Science ch. 16

Machines

Biography

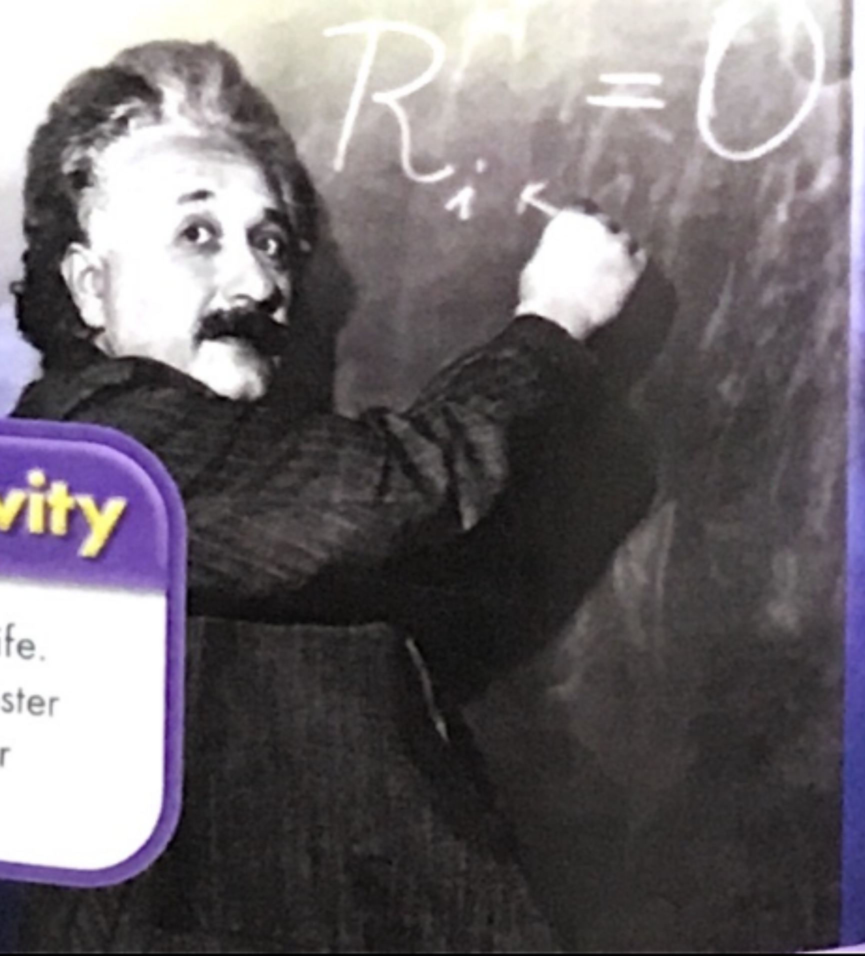
Albert Einstein

When Albert Einstein was 5 years old, his father showed him a magnetic compass. Young Albert was fascinated with it. No matter how he turned the compass, the needle would point in the same direction. He wondered what kept the needle pointing north. Einstein's curiosity and constant wondering would make him one of the greatest scientists the world has ever known.

Einstein was a genius. Like many geniuses, Einstein thought about things in different ways. He was able to come up with ideas that no one had ever thought about before—and show them to be correct.

