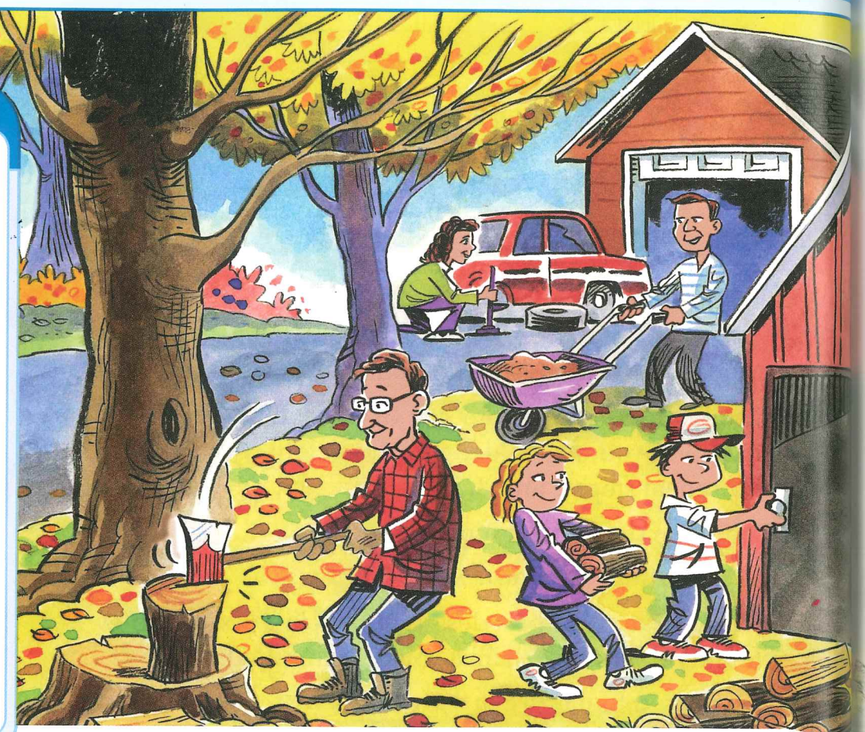
Chapter 2

Machines use forces to do work.



Key Ideas

- Work is done when a force makes an object move.
- A machine is anything that makes work easier for us.
- Machines give us a mechanical advantage by changing the amount or direction of force needed to do work.
- There are six simple machines: the lever, the wheel and axle, the pulley, the inclined plane, the wedge, and the screw.

Can you imagine trying to chop wood without an axe? How would you do it? What if you had to move a load of rocks or soil without a wheelbarrow? What if you had to lift a car to change a tire without a jack? How would you open a door without a doorknob? All of these jobs would be much more difficult to do without machines [muh-SHEENZ].

In this chapter, you will discover how machines make use of forces to do work. You will learn about six simple machines: the lever, the wheel and axle [AK-suhl], the pulley, the inclined plane, the wedge [WEJ], and the screw. You will discover the many ways we use simple machines to make our work easier.

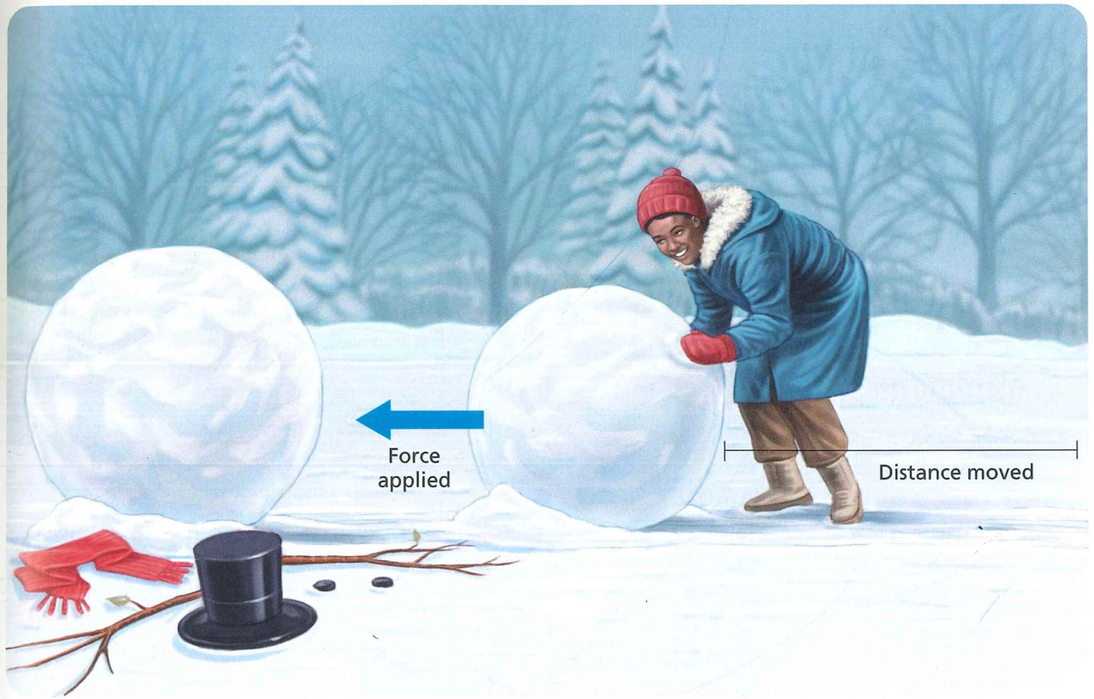
Chapter 2

Machines Make Work Easier

1

Has your teacher ever asked you to get to work? Does it seem like work when you ride a bicycle up a hill? We use the word "work" to mean different things. When scientists use the word "work," they mean something very specific.

