

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.

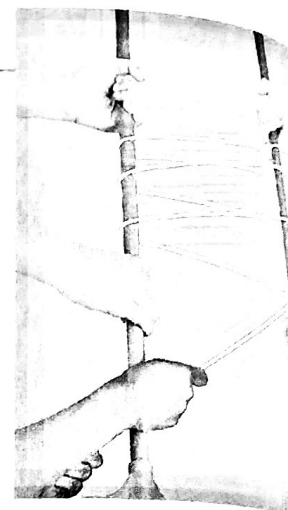
Q.

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?

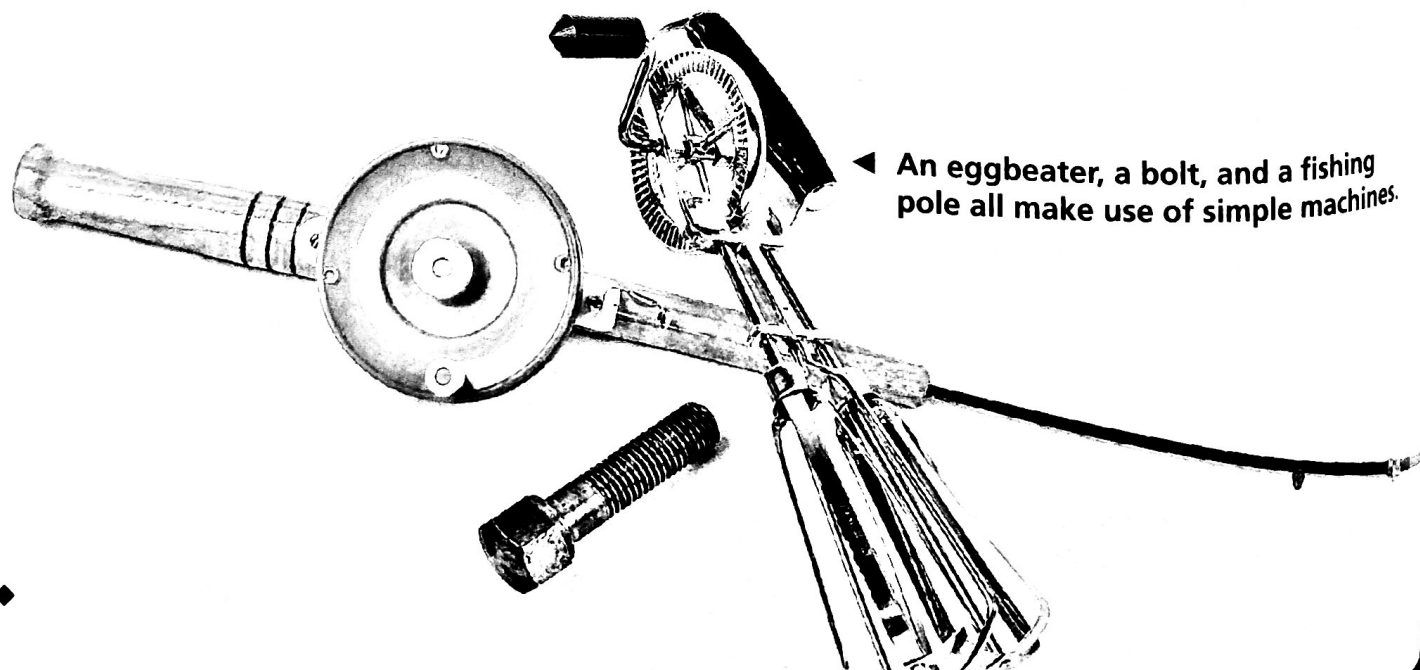


Think It Over

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.