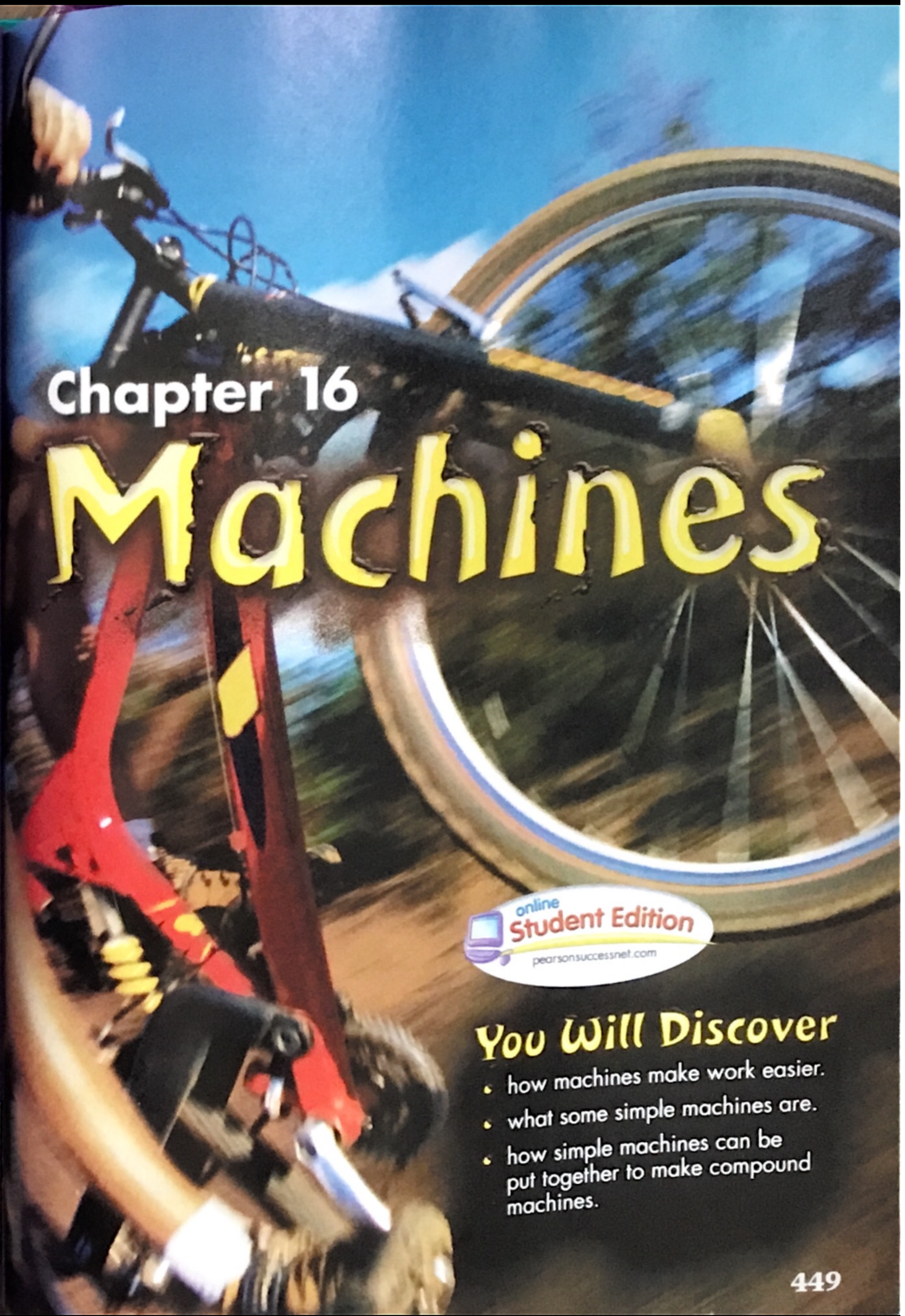
One of these ideas was that matter and energy are interchangeable. In other words, matter can be changed into energy, and energy can be changed into matter. His famous equation, $E = mc^2$, shows that a tiny amount of mass can be changed into a huge amount of energy. This idea led to the use of nuclear power.

Einstein used math to explain and prove his ideas. For example, he developed a theory that predicts no matter can go as fast as the speed of light. Experiments in modern laboratories have shown Einstein to be correct.



Lab zone Take-Home Activity

Einstein lived a quiet yet interesting life. Find out more about him. Then on poster board, create a time line of the major events in his life.



Chapter 16 Machines

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You Will Discover

- how machines make work easier.
- what some simple machines are.
- how simple machines can be put together to make compound machines.

Build Background

How do machines make work easier?