In science, you are doing **work** when you use force to make something move. For example, you are doing work when you roll a large ball of snow to make a snow person. You are applying force to an object that causes that object to move. The amount of work you do depends on the amount of force you use and the distance the object moves.



▲ When you roll a ball of snow to make a snow person, you are doing work.

Machines

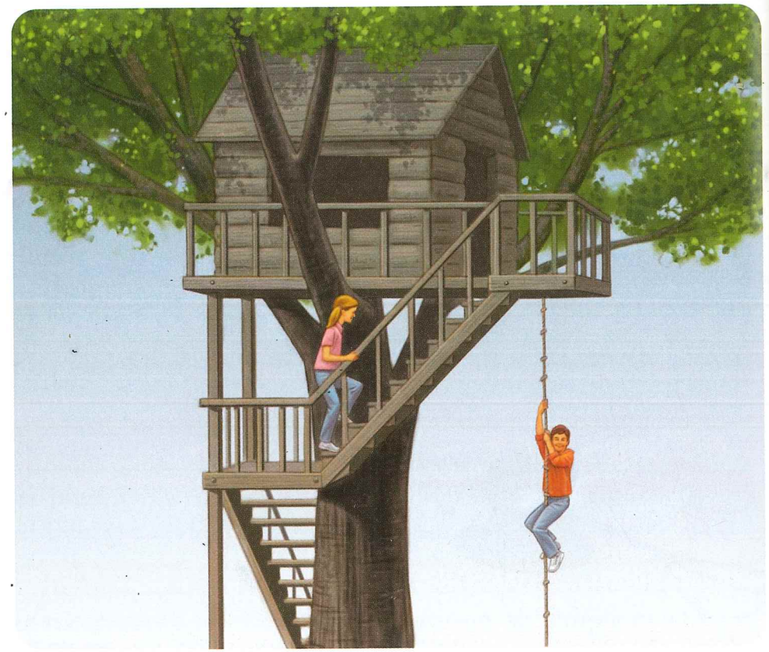
A machine makes work easier to do. A pencil sharpener is a machine that helps you sharpen a pencil more easily than you could without using it. Using a machine does not usually mean that you do less work. It usually means that you do the work using less effort.

The force that is needed to push, pull, or lift an object is called the **effort force.** The force that is holding the object in place is called the load force. To make an object move, a machine must work harder than the load force.

When a machine makes work easier, we say that it gives us a mechanical advantage [muh-KAN-uh-kuhl ad-VAN-tij]. The machine gives us a mechanical advantage because it allows us to use less force or to change the direction of the force that is needed to do work.

Learning Tip

If you find a topic difficult, read more slowly. Go back and reread as many times as you need to until you are sure that you understand.



▲ The stairs to the tree house gives this student a mechanical advantage. She uses less effort force than the student climbing the rope to the tree house.

Try This

Identify Work

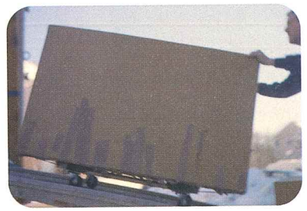
Skills Focus: observing, inferring, communicating

1. Push against the wall of your classroom. Lift your textbook off your desk. Pull your chair along the floor.

2. Draw a sketch to show each situation in step 1. Add an arrow to show the direction of your effort force in each situation. Add another arrow to show the direction that each object moved.
3. Tell a partner whether any work was done in each situation, according to the scientific definition of work.

Check Your Understanding

1. Is any work being done in this picture? Explain your answer.



2. What is a machine? How does a machine make work easier?
3. What is mechanical advantage?

Learning Tip

Do not guess. Look back through the section to find the answers. Even if you remember the answer, it is good to go back and check it.

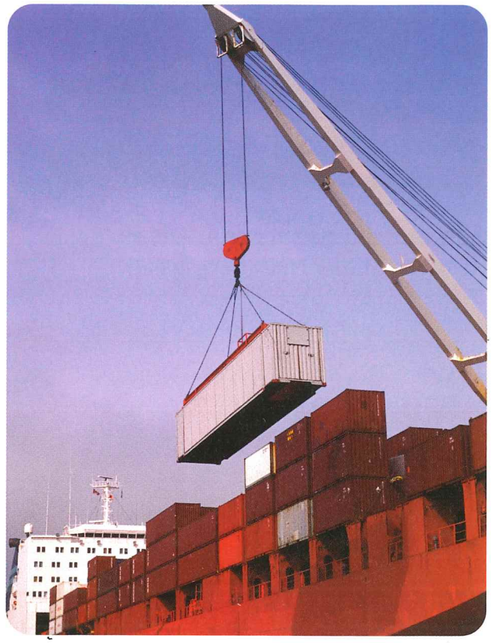
Chapter 2

2 Machines and the Work They Do

Learning Tip

Before you read this section, make sure you understand the meaning of the words "work," "machine," and "effort force." If you aren't sure of the meaning of any of these words, check back in the previous section.

