?
The balls of this Newton's cradle may swing for a long time, but friction will eventually bring them to rest.



Real and Ideal Machines If you could find a machine with an efficiency of 100%, it would be an ideal machine. Unfortunately, such a machine does not exist. In all machines, some work is wasted due to friction. Even the balls in Figure 11 will eventually come to rest. All machines have an efficiency of less than 100%. The machines you use every day, such as scissors, screwdrivers, and rakes, lose some work due to friction.

A machine's ideal mechanical advantage is its mechanical advantage with 100% efficiency. However, if you measure a machine's input force and output force, you will find the efficiency is always less than 100%. A machine's measured mechanical advantage is called actual mechanical advantage.

Reading Checkpoint **What is a machine's ideal mechanical advantage?**

Section 2 Assessment

Target Reading Skill

Identifying Main Ideas Use your graphic organizer to help you answer Question 1 below.

Reviewing Key Concepts

1. a. Defining What is a machine?
   b. Describing In what three ways can machines make work easier?
   c. Applying Concepts How does a screwdriver make work easier?
2. a. Reviewing What is the mechanical advantage of a machine?
   b. Making Generalizations What is the mechanical advantage of a machine that changes only the direction of the applied force?
   c. Calculating If a machine has an input force of 40 N and an output force of 80 N, what is its mechanical advantage?
3. a. Reviewing What must you know in order to calculate a machine's efficiency?
   b. Explaining What is an ideal machine?
   c. Comparing and Contrasting How is a real machine like an ideal machine, and how is it different?

Math Practice

4. Calculating Efficiency The input work you do on a can opener is 12 J. The output work the can opener does is 6 J. What is the efficiency of the can opener?
5. Calculating Efficiency Suppose the efficiency of a manual pencil sharpener is 58%. If the output work needed to sharpen a pencil is 4.8 J, how much input work must you do to sharpen the pencil?

Lab zone **Skills Lab**

Seesaw Science

Problem

What is the relationship between distance and weight for a balanced seesaw?

Skills Focus

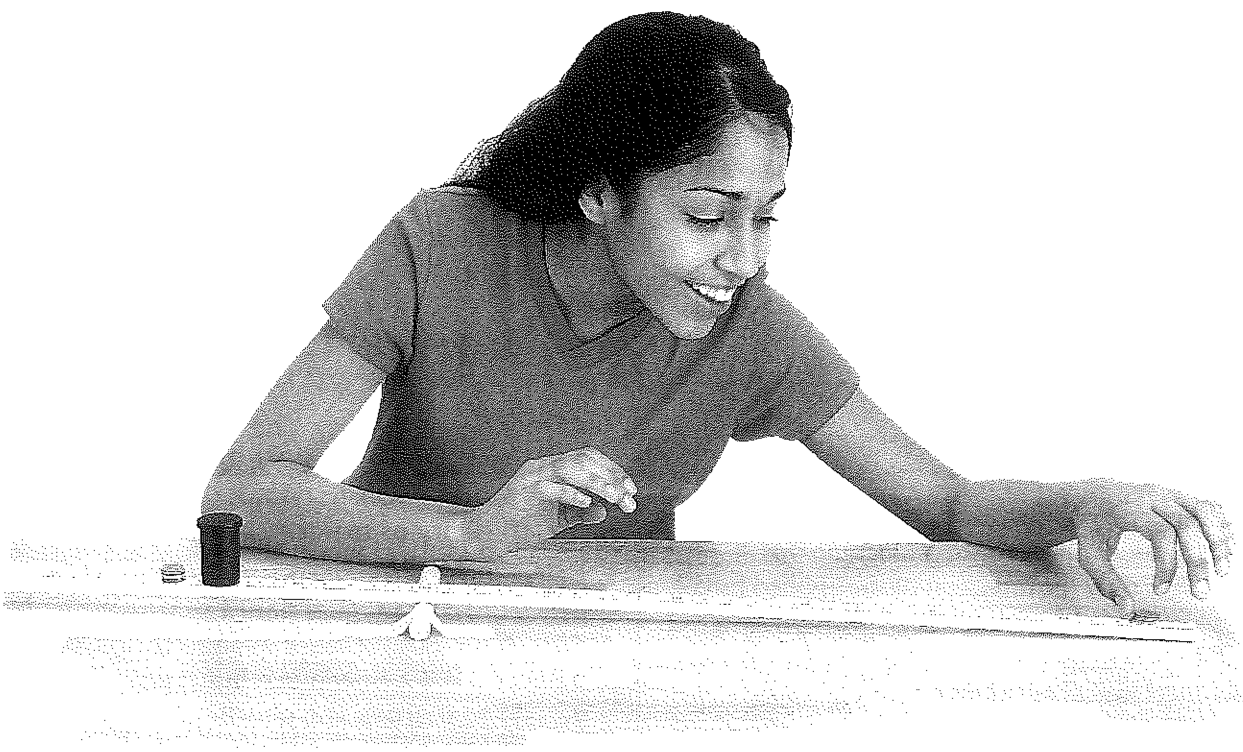
controlling variables, interpreting data

Materials

- meter stick
- masking tape
- 28 pennies, minted after 1982
- small object with a mass of about 50 g
- dowel or other cylindrical object for pivot point, about 10 cm long and 3 cm in diameter

Procedure

1. Begin by using the dowel and meter stick to build a seesaw. Tape the dowel firmly to the table so that it does not roll.
2. Choose the meter stick mark that will rest on the dowel from the following: 55 cm or 65 cm. Record your choice. Position your meter stick so that it is on your chosen pivot point with the 100-cm mark on your right.
3. Slide the 50-g mass along the shorter end of the meter stick until the meter stick is balanced, with both sides in the air. (This is called "zeroing" your meter stick.)
4. Copy the data table into your notebook.
5. Place a stack of 8 pennies exactly over the 80-cm mark. Determine the distance, in centimeters, from the pivot point to the pennies. Record this distance in the "Distance to Pivot" column for the right side of the seesaw.
6. Predict where you must place a stack of 5 pennies in order to balance the meter stick. Test your prediction and record the actual position in the "Position of Pennies" column for the left side of the seesaw.



Data Table					
Your group's pivot point position: ______ cm					
Trial Number	Side of Seesaw	Number of Pennies or Weight of Pennies (pw)	Position of Pennies (cm)	Distance to Pivot (cm)	Weight of Pennies × Distance
1	Right				
	Left				
2	Right				
	Left				
3	Right				

7. Determine the distance, in centimeters, from the pivot point to the left stack of pennies. Record this distance in the "Distance to Pivot" column for the left side of the seesaw.
8. If you use an imaginary unit of weight, the pennyweight (pw), then one penny weighs 1 pw. Multiply the weight of each stack of pennies by the distance to the pivot point. Record the result in the last column of the data table.
9. Predict how the position of the pennies in Step 6 would change if you used 7, 12, 16, and 20 pennies instead of 5 pennies. Test your predictions.

Analyze and Conclude

1. Controlling Variables In this experiment, what is the manipulated variable? The responding variable? How do you know which is which?
2. Interpreting Data As you increase the number of pennies on the left, what happens to the distance at which you must place the stack in order to balance the meter stick?
3. Drawing Conclusions What conclusion can you draw about the relationship between distances and weights needed to balance a seesaw?
4. Controlling Variables Why was it important to zero the meter stick with the 50-g mass?
5. Interpreting Data Compare your results with those of the other groups. How do different pivot point positions affect the results?
6. Communicating Write a dialogue that occurs when two friends try to balance themselves on opposite sides of a seesaw. One friend has a mass of 54 kg and the other friend has a mass of 42 kg.

Design an Experiment

Suppose you have a seesaw with a movable pivot. You want to use it with a younger friend who weighs half what you weigh. If you and your friend sit on the ends of the seesaw, where should you position the pivot point? Develop a hypothesis and then design an experiment to test it. *Obtain your teacher's permission before carrying out your investigation.*

Section 3

Simple Machines

Reading Preview

Key Concepts

- What are the six kinds of simple machines, and how are they used?
- What is the ideal mechanical advantage of each simple machine?
- What is a compound machine?

Key Terms

- inclined plane
- wedge
- screw
- lever
- fulcrum
- wheel and axle
- pulley
- compound machine

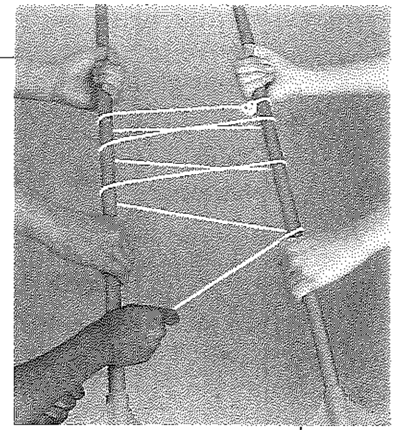
Target Reading Skill

Previewing Visuals Before you read, preview Figure 17. Then write two questions that you have about the diagram in a graphic organizer like the one below. As you read, answer your questions.

Three Classes of Levers

Q.	What are the three classes of levers?
A.	
Q.	

Lab zone Discover Activity



How Can You Increase Force?