Chapter 16 Vocabulary

work page 455

machine page 456

simple machine page 456

compound machine page 456

fulcrum page 458

load page 458

effort force page 458

You Are There!

You shield your eyes from the intense light coming from the factory production line. Sparks are flying everywhere! You're glad you are looking at this activity from a distance. The machine is doing all the work in welding this part for a new car. How would this job get done without machines?

How do machines help people work?

In science, work *means "using force to move an object a certain distance." A machine is any device that helps people do work.*

Measuring Work

What do you think of when you use the word *work?* Do you think of cleaning your room or doing your homework? Do you think of jobs that adults in your family do to make a living? In our everyday lives, all these examples seem to fit the definition of *work.*

In science, however, **work** means using force—pushing or pulling—in order to move an object a certain distance. No matter how much force you use, if something doesn't move, you haven't done work.

Suppose you want to move a piano from one room to another. A team of movers could push the piano on its rollers across the floor. When they rolled the piano in its new position, they could truly say, "We've done some work!" If you tried to move the piano by yourself, though, you probably wouldn't be able to budge it. You might struggle, strain, and sweat a lot, but you couldn't say, "I did work," if the piano didn't move.

To find how much work is done, use this formula:

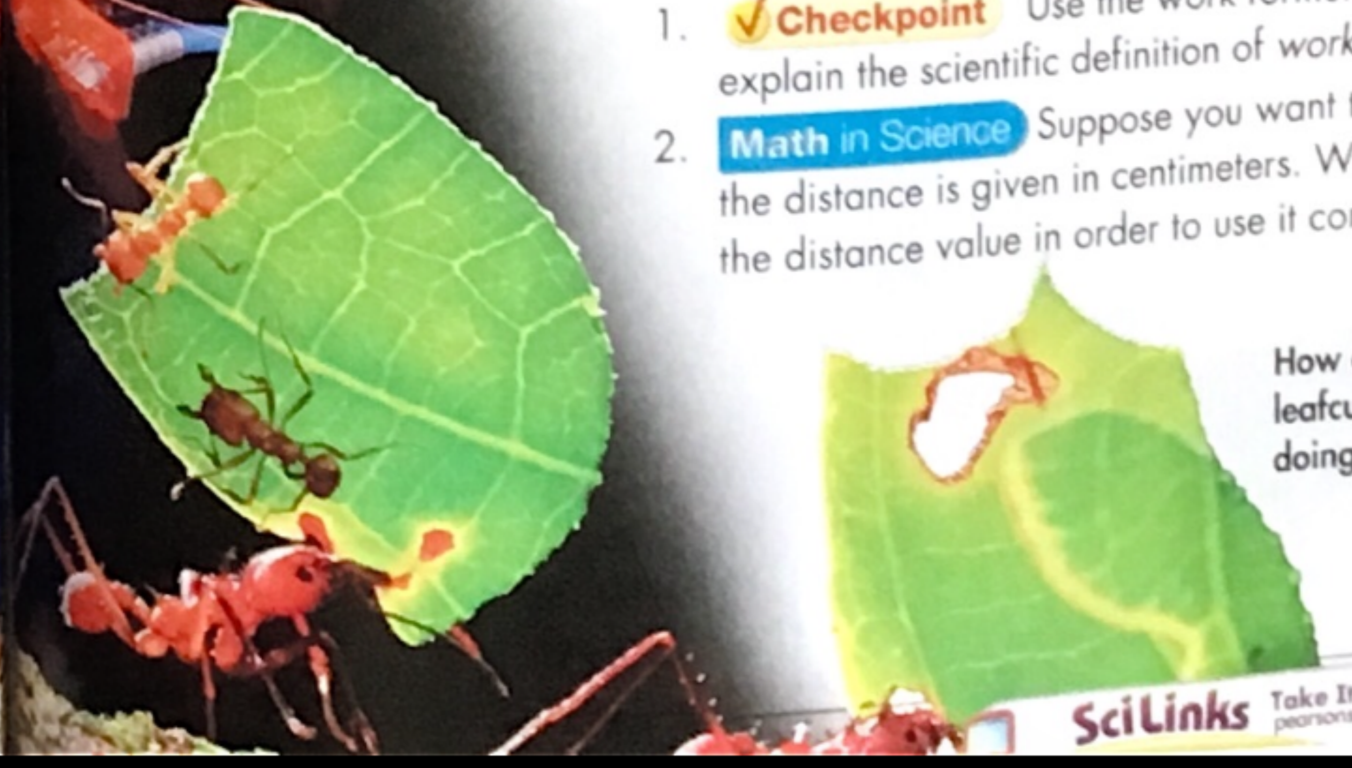
$$\text{work} = \text{force} \times \text{distance}.$$