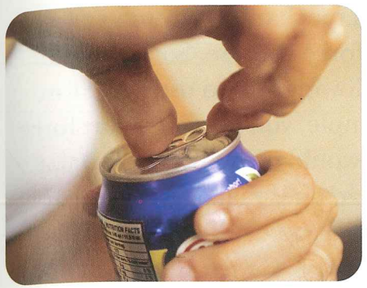
When you apply an effort force to a machine, the machine uses this force to do the work more quickly or more easily than you could have done it without the machine. Think of the weight that this giant crane can lift. An effort force is applied to the crane to help it lift the container.



◀ Machines can easily do work that humans would find difficult or impossible.

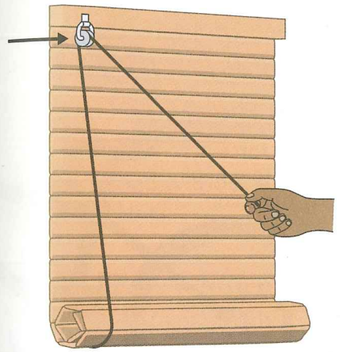
Machines don't have to be big or complicated to do work for us. If you've used a wheelbarrow, you know it allows you to move heavy objects more easily than you could move them with your arms alone. In fact, all machines—no matter how complicated they are—are combinations of six simple machines. The six **simple machines** that are used to make all other machines are

- the lever
- the pulley
- the wedge
- the wheel and axle
- the inclined plane
- the screw



Lever

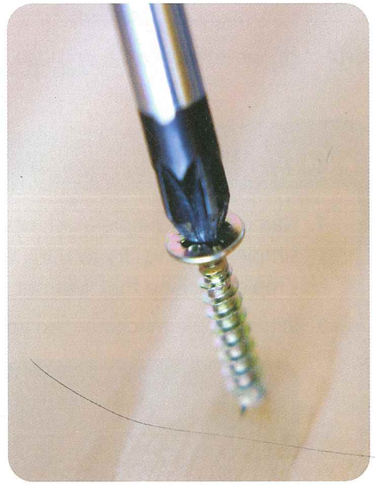
Wheel and axle



Pulley

Inclined plane

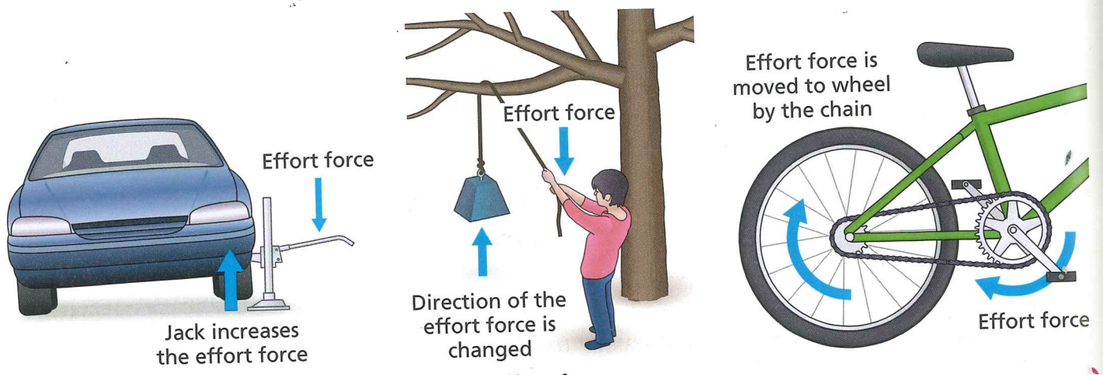
Wedge



Screw

▲ We use simple machines to move things, to lift things, to hold things together, or to push things apart. Which machines on this page are used to move things? Which machines are used to lift things, to hold things together, or to push things apart?

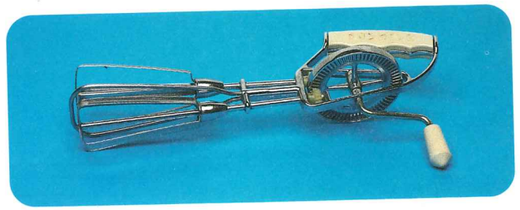
Simple machines can provide a mechanical advantage by changing the effect of the effort force you use. Some simple machines make work easier by allowing you to use less effort force to move an object. For example, you use less effort force to lift a car using a jack than you would if you tried to lift the car on your own. Some simple machines make work easier by changing the direction of a force. If you use a rope thrown over a tree branch to lift an object, you pull down on the rope but the object moves up. Simple machines can also move forces from one place to another. The chain on a bicycle moves the effort force from the pedals to the wheels of the bicycle.