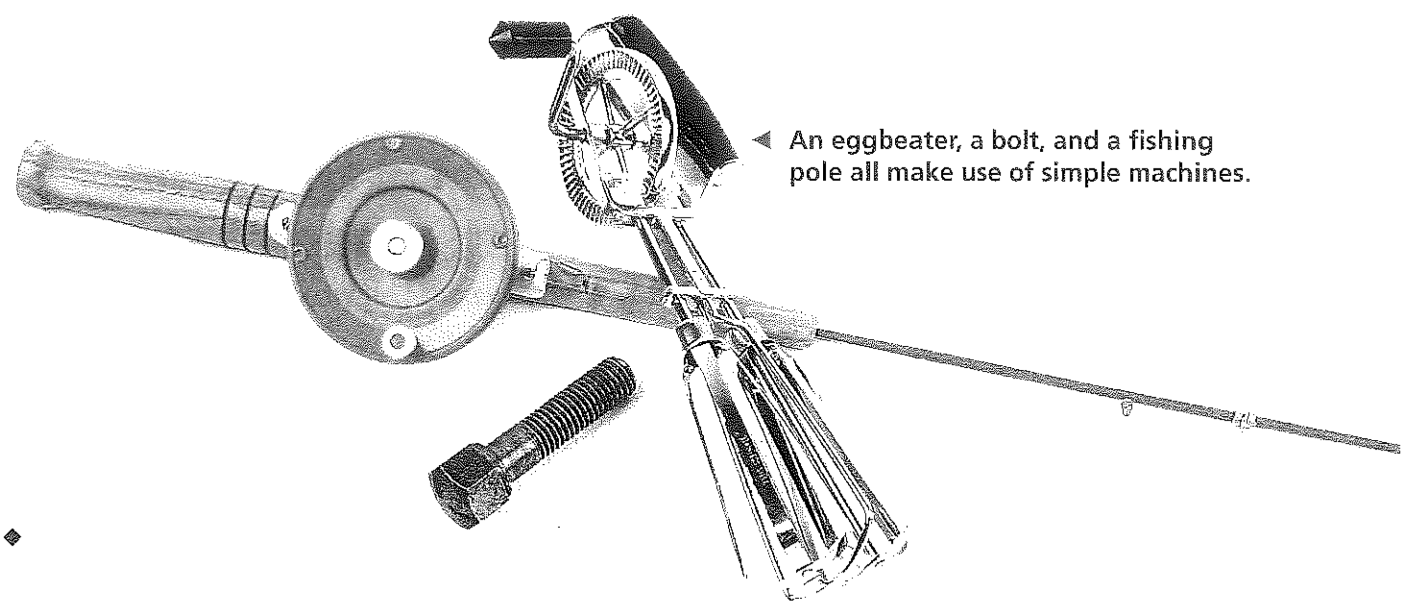
1. Working with two partners, wrap a rope around two broomsticks as shown.
2. Your two partners should try to hold the brooms apart with the same amount of force throughout the activity. For safety, they should hold firmly, but not with all their strength.
3. Try to pull the two students together by pulling on the broomsticks. Can you do it?
4. Can you pull them together by pulling on the rope?

Think It Over

Predicting What do you think will be the effect of wrapping the rope around the broomsticks several more times?

Look at the objects shown on these pages. Which of them would you call machines? Would it surprise you to find out that each is made up of one or more simple machines? As you learned in the last section, a machine helps you do work by changing the amount or direction of the force you apply.

There are six basic kinds of simple machines: the inclined plane, the wedge, the screw, the lever, the wheel and axle, and the pulley. In this section, you will learn how the different types of simple machines help you do work.



◄ An eggbeater, a bolt, and a fishing pole all make use of simple machines.

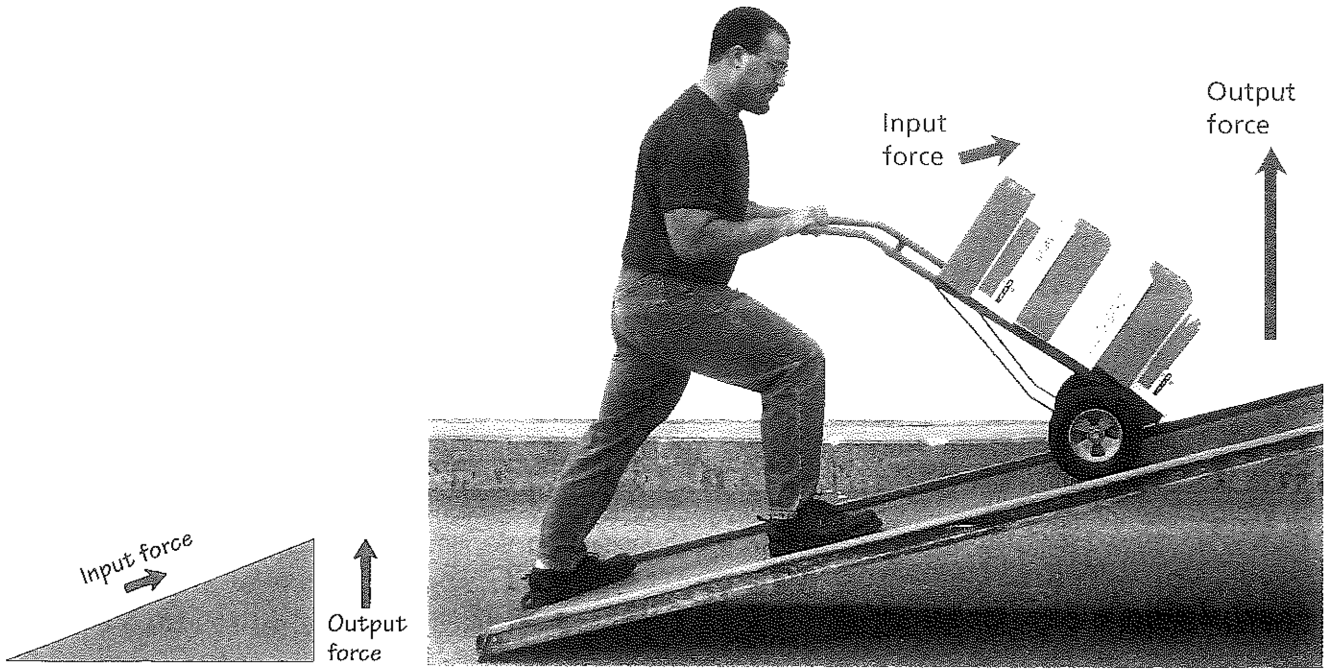


FIGURE 12
Inclined Plane
Although the amount of work is the same whether you lift the boxes or push them up the ramp to the truck, you need less force when you use an inclined plane.
Relating Cause and Effect *When you use a ramp, what happens to the distance over which you exert your force?*

Inclined Plane

Have you ever had to lift something from a lower level to a higher level? The job is much easier if you have a ramp. For example, a ramp makes it much easier to push a grocery cart over a curb. A ramp is an example of a simple machine called an inclined plane. An **inclined plane** is a flat, sloped surface.

How It Works An inclined plane allows you to exert your input force over a longer distance. As a result, the input force needed is less than the output force. The input force that you use on an inclined plane is the force with which you push or pull an object. The output force is the force that you would need to lift the object without the inclined plane. Recall that this force is equal to the weight of the object.

Mechanical Advantage **You can determine the ideal mechanical advantage of an inclined plane by dividing the length of the incline by its height.**

$$\text{Ideal mechanical advantage} = \frac{\text{Length of incline}}{\text{Height of incline}}$$

For example, if you are loading a truck that is 1 meter high using a ramp that is 3 meters long, the ideal mechanical advantage of the ramp is 3 meters ÷ 1 meter, or 3. The inclined plane increases the force you exerted three times. If the height of the incline does not change, increasing the length of the incline will increase the mechanical advantage. The longer the incline, the less input force you need to push or pull an object.

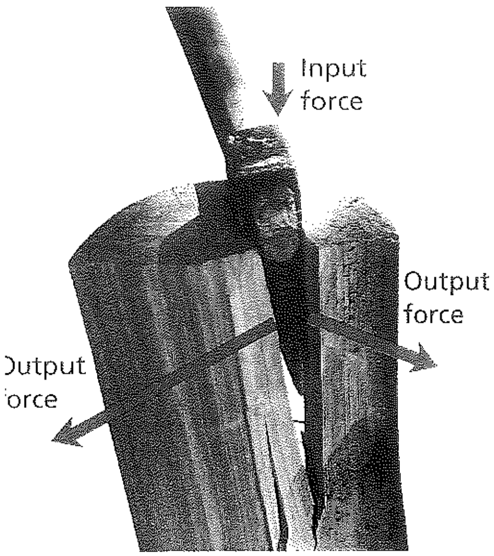
Wedge

If you've ever sliced an apple with a knife, pulled up a zipper, or seen someone chop wood with an ax, you are familiar with another simple machine known as a wedge. A **wedge** is a device that is thick at one end and tapers to a thin edge at the other end. It might be helpful to think of a wedge, like the one shown in Figure 13, as an inclined plane (or sometimes two inclined planes back to back) that can move.

How It Works When you use a wedge, instead of moving an object along the inclined plane, you move the inclined plane itself. For example, when an ax is used to split wood, the ax handle exerts a force on the blade of the ax, which is the wedge. That force pushes the wedge down into the wood. The wedge in turn exerts an output force at a 90° angle to its slope, splitting the wood in two.

Wedges are a part of your everyday life. For example, a zipper depends on wedges to close and open. A pencil sharpener, a cheese grater, and a shovel all make use of wedges.