Work is measured in a unit called the joule. The abbreviation for joule is J.

$$1 \text{ joule (J)} = 1 \text{ newton (N)} \times 1 \text{ meter (m)}$$

For example, suppose you push on a box with a force of 200 newtons. The box moves 1 meter. The work done is 200 N × 1 m, or 200 J.

1. **Checkpoint** Use the work formula to explain the scientific definition of *work.*
2. **Math in Science** Suppose you want to find the work done, and the distance is given in centimeters. What will you need to do to the distance value in order to use it correctly in the formula?



How are these leafcutter ants doing work?

These nail clippers are a machine that can do work.

Work and Machines

Do you know what a machine is? Perhaps you imagine a large, noisy object with many moving parts. Not all machines are complicated, and many don't have moving parts. In science a **machine** is any device that helps people do work. A machine can be quite simple.

You probably don't think of nail clippers or chopsticks as machines, but they are **simple machines.** A simple machine is a tool made up of one or two parts. Think about the way you use chopsticks. You hold them in the middle and squeeze the ends together to grasp bits of food. You then move the food to your mouth. Because you are using force to move something, you are doing work—with help from the chopsticks.

The kind of machine that most people think of when they think of a machine is a compound machine. A compound machine helps people do work too, but it has many parts. A **compound machine** contains one or more simple machines among its parts. You probably can think of many compound machines. Some, such as cars, trucks, and airplanes, have thousands of parts.

Chopsticks help you do work.

How Machines Help

There is nothing magic about what a machine can do for you. Every machine makes some kind of tradeoff that helps you in some way. Recall that work is equal to force times distance. Some machines decrease the force required to do a task. A car jack is an example. If you tried to lift a car without a machine, you wouldn't be able to supply enough force. But when you use a car jack, the task becomes much easier. The jack decreases the required force by increasing the distance over which the force is applied.

Think about twisting a screw-top lid on a jar. A person might be able to force the lid onto the jar top by slamming down hard with a fist. However, screwing on the top is a lot easier. When you screw on the lid, you apply the force over more distance as you turn and turn the lid, but you don't have to use as much force.

A wheelbarrow is a compound machine because it is made up of several simple machines.

Machines and Friction

In order for a machine to do its job, work must go into it. If you supply a force—a push or a pull—on a machine, you are doing work. Sometimes the work that goes into a machine comes from another energy source, such as a battery.

You might think that the amount of work that a machine does is equal to the amount of work put into it. But the amount of work done by a machine is less than the amount put into it. Why? The answer is friction.