▲ Simple machines change the effect of the effort force you use.

Check Your Understanding

1. Name the six simple machines. Give two examples of each simple machine. Try to think of at least one example of each simple machine that was not mentioned in this section.
2. What simple machines can you identify in this tool?



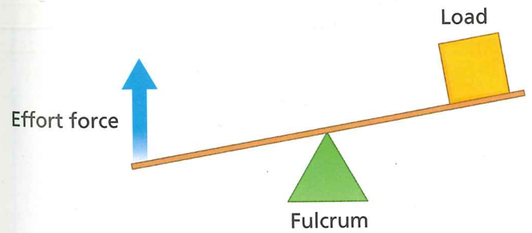
3 Levers

▲ Lifting a load without a lever is much harder work than lifting a load with a lever.

It would be very difficult to lift a gigantic boulder or open a can of paint with only your fingers. To make these jobs easier, we use a simple machine called a lever. A **lever** is a straight rod or board that turns around a fixed point. A lever makes work easier by making a load easier to lift.

Levers require three things to do work:

- effort force: the force you apply to the lever
- load: the object you want to move
- **fulcrum** [FUL-kruhm]: the fixed point on which the lever turns

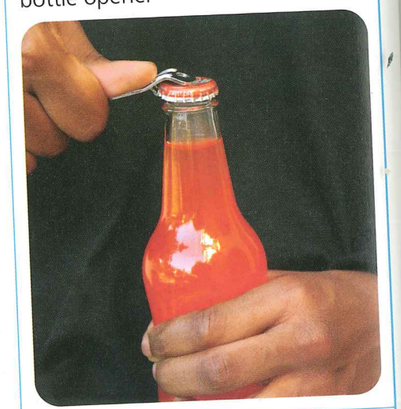
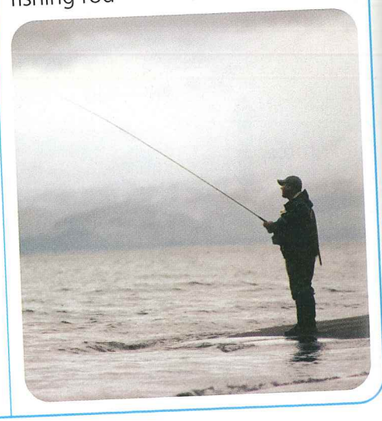


◀ A lever

There are three different classes of levers. Each class of lever is used to do a different type of work and provides a different mechanical advantage.

Learning Tip

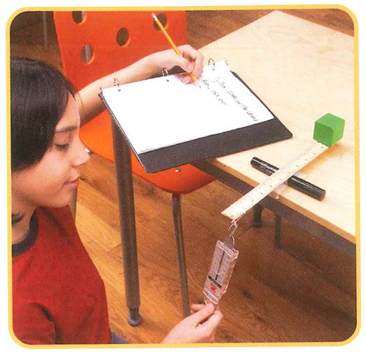
As you read about each class of lever, ask yourself how it makes work easier and how it is different from the other two classes of levers.

Class of lever	Mechanical advantage	Example
first-class lever Effort force Load Fulcrum ▲ Fulcrum between load and effort	A first-class lever gives you a mechanical advantage by changing the direction of the force you use. When you use effort force to push or pull in one direction, the load travels in the other direction.	seesaw 
second-class lever Load Effort force Fulcrum ▲ Load between effort and fulcrum	A second-class lever gives you a mechanical advantage by allowing you to use less effort force to lift an object. With a second-class lever, the direction of the effort force and the load remains the same. When you use effort force in one direction, the load travels in the same direction.	bottle opener 
third-class lever Load Effort force Fulcrum ▲ Effort between load and fulcrum	A third-class lever gives you a mechanical advantage by increasing the speed and distance you are able to move the load. The direction of the effort force and the load remains the same. When you use effort force in one direction, the load travels in the same direction.	fishing rod 

Try This

Build and Use Levers

Skills Focus: observing, measuring, inferring, communicating



1. Use a spring scale to measure the force required to lift an object, such as a small block.
2. Using a ruler and a marker, create a first-class, second-class, or third-class lever. Use your lever to lift your object.
   - For the first-class lever, place the fulcrum midway between the load (the object you are lifting) and the spring scale. Use the spring scale to pull down on the lever.
   - For the second-class lever, place the load midway between the fulcrum and the spring scale.
   - For the third-class lever, place the spring scale midway between the load and the fulcrum. You will have to hold the fulcrum in place.
3. Compare the effort force of lifting the object using your lever with the effort force of lifting the object not using your lever. How much effort was saved?
4. Experiment with the amount of space between the load, fulcrum, and spring scale for each lever. How can you use the least effort for each lever?
5. As a class, compare the mechanical advantage of each lever. You must be able to describe and name the type of lever you built.

Sometimes two levers work together. A nutcracker is an example of two second-class levers. Scissors are an example of two first-class levers. Can you think of two other examples of levers working together?