Mechanical Advantage The mechanical advantage of the wedge and the inclined plane are similar. **The ideal mechanical advantage of a wedge is determined by dividing the length of the wedge by its width.** The longer and thinner a wedge is, the greater its mechanical advantage. For example, the cutting edge of a steel carving knife is a wedge. When you sharpen a knife, you make the wedge thinner and increase its mechanical advantage. That is why sharp knives cut better than dull knives.



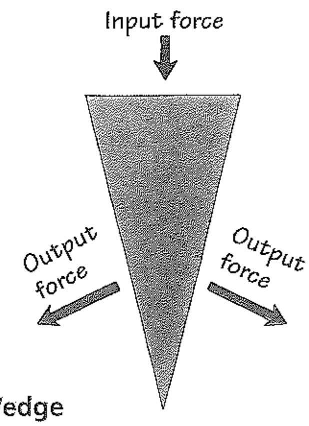


FIGURE 13
Forces of a Wedge
The input force exerted on a wedge results in output forces that can split the log.

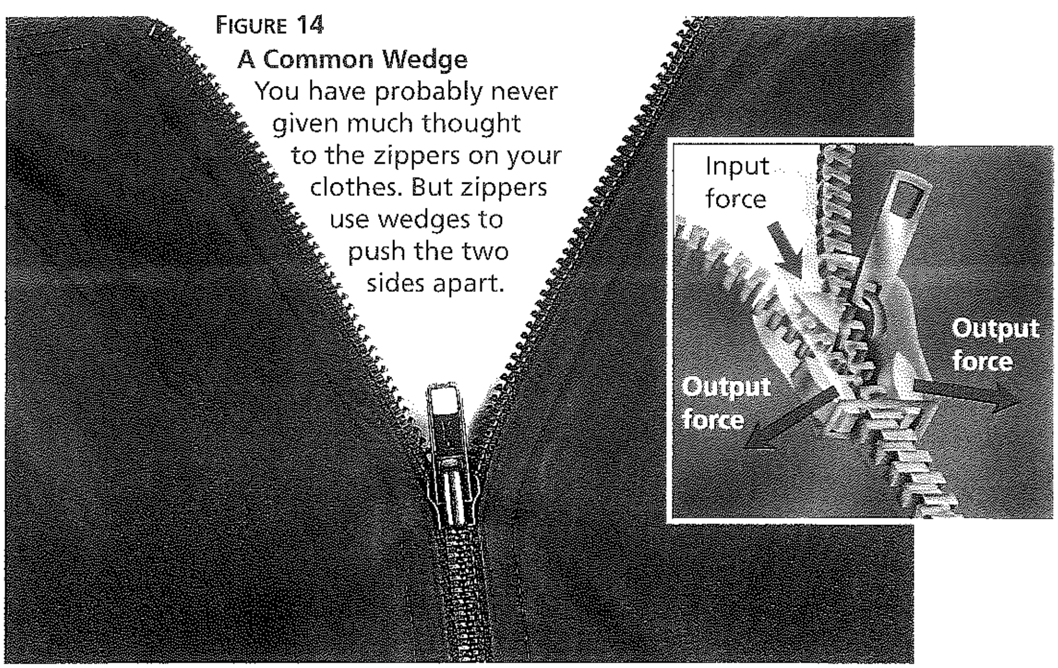


FIGURE 14
A Common Wedge
You have probably never given much thought to the zippers on your clothes. But zippers use wedges to push the two sides apart.

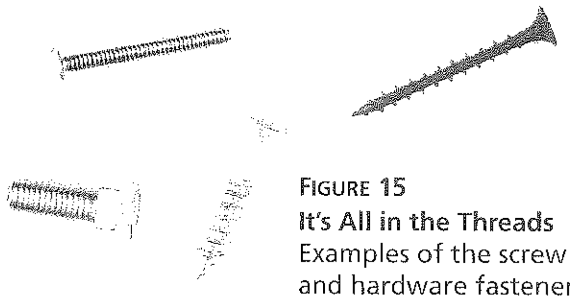


FIGURE 15
It's All in the Threads
Examples of the screw are found in jars and hardware fasteners.
Relating Cause and Effect *How does the distance between the threads of a screw affect its mechanical advantage?*

Screws

Like a wedge, a screw is a simple machine that is related to the inclined plane. A **screw** can be thought of as an inclined plane wrapped around a cylinder. This spiral inclined plane forms the threads of the screw.

How It Works When you twist a screw into a piece of wood, you exert an input force on the screw. The threads of a screw act like an inclined plane to increase the distance over which you exert the input force. As the threads of the screw turn, they exert an output force on the wood, pulling the screw into the wood. Friction between the screw and the wood holds the screw in place.

Many devices act like screws. Examples include bolts, light bulbs, and jar lids. Look at the jar lid in Figure 15. When you turn the lid, your small input force is greatly increased because of the screw threads on the lid. The threads on the lid are pulled against the matching threads on the jar with a strong enough force to make a tight seal.

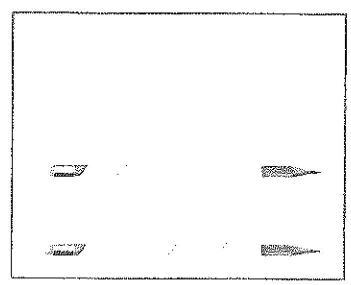
Mechanical Advantage The closer together the threads of a screw are, the greater the mechanical advantage. This is because the closer the threads are, the more times you must turn the screw to fasten it into a piece of wood. Your input force is applied over a longer distance. The longer input distance results in an increased output force. Think of the length around the threads as the length of the inclined plane, and the length of the screw as the height of the inclined plane. **The ideal mechanical advantage of a screw is the length around the threads divided by the length of the screw.**

Reading Checkpoint **How is a screw like an inclined plane?**

Lab zone Try This Activity

A Paper Screw

1. To make a paper model of a screw, cut out a triangle from a piece of paper.
2. Tape the wide end of the triangle to a pencil. Then wind the paper around the pencil.



Making Models How does this model represent a real screw? Can you think of a way to calculate the ideal mechanical advantage of your model screw?

Levers

Have you ever ridden on a seesaw or pried open a paint can with an opener? If so, then you are already familiar with another simple machine called a lever. A **lever** is a rigid bar that is free to pivot, or rotate, on a fixed point. The fixed point that a lever pivots around is called the **fulcrum.**

How It Works To understand how levers work, think about using a paint-can opener. The opener rests against the edge of the can, which acts as the fulcrum. The tip of the opener is under the lid of the can. When you push down, you exert an input force on the handle, and the opener pivots on the fulcrum. As a result, the tip of the opener pushes up, thereby exerting an output force on the lid.

Mechanical Advantage A lever like the paint-can opener helps you in two ways. It increases your input force and it changes the direction of your input force. When you use the paint-can opener, you push the handle a long distance down in order to move the lid a short distance up. However, you are able to apply a smaller force than you would have without the opener.

The ideal mechanical advantage of a lever is determined by dividing the distance from the fulcrum to the input force by the distance from the fulcrum to the output force.

$$\text{Ideal mechanical advantage} = \frac{\text{Distance from fulcrum to input force}}{\text{Distance from fulcrum to output force}}$$

In the case of the paint can opener, the distance from the fulcrum to the input force is greater than the distance from the fulcrum to the output force. This means that the mechanical advantage is greater than 1.

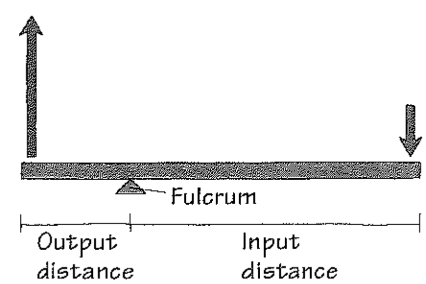


FIGURE 16
Mechanical Advantage of a Lever
A lever's input distance and output distance determine its ideal mechanical advantage.

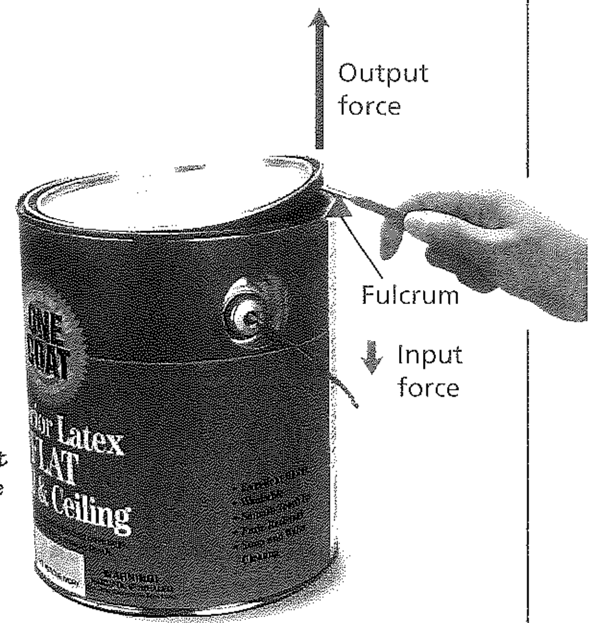
Different Types of Levers When a paint-can opener is used as a lever, the fulcrum is located between the input and output forces. But this is not always the case. As shown in Figure 17, there are three different types of levers. Levers are classified according to the location of the fulcrum relative to the input and output forces.