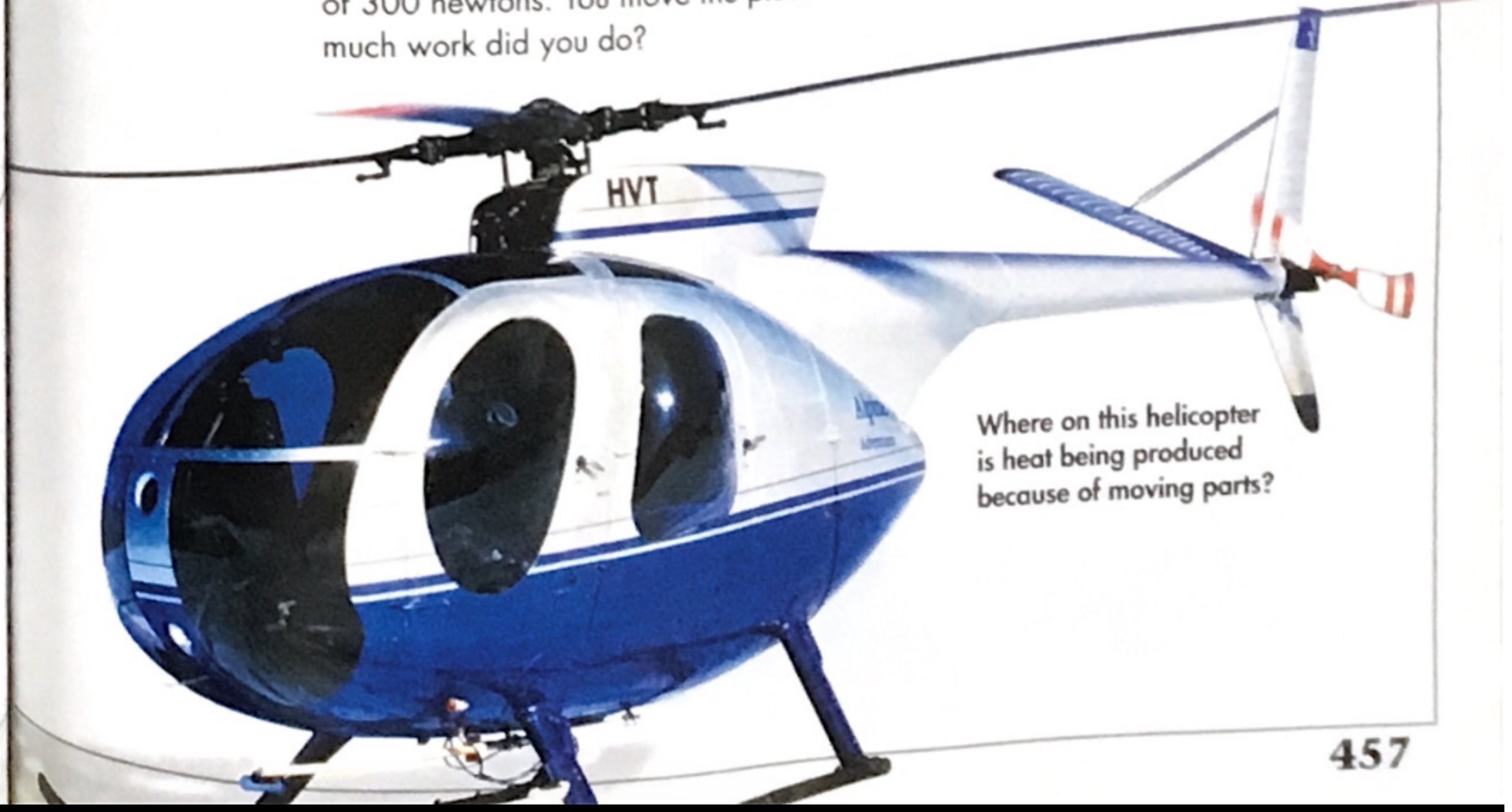
You've probably noticed that often when you use a machine, it gives off heat. The heat is produced as a result of the friction between the moving parts of the machine. In general, the more moving parts a machine has, the more work is lost to friction.

People who design machines try to make machines more efficient by reducing the friction between the machine's parts. One way to do this is by using lubricants. Lubricants include substances such as oil, wax, and grease.

Another way to reduce friction is to use wheels, rollers, or balls. The ball bearings placed in the wheels of inline skates reduce friction. Using a lubricant would reduce friction even more.

✓ Lesson Checkpoint

1. How do machines make doing work easier?
2. **Cause and Effect** How does friction affect the work of a machine?
3. **Math in Science** Suppose you need to move a board that is nailed to the floor. You pry down with a crow bar with a force of 300 newtons. You move the piece of wood 0.5 meters. How much work did you do?