Check Your Understanding

1. What class of lever is shown in each picture?

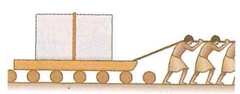


2. Describe the mechanical advantages that levers can give you.

Chapter 2

4 Wheels and Axles

Did you know?



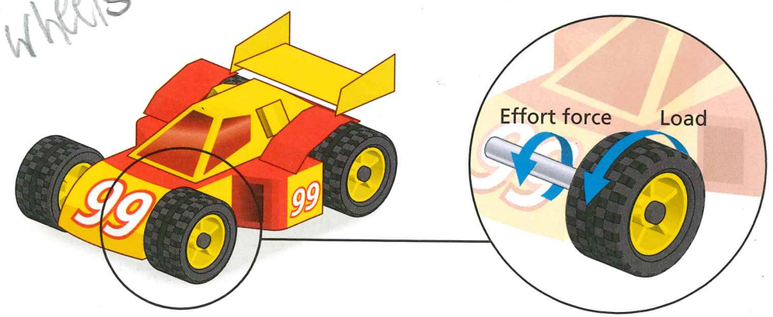
Rollers were the earliest form of the wheel and axle. Rollers were used by the ancient Egyptians to move the large blocks of stone they used to build the pyramids.

A wheel and axle is a simple machine that can help you move, turn, or lift an object. It has a **wheel** that turns around a rod. The rod is called an **axle.** A wheel and axle is like a lever that can rotate in a circle. The axle in the centre of the wheel is the fulcrum of the lever.

◀ A wheel and axle helps you move, turn, or lift an object.

Moving with a Wheel and Axle

A wheel and axle can be used to move things. Cars and bicycles use wheels and axles to move. The effort force is at the axle, and the load is on a wheel. When the axle turns, the wheel also turns because they are attached. When the axle turns one time, the wheel also turns one time. Since the wheel is larger than the axle, a small turn of the axle creates a much larger turn of the wheel. This is the mechanical advantage of a wheel and axle.

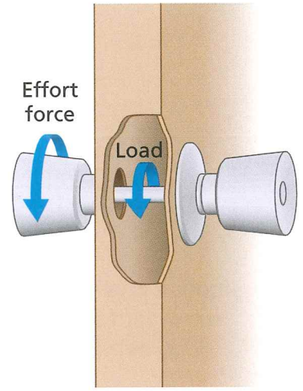


▶ Car wheels are attached to an axle. When the axle turns, the wheels turn and move the car.

Turning with a Wheel and Axle

A wheel and axle can be used to turn things. For example, a wheel and axle is what makes a doorknob work. The knob is the wheel, and the load is the axle inside the door. You use a doorknob by putting the effort force on the wheel. This turns the axle.

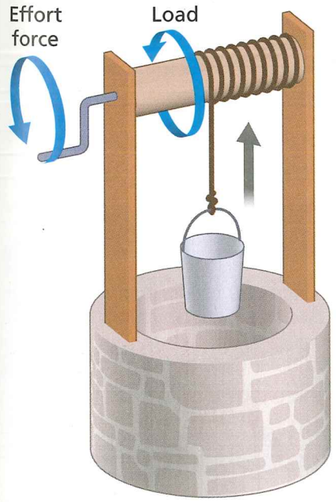
Do you think the size of the knob makes a difference? Is it easier to open a door using a knob that is the size of a pea or the size of an orange? The size of the knob changes the amount of effort force you have to use. When the wheel (the knob) is larger than the axle, you use less effort force to make the axle turn. So, a larger doorknob makes it easier to open the door.



▲ You open a door by putting effort force on the doorknob to turn the axle inside the door.

Lifting with a Wheel and Axle

A wheel and axle can be used to lift things. A well has this type of wheel and axle to lift water in a pail. The handle makes a complete circle when it turns, just like a wheel. You use effort force on the wheel while the load is on the axle. The wheel and axle gives you a mechanical advantage because it allows you to lift a heavy pail of water with less force, although you have to turn the handle several times to get the pail to the top.



◀ You can lift a pail of water using a wheel and axle.

Learning Tip

The diagrams in this chapter will help you understand how simple machines work. First read the explanation of how the simple machine works. Then look carefully at the diagram. Make sure that you understand what is shown. If an idea still isn't clear, reread the paragraph, then look at the diagram again until the meaning is clear.

Try This: Lift with a Wheel and Axle

Skills Focus: creating models, observing, communicating

1. Work with a partner. Punch two holes, directly across from each other, in a paper cup. Place a bendable straw through the two holes. Bend the short end of the straw up.
2. Take a 30 cm piece of string, and tie one end around a washer. Tie or tape the other end to the straw, as shown in the photo.

3. Slowly turn the short end of the straw. What happens to the washer? What happens to the straw?
4. Discuss your observations with another pair of students. What part of the set-up was the wheel? What part was the axle?