Reading Checkpoint **What point on a lever does not move?**

FIGURE 17

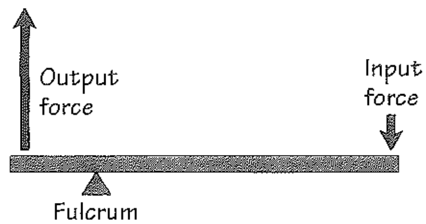
Three Classes of Levers

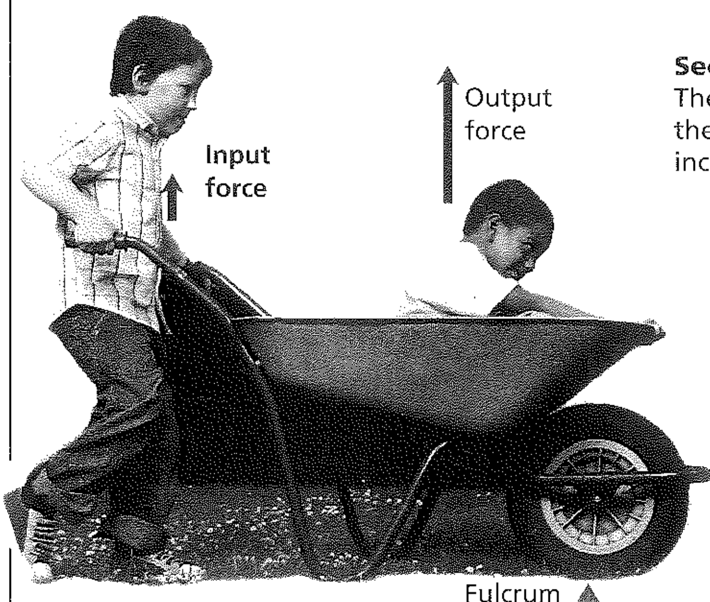
The three classes of levers differ in the positions of the fulcrum, input force, and output force. Applying Concepts *Which type of lever always has an ideal mechanical advantage less than 1?*



First-Class Levers

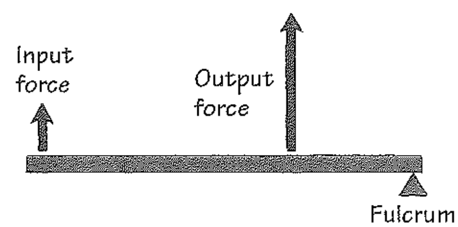
First-class levers always change the direction of the input force. If the fulcrum is closer to the output force, these levers also increase force. If the fulcrum is closer to the input force, these levers also increase distance. Other examples include scissors, pliers, and seesaws.





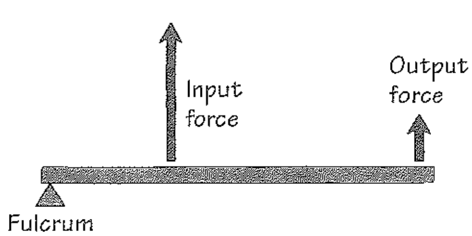
Second-Class Levers

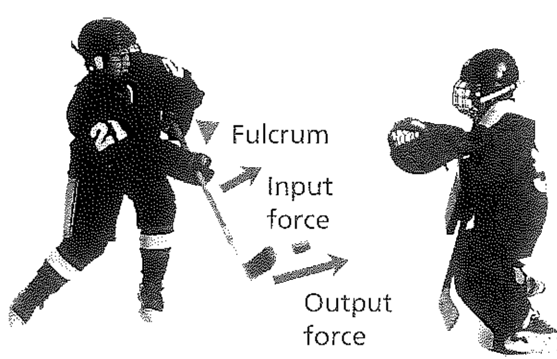
These levers increase force, but do not change the direction of the input force. Other examples include doors, nutcrackers, and bottle openers.



Third-Class Levers

These levers increase distance, but do not change the direction of the input force. Other examples include fishing poles, shovels, and baseball bats.





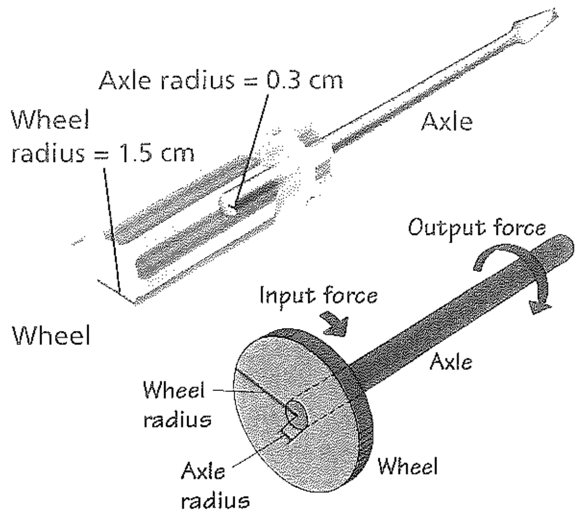


FIGURE 18
Wheel and Axle
A screwdriver increases force by exerting the output force over a shorter distance.
Observing *Which has a larger radius, the wheel or the axle?*

Wheel and Axle

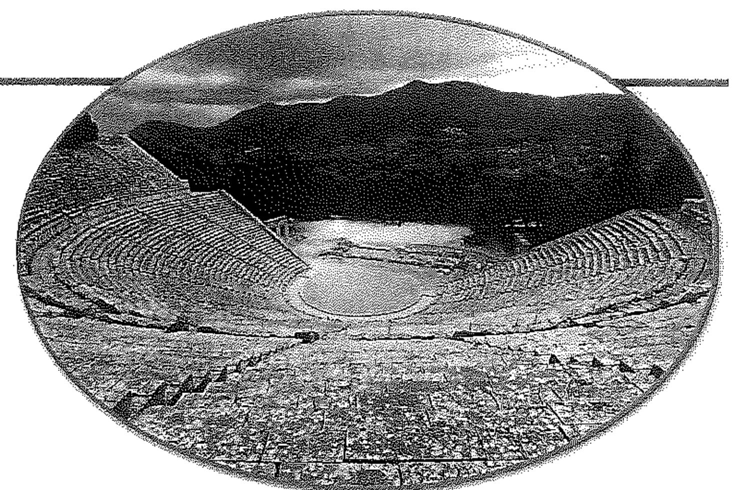
It's almost impossible to insert a screw into a piece of wood with your fingers. But with a screwdriver, you can turn the screw easily. A screwdriver makes use of a simple machine known as the **wheel and axle.** A wheel and axle is a simple machine made of two circular or cylindrical objects fastened together that rotate about a common axis. The object with the larger radius is called the wheel and the object with the smaller radius is called the axle. In a screwdriver, the handle is the wheel and the shaft is the axle. A doorknob and a car's steering wheel are also examples of a wheel and axle.

Science and **History**

Engineering Marvels

Simple machines have been used to create some of the most beautiful and useful structures in the world.

2550 B.C.
Great Pyramid, Giza, Egypt
Workers used wooden wedges to cut 2.3 million blocks of stone to build the pyramid. At the quarry, the wedges were driven into cracks in the rock. The rock split into pieces. Workers hauled the massive blocks up inclined planes to the tops of pyramid walls.



500 B.C.
Theater at Epidaurus, Greece
Instead of ramps, the Greeks relied on a crane powered by pulleys to lift the stone blocks to build this theater. The crane was also used to lower actors to the stage during performances.

3000 B.C. **2000 B.C.** **1000 B.C.**

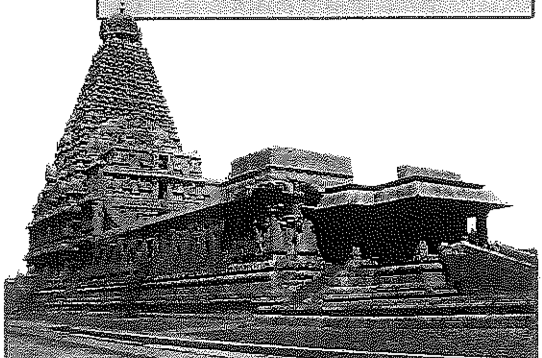
How It Works How does a screwdriver make use of a wheel and axle to do work? Look at Figure 18. When you use a screwdriver, you apply an input force to turn the handle, or wheel. Because the wheel is larger than the shaft, or axle, the axle rotates and exerts a large output force. The wheel and axle increases your force, but you must exert your force over a long distance.

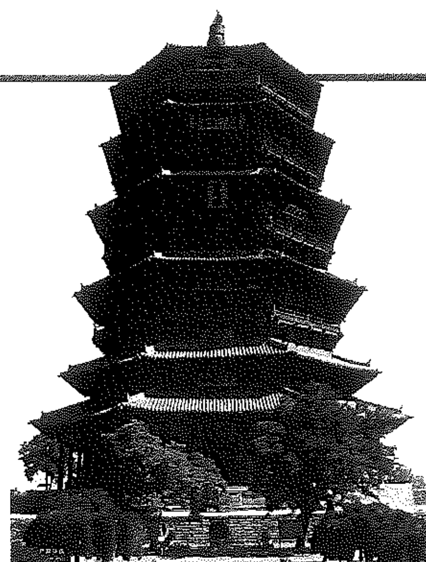
What would happen if the input force were applied to the axle rather than the wheel? For the riverboat in Figure 19 on the next page, the force of the engine is applied to the axle of the large paddle wheel. The large paddle wheel in turn pushes against the water. In this case, the input force is exerted over a short distance. So when the input force is applied to the axle, a wheel and axle mulitplies distance.