Where on this helicopter is heat being produced because of moving parts?

Lesson 2

What are types of simple machines?

There are six basic types of simple machines. Each machine works in a unique way to help you do work.

Types of Simple Machines

If you study the parts of any compound machine, you will find that it is made from two or more simple machines. The six types of simple machines are the lever, inclined plane, wedge, screw, wheel and axle, and pulley.

Lever

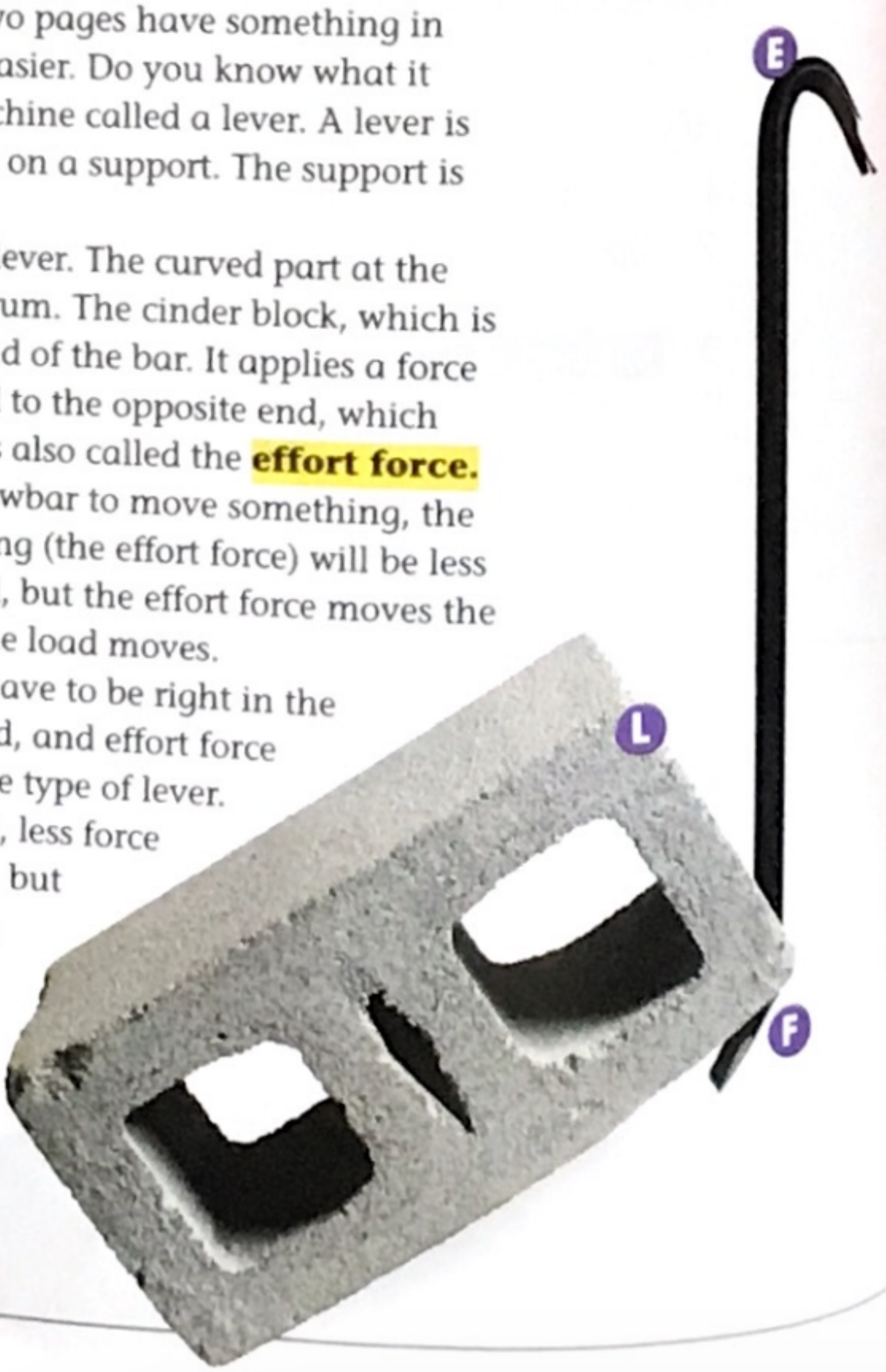
The objects pictured on these two pages have something in common that helps make work easier. Do you know what it is? They all contain a simple machine called a lever. A lever is made of one or more bars resting on a support. The support is called the **fulcrum.**