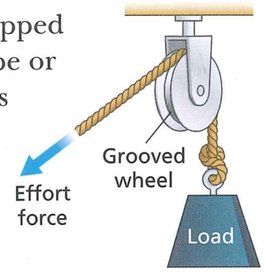
Check Your Understanding

1. Describe three ways that a wheel and axle can be used to make work easier.
2. List or sketch wheels and axles that you have used at home or at school. Group them according to the three jobs they can do.

Pulleys 5

A **pulley** is a rope or chain that is wrapped around a grooved wheel. When the rope or chain is pulled, the wheel turns. Pulleys make it easier to lift objects.

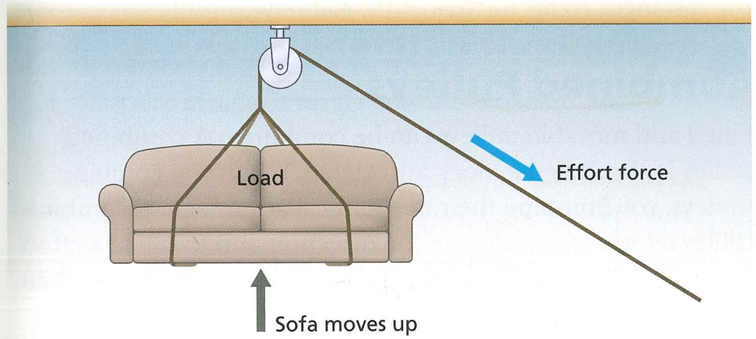
There are three different types of pulleys: fixed pulleys, movable pulleys, and combined pulleys.



◀ A pulley is a simple machine that makes lifting easier.

Fixed Pulleys

A fixed pulley has the wheel attached to the ceiling or to another object that does not move. Since the pulley does not move, it is called a fixed pulley.



◀ A fixed pulley

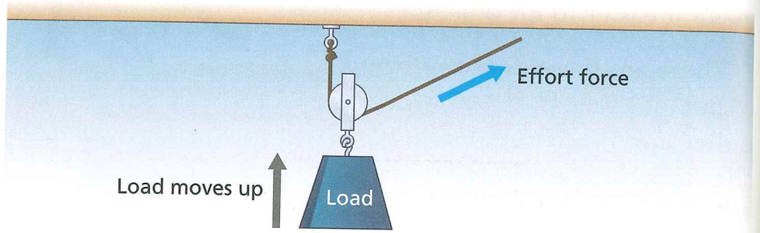
A fixed pulley gives you a mechanical advantage because you change the direction of your effort force. When you pull down on the rope, the load goes up. This is very useful when you are trying to lift a heavy object. If you are trying to lift a sofa, pulling down on the rope is easier than lifting the sofa with your hands. However, with only one pulley, you still use the same amount of effort force you would have used without the pulley. You also have to pull the rope the same distance that the object is lifted. To lift the sofa 1 m, you must pull down 1 m of rope.

Learning Tip

Look at the three diagrams of pulley systems. Ask yourself, "How are they different? How are they the same?"

Movable Pulleys

When you attach a pulley to a load you are trying to lift, you create a movable pulley. You attach one end of the rope to the ceiling and pull the other end. The pulley moves when the load is lifted. A movable pulley requires less effort force to lift the load because some of the load is supported by the ceiling.

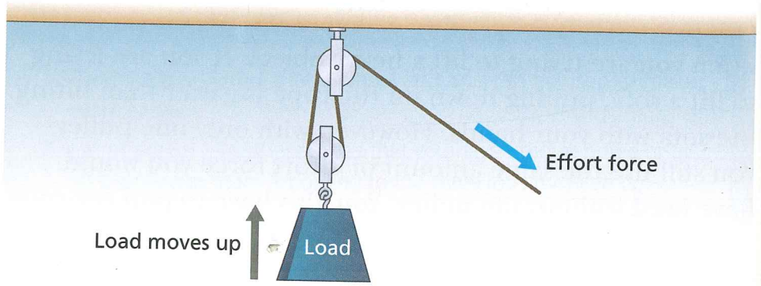


▶ A movable pulley

There are disadvantages to a movable pulley. When you use a movable pulley, you pull in the same direction as the load being lifted. As well, you have to use the effort force for twice the distance. To lift the load 1 m, you have to pull 2 m of rope.

Combined Pulleys

Fixed and movable pulleys can be combined. A combined pulley is also called a block and tackle. When you combine pulleys, you combine their mechanical advantage. A combined pulley allows you to change the direction and to use less effort force. The fixed pulley allows the load to move in the opposite direction of the effort force. The movable pulley reduces the effort force needed to move the load because half of the load is supported by the ceiling.



▶ A combined pulley

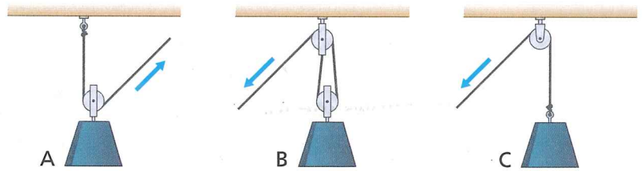
Try This — Measure the Effort Force

Skills Focus: measuring

1. Use a spring scale to measure the effort force needed to lift a can 10 cm.
2. Now measure the effort force required to lift the can 10 cm using a fixed pulley, a movable pulley, and a combined pulley. For each type of pulley,
   - sketch the pulley system you built
   - record the effort force needed to lift the can
   - record the amount of string needed to lift the can
3. Compare the effort force of lifting the can using each pulley with the effort force of lifting the can not using a pulley. How much effort was saved by using each pulley?