Writing in Science

Research and Write Suppose that you are the person who first thought of using a simple machine at one of the construction sites in the timeline. Write out your proposal. You'll need to research the time and place. Explain to the people in charge why the simple machine you suggest will give workers a mechanical advantage.

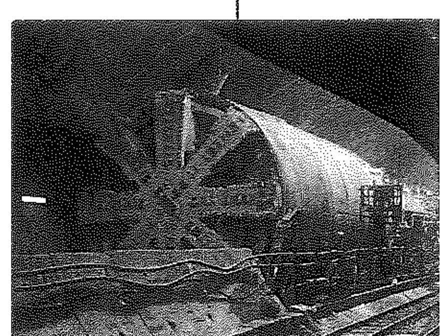
A.D. 1000 Brihadeshwara Temple, India
The temple's tower at Thanjavur is more than 60 meters high. Workers dragged the dome-shaped capstone, a mass of 70,000 kilograms, to the top of the structure along an inclined plane several kilometers long.





A.D. 1056 Yingxian Pagoda, China
Slanted wooden beams called *ang* act as first-class levers to hold up the roof of this pagoda. The weight of the center of the roof presses down on one end of the beam. The other end of the beam swings up to support the outer edge of the roof.

A.D. 1994 The Chunnel, United Kingdom to France
Special drilling equipment was built to tunnel under the English Channel. Opened in May of 1994, the tunnel is 50 kilometers long. It carries only railway traffic.



0 | A.D. 1000 | A.D. 2000

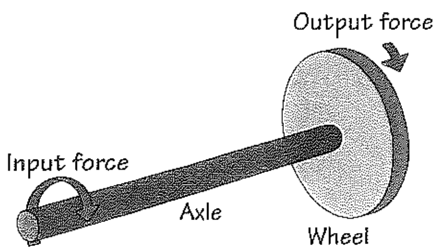


FIGURE 19
Increasing Distance
In a riverboat paddle wheel, the axle turns the wheel. The output force is less than the input force, but it is exerted over a longer distance.

Mechanical Advantage **You can find the ideal mechanical advantage of a wheel and axle by dividing the radius of the wheel by the radius of the axle.** (A radius is the distance from the outer edge of a circle to the circle's center.) The greater the ratio between the radius of the wheel and the radius of the axle, the greater the mechanical advantage.

$$\text{Mechanical advantage} = \frac{\text{Radius of wheel}}{\text{Radius of axle}}$$

Suppose the radius of a screwdriver's wheel is 1.5 cm and its axle radius is 0.3 cm. The screwdriver's ideal mechanical advantage would be 1.5 centimeters ÷ 0.3 centimeter, or 5.

Reading Checkpoint **What is a radius?**

Pulley

When you raise a flag on a flagpole or when you open and close window blinds, you are using a pulley. A **pulley** is a simple machine made of a grooved wheel with a rope or cable wrapped around it.

How It Works You use a pulley by pulling on one end of the rope. This is the input force. At the other end of the rope, the output force pulls up on the object you want to move. To move a heavy object over a distance, a pulley can make work easier in two ways. First, it can decrease the amount of input force needed to lift the object. Second, the pulley can change the direction of your input force. For example, you pull down on the flagpole rope, and the flag moves up.

Types of Pulleys There are two basic types of pulleys. A pulley that you attach to a structure is called a fixed pulley. Fixed pulleys are used at the tops of flagpoles. If you attach a pulley to the object you wish to move, you use a movable pulley. Construction cranes often use movable pulleys. By combining fixed and movable pulleys, you can make a pulley system called a block and tackle. **The ideal mechanical advantage of a pulley is equal to the number of sections of rope that support the object.**

Reading Checkpoint **A pulley is attached to the object that is being moved. What kind of pulley is it?**

Lab zone Skills Activity

Communicating

Write a packaging label for a machine that uses a wheel and axle. On your label, describe the advantages of using this simple machine. Include a drawing of the forces that act on the machine.

FIGURE 20

Types of Pulleys

A fixed pulley and a movable pulley are the two basic types of pulleys. A block and tackle combines a fixed and movable pulley. Comparing and Contrasting *Which type of pulley has the greatest mechanical advantage?*

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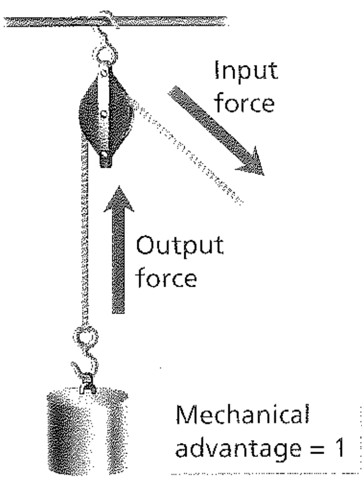
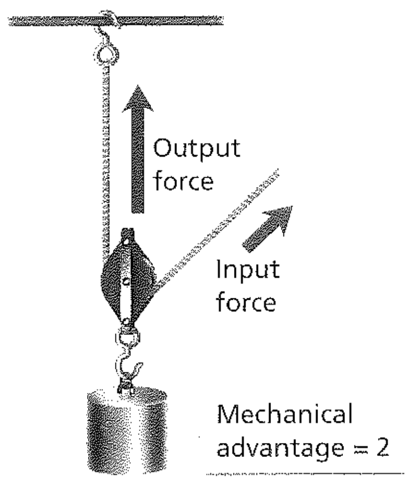
Fixed Pulley

A fixed pulley does not change the amount of force applied. It does change the direction of the force.



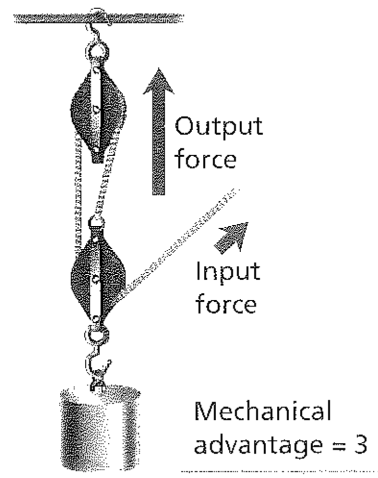
Movable Pulley

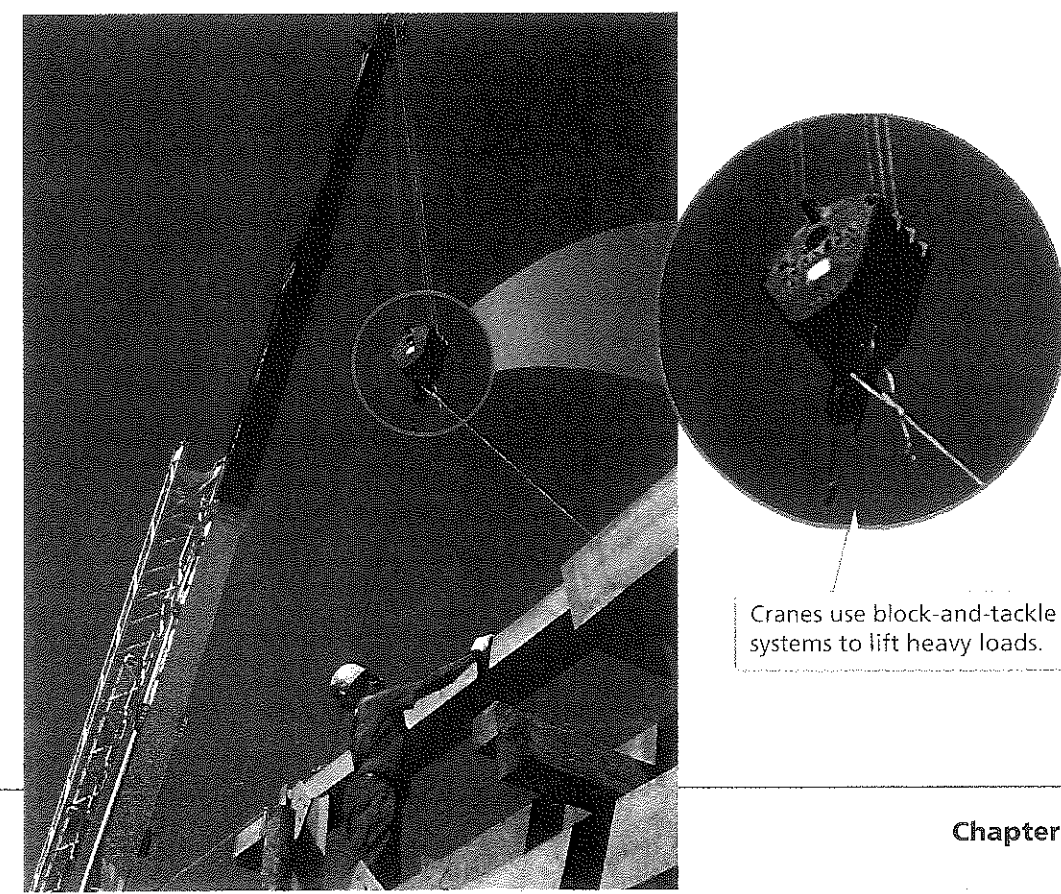
A movable pulley decreases the amount of input force needed. It does not change the direction of the force.