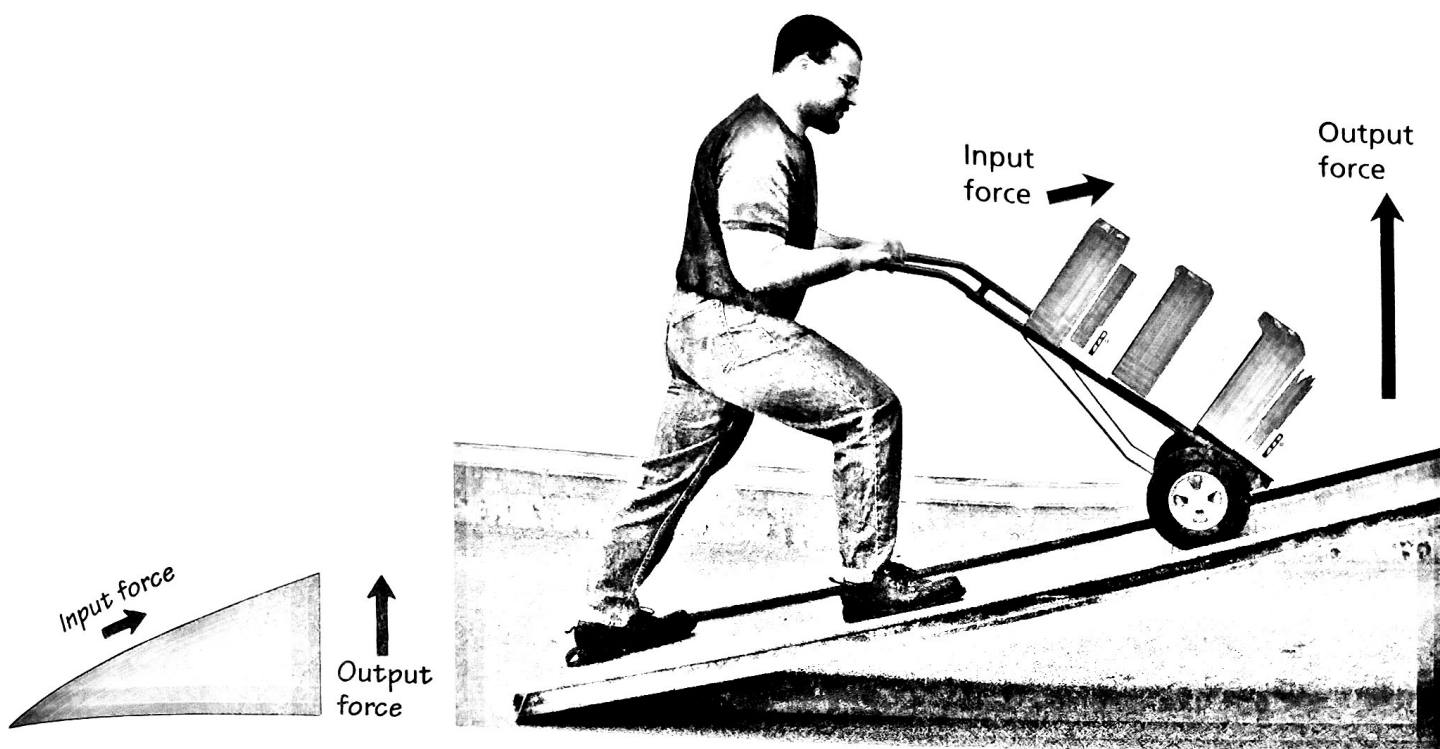


FIGURE 12
Inclined Plane

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 $3 \text{ meters} \div 1 \text{ meter}$, 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.