Check Your Understanding

1. What kind of pulley is being shown in each picture: fixed, movable, or combined?



2. In your notebook, make a table like the one below. Complete the table to show what you have learned about pulleys. Hint: You will leave one box empty!

	Type of pulley	Sketch of pulley	Mechanical advantage of pulley	Disadvantage of pulley

Chapter 2

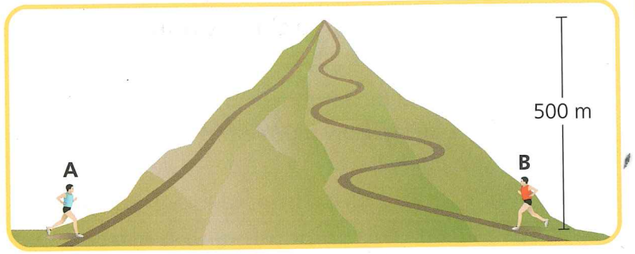
6 Inclined Planes and Wedges

Inclined Planes

Try This — Find the Easiest Route

Skills Focus: observing, inferring

1. Look at the picture. The two runners are of the same skill level and travel at the same speed. Which runner will get to the top of the mountain first? Which runner will travel the farthest?
2. Which route would you take? Explain why.



An **inclined plane** is a sloped surface, such as a ramp. It lets you move something to a higher level more easily than you could lift it. For example, moving a wagon filled with rocks up an inclined plane is easier than lifting the wagon the same distance. An inclined plane is different from other simple machines because it does not move. Instead, an object is moved on the inclined plane. Inclined planes that you may have seen include stairs, wheelchair ramps, and ladders.



▲ These inclined planes allow you to use less effort force to move to a higher level.

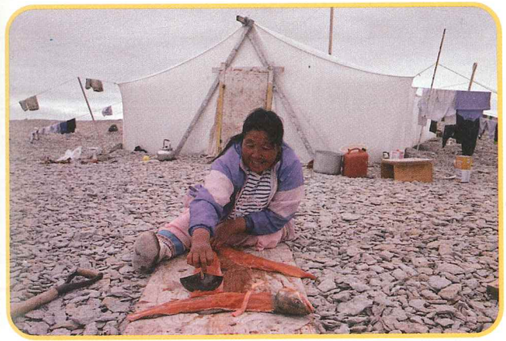
An inclined plane gives you a mechanical advantage because you use less effort force to raise an object. The less sloped the inclined plane is, the less force you need to raise the object. The disadvantage is that you must move the object a greater distance. An inclined plane allows you to raise a large load with little effort force, but you need to move the load over a greater distance.

In the Try This activity, runner B would use less effort to travel up the zigzag trail because the inclined planes are not as steep. However, the zigzag trail is a greater distance than the trail that goes straight up the mountain.

Wedges

Try This — Use an Ulu

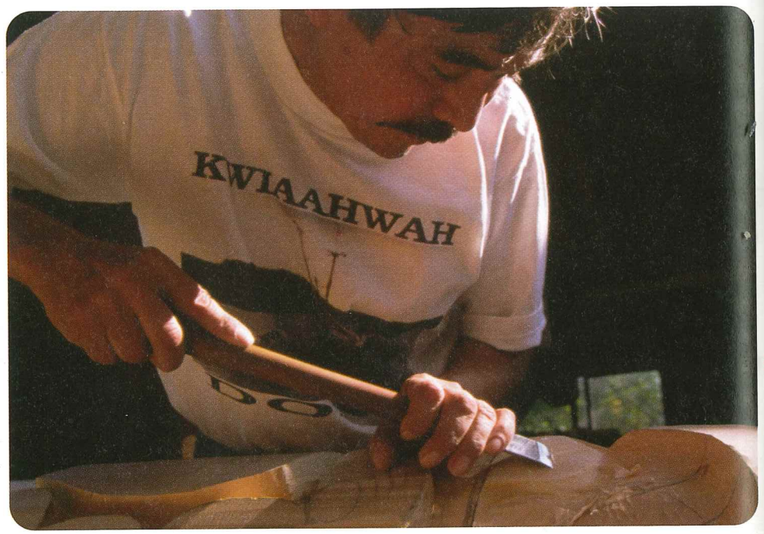
Skills Focus: creating models, inferring, communicating




1. Inuit [IN-oo-eet] in the Canadian Arctic have used ulus for more than 1000 years. An ulu [OO-loo] is a cutting tool that has many uses, such as removing the fur from animals or taking the skin off fish. Look carefully at the shape of the ulu in the picture on the right. Notice the shape of the blade and the way the handle is attached.
2. Use cardboard or Bristol board to create a model of an ulu. Hold your model in your hand, and move it to see how it might be used to remove the fur from an animal or the skin from a salmon. Show a partner how you think this tool is used.