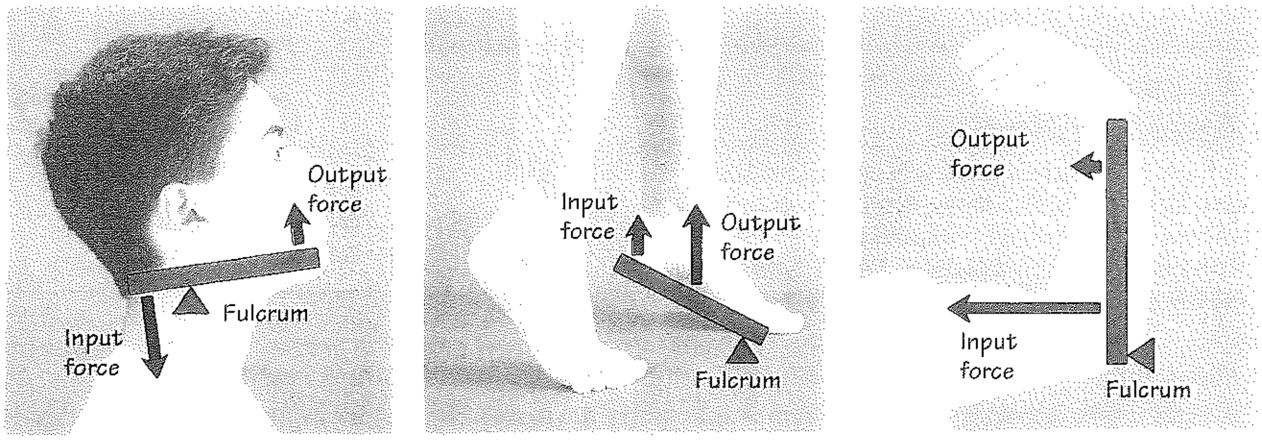
Block and Tackle

A block and tackle is a pulley system made up of fixed and movable pulleys.





Cranes use block-and-tackle systems to lift heavy loads.



First-Class Lever The joint at the top of your neck is the fulcrum of a first-class lever. The muscles in the back of your neck provide the input force. The output force is used to tilt your head back.

Second-Class Lever The ball of your foot is the fulcrum of a second-class lever. The muscle in the calf of your leg provides the input force. The output force is used to raise your body.

Third-Class Lever Your elbow is the fulcrum of a third-class lever. Your biceps muscle provides the input force. The output force is used to lift your arm.

FIGURE 21
Levers in the Body
You don't need to look further than your own body to find simple machines. Three different types of levers are responsible for many of your movements.

Simple Machines in the Body

You probably don't think of the human body as being made up of machines. Believe it or not, machines are involved in much of the work that your body does.

Living Levers **Most of the machines in your body are levers that consist of bones and muscles.** Every time you move, you use a muscle. Your muscles are attached to your bones by connecting structures called tendons. Tendons and muscles pull on bones, making them work as levers. The joint, near where the tendon is attached to the bone, acts as the fulcrum. The muscles produce the input force. The output force is used for doing work, such as lifting your hand.

Working Wedges When you bite into an apple, you use your sharp front teeth, called incisors. Your incisors are shaped like wedges to enable you to bite off pieces of food. When you bite down on something, the wedge shape of your front teeth produces enough force to break it into pieces, just as an ax splits a log. The next time you take a bite of a crunchy apple, think about the machines in your mouth!

Reading Checkpoint **What type of simple machine do your front teeth resemble?**

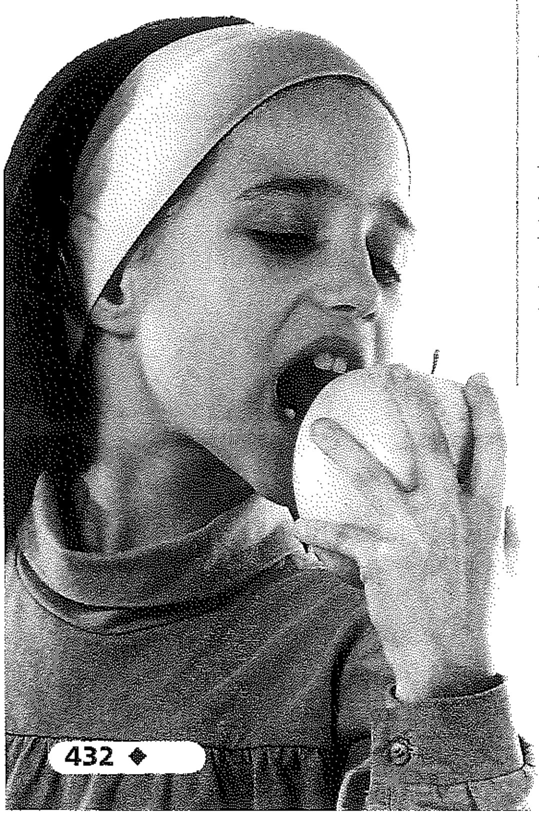


FIGURE 22
Wedges to Help You Eat
Your front teeth, known as incisors, are shaped like wedges.

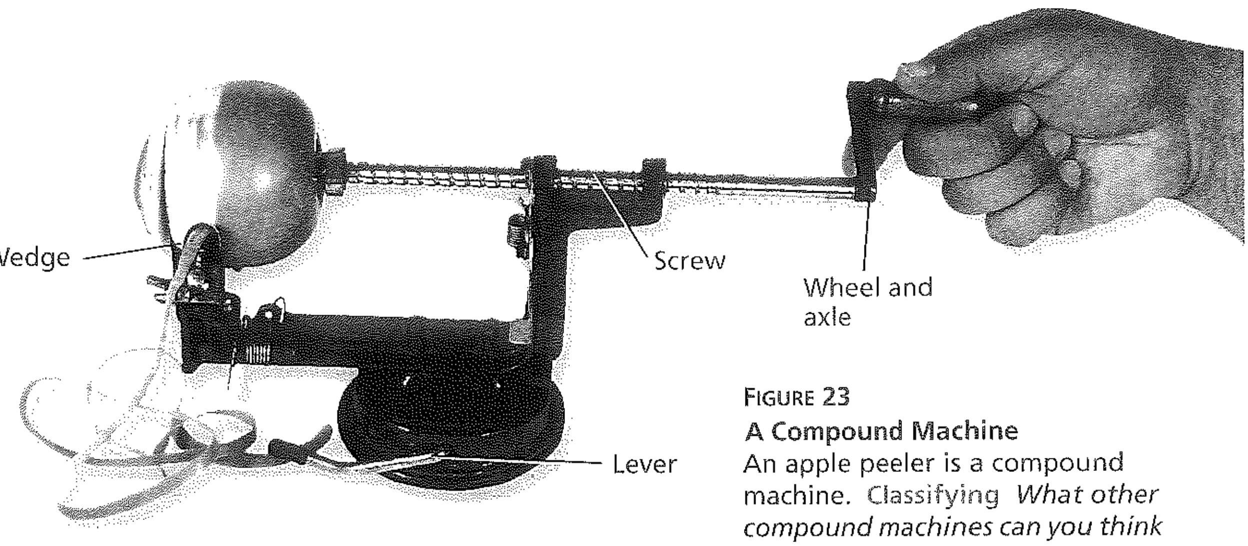


FIGURE 23
A Compound Machine
An apple peeler is a compound machine. Classifying *What other compound machines can you think of? What simple machines make them up?*

Compound Machines

Many machines do not resemble the six simple machines you just read about. That's because many machines consist of combinations of simple machines.

A **compound machine** is a machine that utilizes two or more simple machines. **The ideal mechanical advantage of a compound machine is the product of the individual ideal mechanical advantages of the simple machines that make it up.**

An apple peeler like the one shown in Figure 23 is a compound machine. Four different simple machines make it up. The handle is a wheel and axle. The axle is also a screw that turns the apple. A wedge peels the apple's skin. To hold the machine in place, a lever can be switched to engage a suction cup.

Section 3 Assessment

Target Reading Skill Previewing Visuals Refer to your questions and answers about Figure 17 to help you answer Question 1 below.

Reviewing Key Concepts

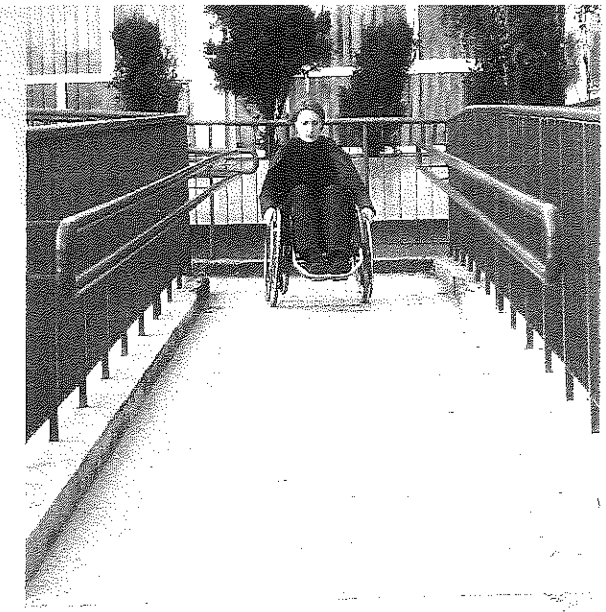
1. a. Listing List the six kinds of simple machines.
   b. Classifying What type of simple machine is a door stopper? A rake? A windmill? A slide?
   c. Developing Hypotheses Can you consider your thumb to be a lever? Why or why not?
2. a. Identifying What is the ideal mechanical advantage of each type of simple machine?
   b. Inferring How can you increase a pulley's mechanical advantage?
   c. Drawing Conclusions How is calculating the ideal mechanical advantage of an inclined plane similar to calculating that of a screw?
3. a. Reviewing How many simple machines are needed to make a compound machine?
   b. Describing How do you find the mechanical advantage of a compound machine?