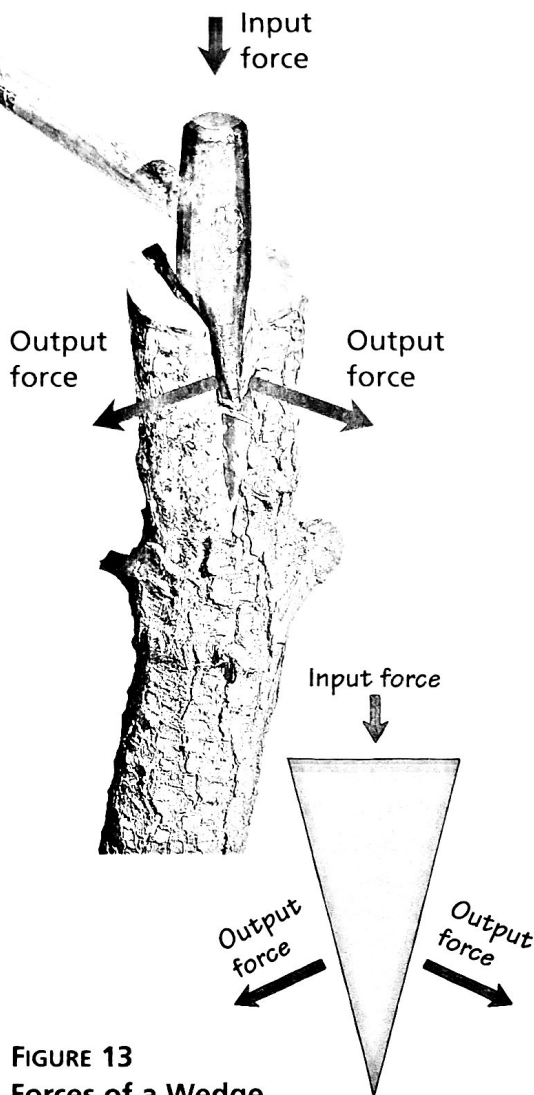


FIGURE 13
Forces of a Wedge
 The input force exerted on a wedge results in output forces that can split the log.

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.

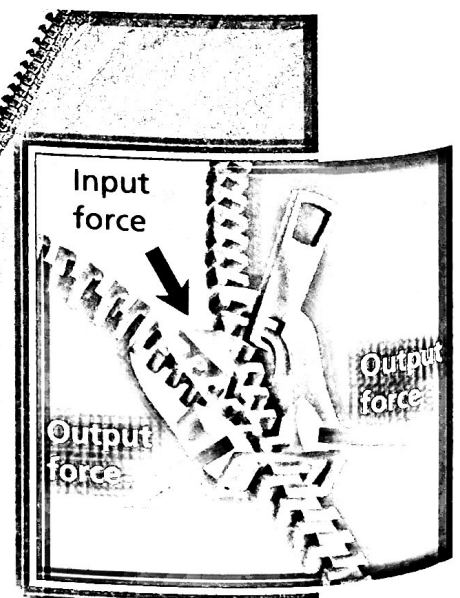
Wedges are a part of your everyday life. For example, a zipper depends on wedges to close and open. A pencil sharpener, a cheese grater, and a shovel all make use of wedges.

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 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.



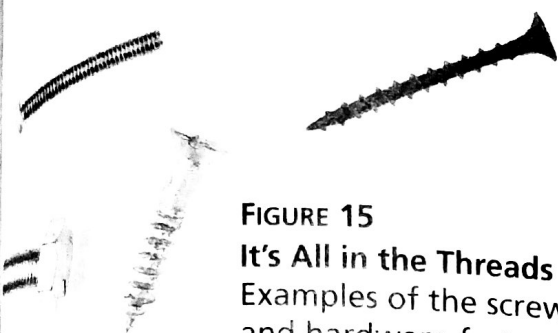


FIGURE 15

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.

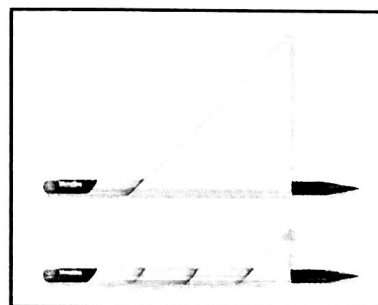
Many devices act like screws. Examples include bolts, light bulbs, and jar lids. Look at the jar lid in Figure 15. When you turn the lid, your small input force is greatly increased because of the screw threads on the lid. The threads on the lid are pulled against the matching threads on the jar with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

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?

Reading
Checkpoint

How is a screw like an inclined plane?

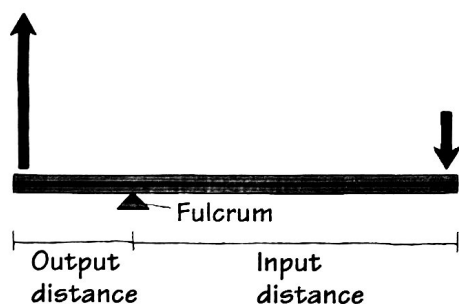


FIGURE 16

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

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.

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.



What point on a lever does not move?