A **wedge** is a simple machine with a thick end and a thin end. Its pointed (thin) end is used to lift, hold, or push objects apart. A wedge is similar to an inclined plane, except the wedge usually moves to do work.

A wedge works when you push on its thickest part. This gives you a mechanical advantage by changing the direction of your force. Most wedges have a handle to make them easier to use. An ulu is an example of a wedge with a handle. A chisel [CHIZ-uhl] is another example of a wedge with a handle.



▲ The chisel that this carver is using is a wedge. The carver pushes the wedge to separate the wood.

The wedge was one of the earliest simple machines used. The first wedges were rocks or sticks shaped into arrows or spears. They were used to hunt and skin animals, and to dig in the ground. Early peoples realized that when a rock or stick was sharper, it worked better. They realized that sharpening a wedge increased its mechanical advantage because less effort force was needed to use it.

When you push down on a wedge to cut, the edge of the wedge splits the object apart. A thin wedge needs less effort force to cut than a thick wedge does.

Types of Wedges

Most wedges are two inclined planes put together. These wedges are used to split apart objects. The blade of an axe is one example of this type of wedge. Your front teeth are another example. They split food into pieces as you bite down.

Other wedges have only one inclined plane. These wedges are used to lift objects or to stop objects from moving. A doorstop is an example of this type of wedge. It is used to keep a door from moving.

▲ Your front teeth act as wedges when you bite into food.

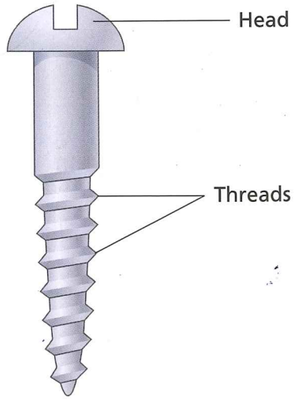
▲ This wedge is used to stop a door from moving.

Check Your Understanding

1. What is an inclined plane?
2. Is an inclined plane the same as other simple machines? Explain.
3. How does an inclined plane make work easier? What is the disadvantage of an inclined plane?
4. Think of a wedge you use. Explain how it makes work easier.
5. Draw a picture to show how you would improve this wedge.

Chapter 2

7 Screws



▲ A screw is an inclined plane that wraps around a centre core.

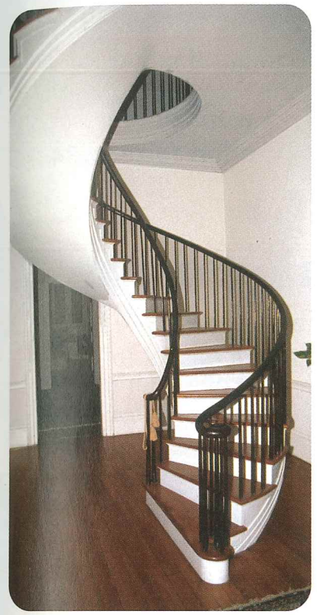
Look around your classroom. What holds things, like your desk or chair, together? Many objects are held together with a simple machine called a screw. A **screw** is an inclined plane that is wrapped around a central core to form a spiral.

As you turn the head of a screw, the screw moves down into a block of wood. The screw acts like a wedge, pushing the wood apart. When the threads of a screw are closer together, you use less effort force to put the screw in the wood because the length of the inclined plane is longer. However, the increased length means that you must turn the screw more times to drive it into the wood. This is the same disadvantage that the inclined plane has—to use less effort force, you need to move a greater distance.

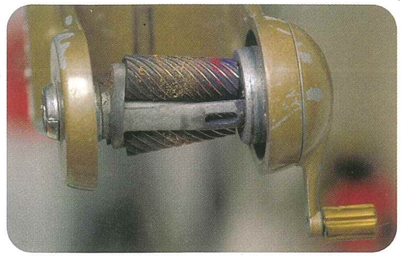
Over 2000 years ago, a mathematician named Archimedes invented a screw that could be used to lift water. The lower end of the screw was placed in the water. As the screw was turned, water was lifted up by the threads until it reached the top, where it poured out.

▲ An Archimedes screw

There are many examples of how a screw is used. A few examples are shown below.



▲ A spiral staircase is a screw that you can walk on to raise yourself to a higher level.



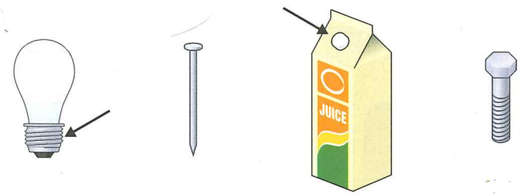
▲ If you take the cover off a pencil sharpener, you will find two screws that work together to grind away your dull pencil.

▲ Screws called propellers make travelling through air easier.

▲ When you close the lid on a pickle jar, you are using a screw to attach the lid to the jar.

Check Your Understanding

1. Which of these objects is a screw? Explain your answer.



2. What is the advantage of a screw? What is the disadvantage?