Lab zone At-Home Activity

Machines in the Kitchen Look around your kitchen with a family member. Identify at least five machines. Classify each as a simple machine or a compound machine. Explain to your family member how each machine makes work easier.

Lab zone **Skills Lab**

Angling for Access



Problem

How does the steepness of a wheelchair-access ramp affect its usefulness?

Skills Focus

making models, calculating

Materials

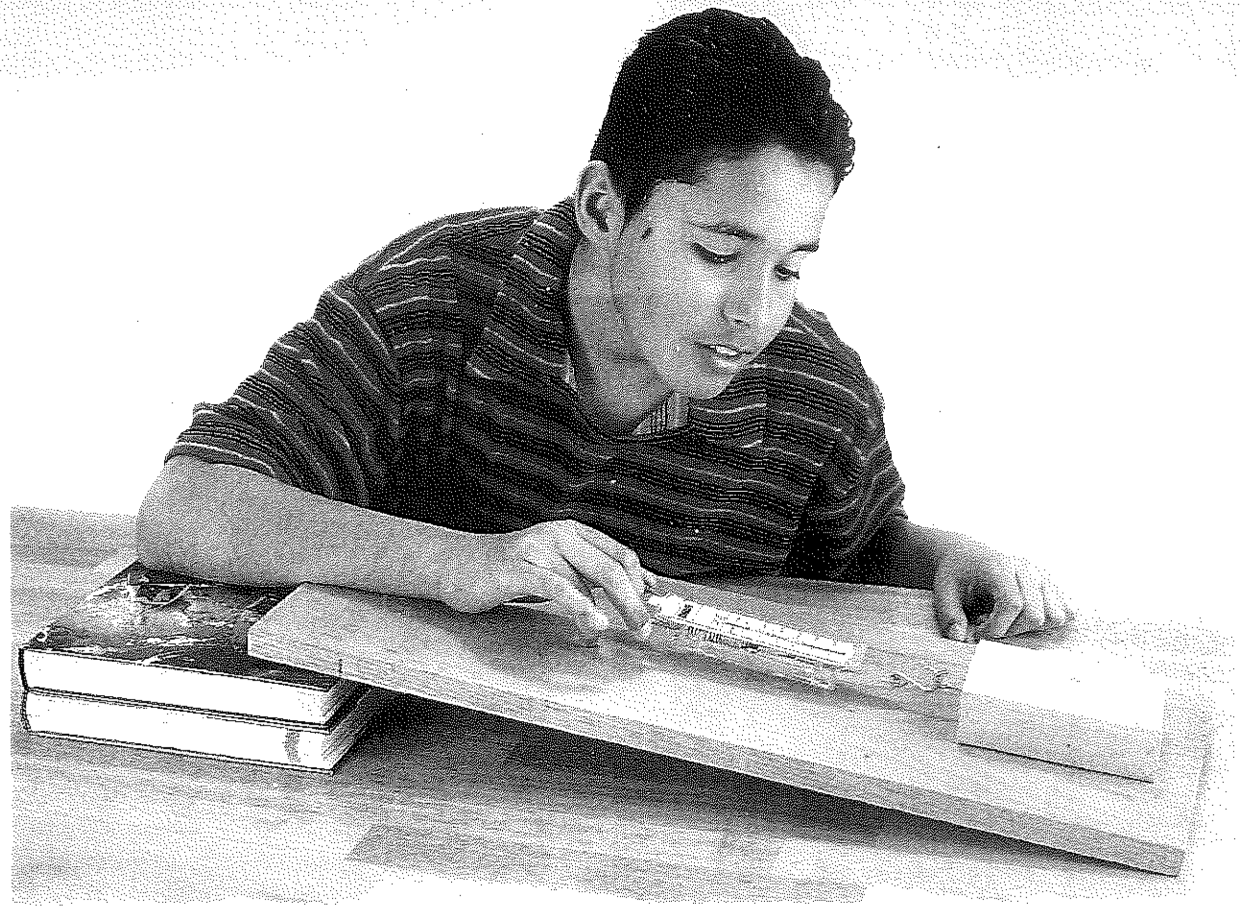
- 4 books, about 2 cm thick
- metric ruler
- wooden block with eye-hook
- marker
- board, at least 10 cm wide and 50 cm long
- spring scale, 0–10 N, or force sensor

Procedure

1. Preview the following steps that describe how you can construct and use a ramp. Then copy the data table into your notebook.
2. The output force with an inclined plane is equal to the weight of the object. Lift the block with the spring scale to measure its weight. Record this value in the data table. If you are using a force sensor, see your teacher for instructions.
3. Make a mark on the side of the board about 3 cm from one end. Measure the length from the other end of the board to the mark and record it in the data table.
4. Place one end of the board on top of a book. The mark you made on the board should be even with the edge of the book.
5. Measure the vertical distance in centimeters from the top of the table to where the underside of the incline touches the book. Record this value in the data table as "Height of Incline."
6. Lay the block on its largest side and use the spring scale to pull the block straight up the incline at a slow, steady speed. Be sure to hold the spring scale parallel to the incline, as shown in the photograph. Measure the force needed and record it in the data table.
7. Predict how your results will change if you repeat the investigation using two, three, and four books. Test your predictions.
8. For each trial, determine the ideal mechanical advantage and the actual mechanical advantage. Record the calculations in your data table.

Data Table

Number of Books	Output Force (N)	Length of Incline (cm)	Height of Incline (cm)	Input Force (N)	Ideal Mechanical Advantage	Actual Mechanical Advantage
1						
2						
3						
4						



Analyze and Conclude

1. Interpreting Data How did the ideal mechanical advantage and the actual mechanical advantage compare each time you repeated the experiment? Explain your answer.
2. Making Models How did the model help you in determining the ramp's usefulness? What kind of limitations does your model have?
3. Making Models What happens to the actual mechanical advantage as the inclined plane gets steeper? On the basis of this fact alone, which of the four inclined planes models the best steepness for a wheelchair-access ramp? Explain your answer.
4. Drawing Conclusions What other factors, besides mechanical advantage, should you consider when deciding on the steepness of the ramp?
5. Calculating Suppose the door of the local public library is 2.0 m above the ground and the distance from the door to the parking lot is 15 m. What is the ideal mechanical advantage of a ramp built from the door to the parking lot?
6. Communicating Write a letter to a local business explaining how a ramp could help the employees and customers. Give some examples of work that could be made easier using a ramp. Explain how the steepness of a ramp affects its mechanical advantage.

More to Explore

Find actual ramps that provide access for people with disabilities. Measure the heights and lengths of these ramps and calculate their ideal mechanical advantages. Find out what the requirements are for access ramps in your area. Should your ramp be made of a particular material? Should it level off before it reaches the door? How wide should it be? How does it provide water drainage?

Chapter 12 Study Guide

The BIG Idea

Work and Energy Simple machines make work easier by changing the amount of force needed, the distance over which a force is exerted, or the direction in which a force is exerted.

1 What Is Work?

Key Concepts

- Work is done on an object when the object moves in the same direction in which the force is exerted.
- The amount of work done on an object can be determined by multiplying force times distance.

$$\text{Work} = \text{Force} \times \text{Distance}$$

- Power equals the amount of work done on an object in a unit of time.

$$\text{Power} = \frac{\text{Work}}{\text{Time}}$$

Key Terms

work joule power

2 How Machines Do Work

Key Concepts

- A machine makes work easier by changing at least one of three factors. A machine may change the amount of force you exert, the distance over which you exert your force, or the direction in which you exert your force.
- A machine's mechanical advantage is the number of times a machine increases a force exerted on it.

$$\text{Mechanical advantage} = \frac{\text{Output force}}{\text{Input force}}$$

- To calculate the efficiency of a machine, divide the output work by the input work and multiply the result by 100 percent.

$$\text{Efficiency} = \frac{\text{Output work}}{\text{Input work}} \times 100\%$$

Key Terms

machine
input force
output force
input work
output work
mechanical advantage
efficiency