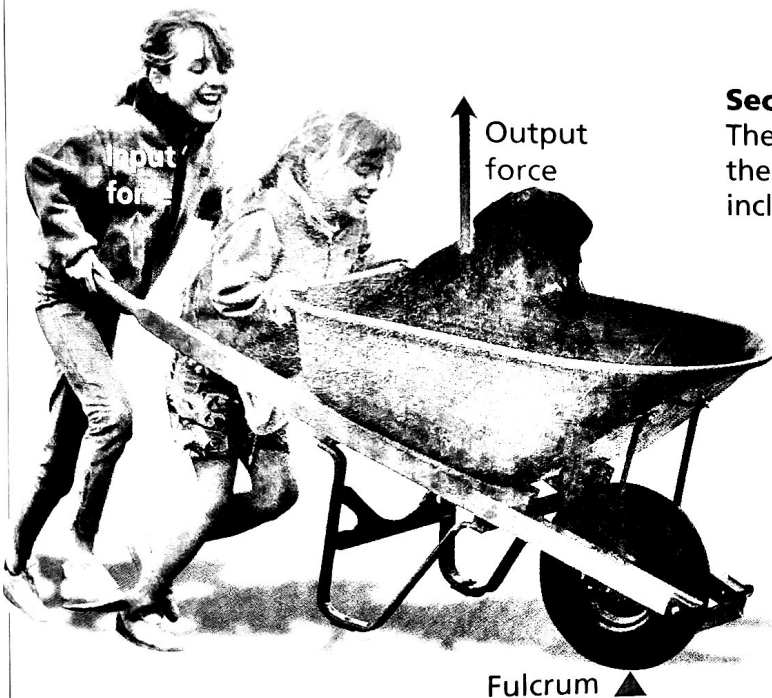
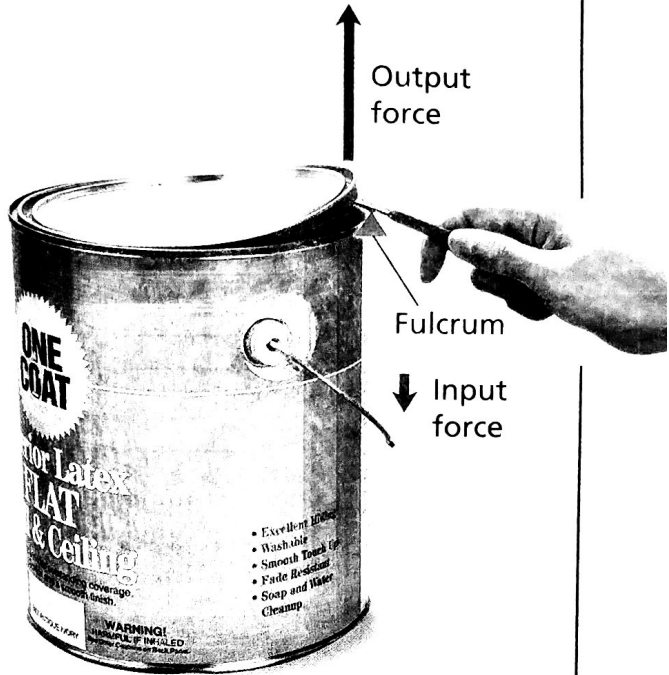
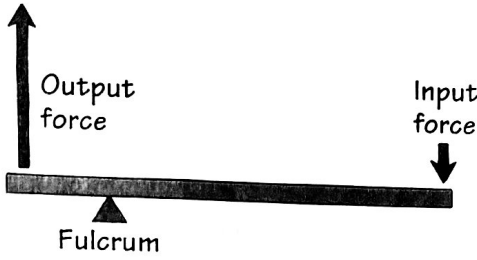
FIGURE 17

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?

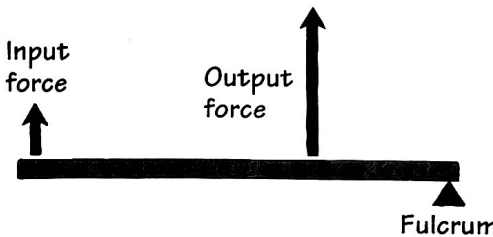
First-Class Levers

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.