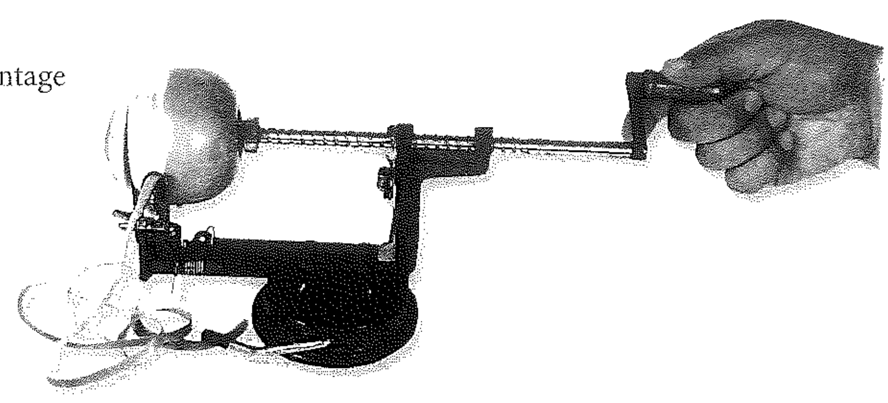
3 Simple Machines

Key Concepts

- There are six basic kinds of simple machines: the inclined plane, the wedge, the screw, the lever, the wheel and axle, and the pulley.
- You can determine the ideal mechanical advantage of an inclined plane by dividing the length of the incline by its height.
- The ideal mechanical advantage of a wedge is determined by dividing its length by its width.
- The ideal mechanical advantage of a screw is the length around the threads divided by the length of the screw.
- The ideal mechanical advantage of a lever is determined by dividing the distance from the fulcrum to the input force by the distance from the fulcrum to the output force.
- You can find the ideal mechanical advantage of a wheel and axle by dividing the radius of the wheel by the radius of the axle.
- The ideal mechanical advantage of a pulley is equal to the number of sections of rope that support the object.
- Most of the machines in your body are levers that consist of bones and muscles.
- The ideal mechanical advantage of a compound machine is the product of the individual ideal mechanical advantages of the simple machines that make it up.

Key Terms

- inclined plane • wedge • screw • lever
- fulcrum • wheel and axle • pulley
- compound machine



Review and Assessment

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Organizing Information

Comparing and Contrasting Copy the compare/contrast table about simple machines onto a separate sheet of paper. Then complete it for each type of simple machine and add a title. (For more on Comparing and Contrasting, see the Skills Handbook.)

Simple Machine	Mechanical Advantage	Example
Inclined plane	Length of incline ÷ Height of incline	Ramp
a. ___?___	b. ___?___	c. ___?___

Reviewing Key Terms

Choose the letter of the best answer.

1. The amount of work done on an object is obtained by multiplying
   a. input force and output force.
   b. force and distance.
   c. time and force.
   d. efficiency and work.
2. The rate at which work is done is called
   a. output force.
   b. efficiency.
   c. power.
   d. mechanical advantage.
3. One way a machine can make work easier for you is by
   a. decreasing the amount of work you do.
   b. changing the direction of your force.
   c. increasing the amount of work required for a task.
   d. decreasing the friction you encounter.
4. The output force is greater than the input force for a
   a. pizza cutter.
   b. hockey stick.
   c. single fixed pulley.
   d. screw.
5. An example of a second-class lever is a
   a. seesaw.
   b. shovel.
   c. paddle.
   d. wheelbarrow.

If the statement is true, write *true*. If it is false, change the underlined word or words to make the statement true.

6. The SI unit of work is the <u>newton</u>.
7. The work you do on a machine is called the <u>input work</u>.
8. The ratio of output work to input work is <u>mechanical advantage</u>.
9. An <u>inclined plane</u> is a flat, sloped surface.
10. A <u>pulley</u> can be thought of as an inclined plane wrapped around a cylinder.

Writing in Science

Proposed Solution A community of people in Pennsylvania known as the Old Order Amish can build a wooden barn in a single day—without using electricity. Suppose you were faced with this task. Propose how you would use simple machines to help with the construction.

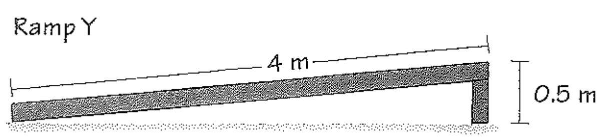
Review and Assessment

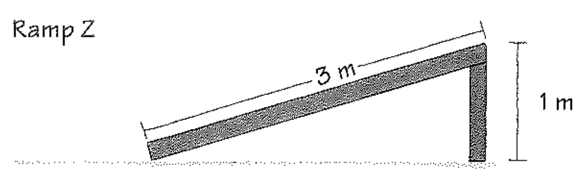
Checking Concepts

11. The mythical god Atlas was believed to hold the weight of the sky on his shoulders. Was Atlas performing any work? Explain.
12. The mechanical advantage of a machine is 3. If you exert an input force of 5 N, what output force is exerted by the machine?
13. Which has a greater mechanical advantage, a wedge that is 6 cm long and 3 cm wide, or a wedge that is 12 cm long and 4 cm wide? Explain your answer.
14. Why will decreasing the radius of the axle improve the mechanical advantage of a wheel and axle?
15. Describe a lever in your body. Locate the input force, output force, and fulcrum.

Thinking Critically

16. Relating Cause and Effect Describe the relationship between friction and the efficiency of a machine.
17. Classifying What type of simple machine would be used to lower an empty bucket into a well and then lift the bucket full of water?
18. Applying Concepts To open a door, you push on the part of the door that is farthest from the hinges. Why would it be harder to open the door if you pushed on the center of it?
19. Interpreting Diagrams Which ramp has the greater ideal mechanical advantage?



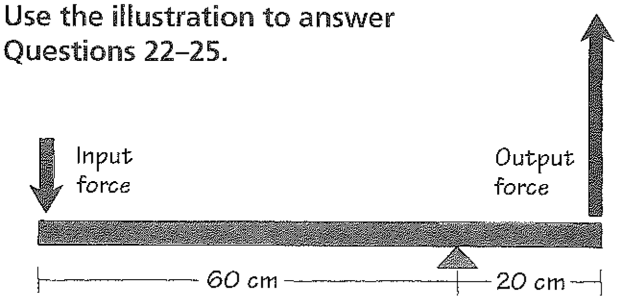


Math Practice

20. Calculating Power A bulldozer does 72,000 J of work in 48 seconds. How much power does the bulldozer use?
21. Calculating Efficiency A machine with 75% efficiency does 3,300 J of work. Using the machine, how much work did you do?

Applying Skills

Use the illustration to answer Questions 22–25.



22. Calculating Use the input and output distances to calculate the ideal mechanical advantage of the lever.
23. Predicting What would the ideal mechanical advantage be if the distance from the fulcrum to the input force were 20 cm? 40 cm? 80 cm?
24. Graphing Use your answers to Questions 22 and 23 to graph the distance from the fulcrum to the input force on the x-axis and the ideal mechanical advantage on the y-axis.
25. Interpreting Data What does your graph show you about the relationship between the ideal mechanical advantage of a first-class lever and the distance between the fulcrum and the input force?

Lab zone Chapter Project

Performance Assessment Finalize your design and build your machine. Consider how you can improve the machine's efficiency. Check all measurements and calculations. Does it lift the soup can at least 5 cm? Is it made of two or more simple machines? When you show your machine to the class, explain why you built it as you did.

Standardized Test Prep

Test-Taking Tip

Reading All the Answer Choices

For multiple-choice questions, read every answer choice before you give your answer. Some choices may contain part of the answer but may not include all the information that the question asks for. Also look out for questions that may be answered by "all of the above." In this case, all of the answer choices may be correct in some way, but "all of the above" may be the only complete answer.

Sample Question

Why does it take more work to move a 2.3-kg bag of birdseed 100 m than it takes to move a 1.6-kg bag of cat food 50 m?

- **A** The birdseed is packed in the store.
- **B** The birdseed has to be moved farther.
- **C** The cat food has less mass than the birdseed.
- **D** The birdseed has greater mass and has to be moved farther.

Answer

The correct answer is **D**. Answer **A** is not related to the question. Answers **B** and **C** are both true, but provide only part of the correct answer. Only answer **D** is completely correct. It mentions both the mass of the object, which is needed to determine force, and the distance the object is to be moved. Both force and distance affect the amount of work.

Choose the letter of the best answer.

1. What simple machine is used in *all* of the following jobs: moving a flag to the top of a flagpole, lifting equipment with a construction crane, and using a block and tackle to move a crate?
   - **A** lever
   - **B** pulley
   - **C** wedge
   - **D** wheel and axle

2. The table below shows the input work and output work for four different pulleys. Which pulley has the highest efficiency?

Work of Different Pulleys

Pulley	Input Work	Output Work
Fixed pulley A	20,000 J	8,000 J
Fixed pulley B	20,000 J	10,000 J
Movable pulley	20,000 J	12,000 J
Block and tackle	20,000 J	16,000 J

   - **F** Fixed pulley A
   - **G** Fixed pulley B
   - **H** Movable pulley
   - **J** Block and tackle

3. Which is the *best* definition of a machine?
   - **A** A machine is a time-saving device that uses motors and gears.
   - **B** A machine changes the amount of input force.
   - **C** A machine makes work easier by changing force, distance, or direction.
   - **D** A machine can be either simple or compound.

4. Which of the following will increase the ideal mechanical advantage of a wheel and axle?
   - **F** increasing the wheel's radius
   - **G** decreasing the wheel's radius
   - **H** increasing the axle's radius
   - **J** increasing the wheel's radius and the axle's radius equally

5. Which activity describes work being done on an object?
   - **A** walking a dog on a leash
   - **B** lifting a bag of groceries
   - **C** holding up an umbrella
   - **D** pressing a stamp onto an envelope

Constructed Response

6. Explain why an engineer would design a road to wind around a mountain rather than go straight up the side. Show how this design would be better.