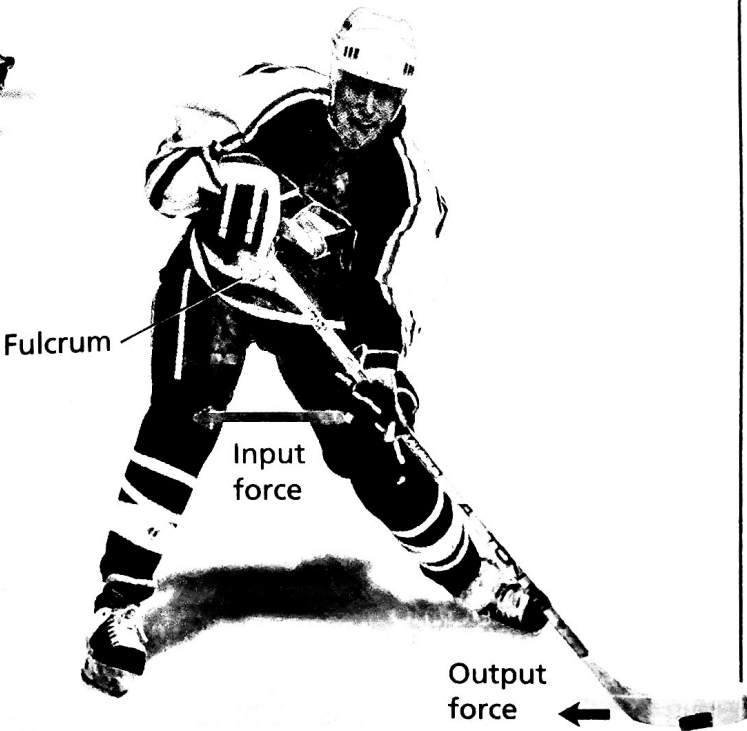
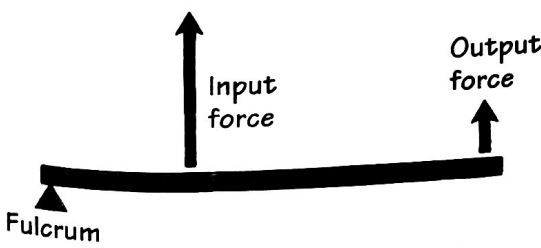
Second-Class Levers

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.



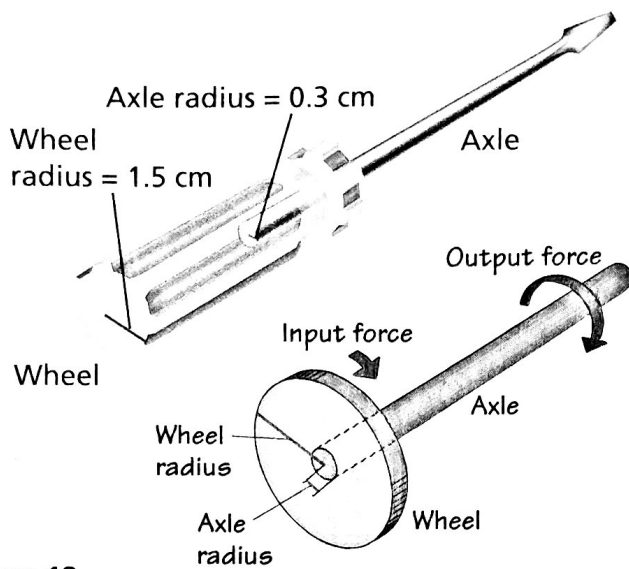


FIGURE 18

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

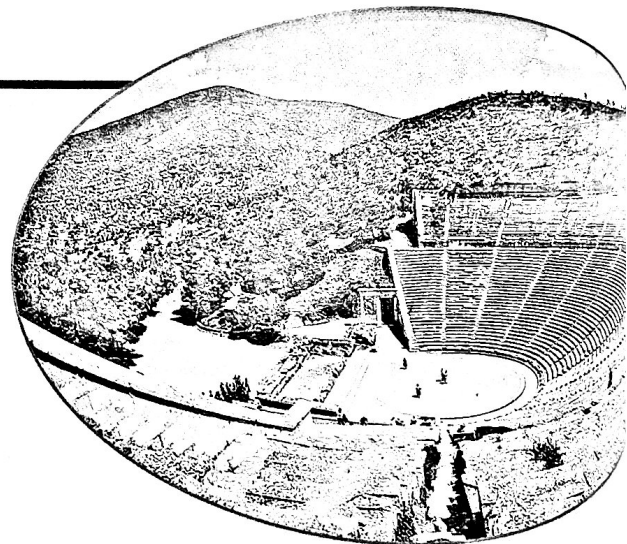
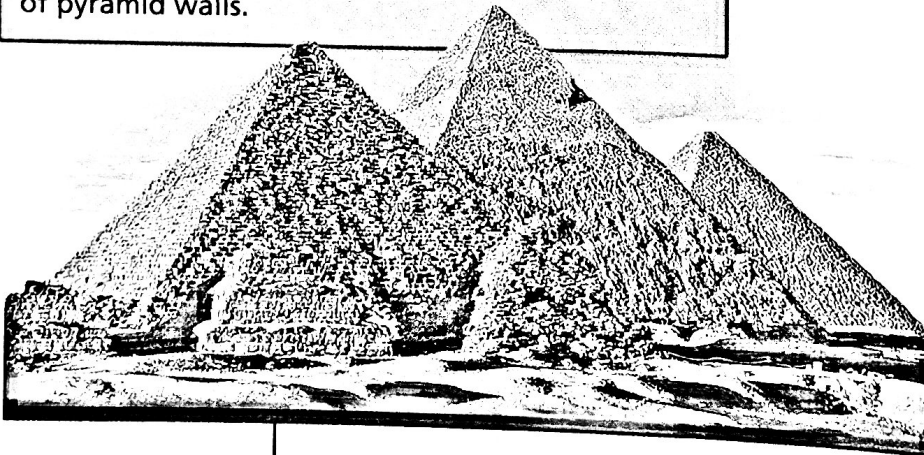
Engineering Marvels

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 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.

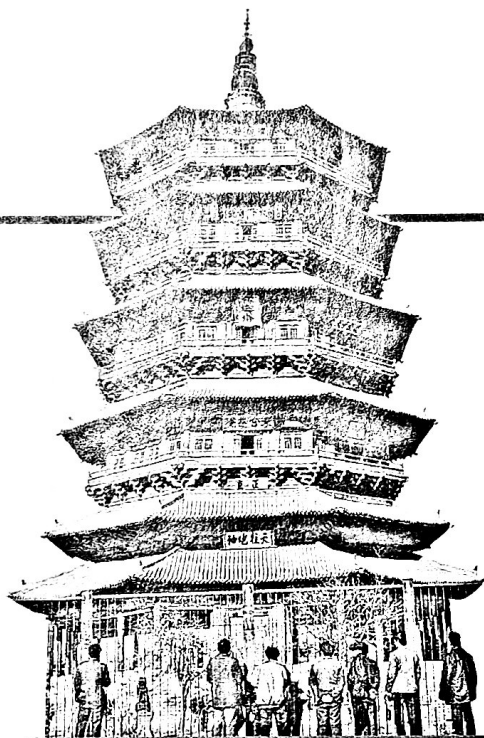
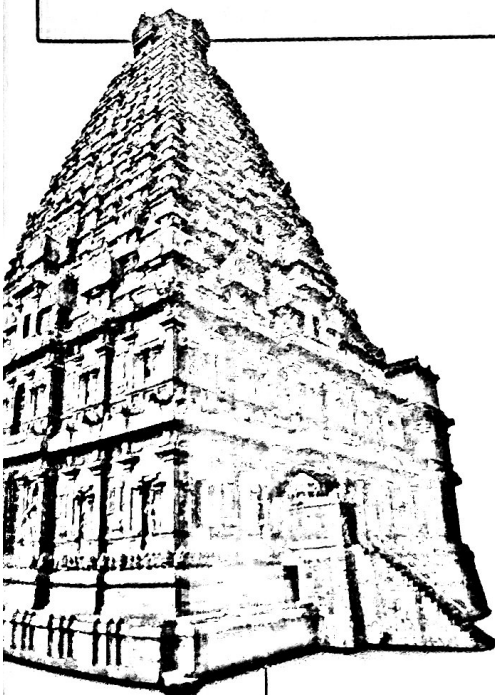
1000 B.C.

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 multiplies distance.

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.

Writing in Science

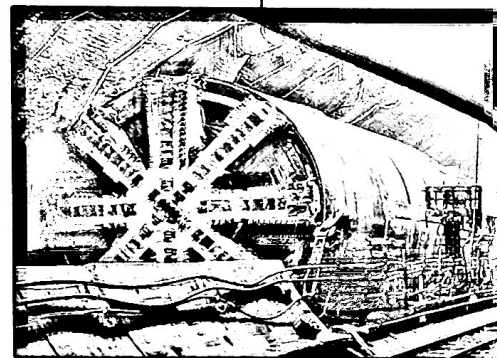
Research and Write

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. 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.



A.D. 1000

A.D. 2000