The crowbar in the picture is a lever. The curved part at the bottom of the crowbar is the fulcrum. The cinder block, which is also called the **load,** is on one end of the bar. It applies a force on the crowbar. A force is applied to the opposite end, which lifts the load. This applied force is also called the **effort force.** When a person pushes on the crowbar to move something, the force created by the person pushing (the effort force) will be less than the force applied to the load, but the effort force moves the handle a greater distance than the load moves.

The fulcrum of a lever doesn't have to be right in the middle. The order of fulcrum, load, and effort force can be different, depending on the type of lever. If the fulcrum is closer to the load, less force will be required to move the load, but the load will not be lifted as high. If the fulcrum is closer to the effort force, more force will be required, but the load will be lifted higher. In both examples, the trade off is between force and distance.

Key

- E Effort force
- F Fulcrum
- L Load

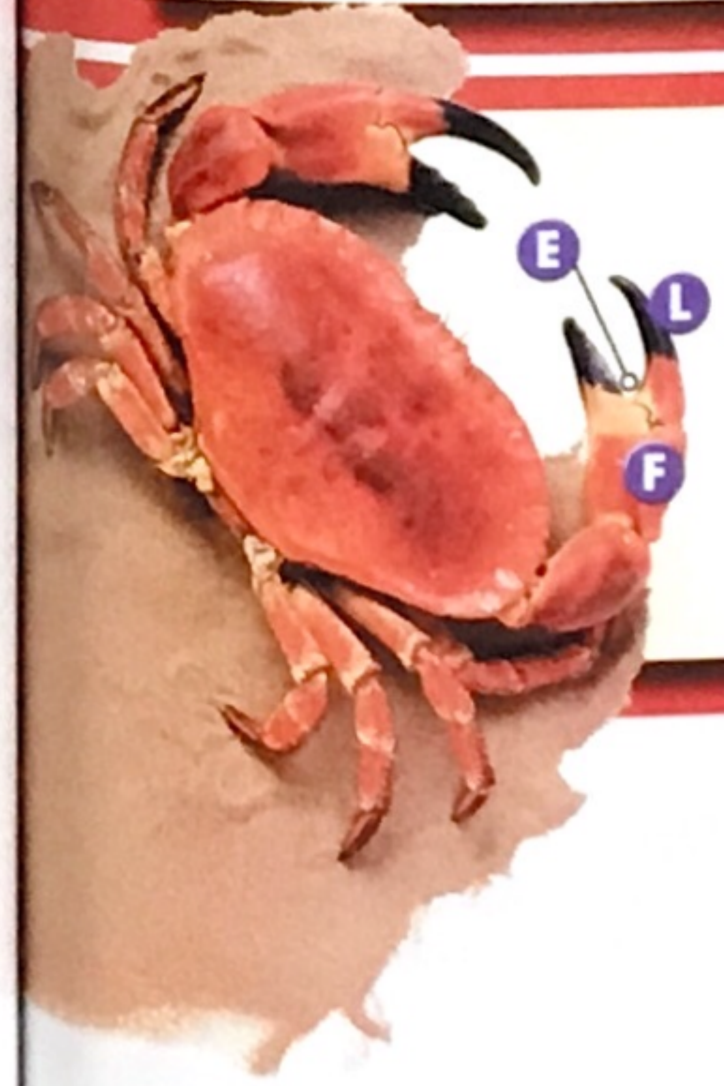


First-Class Lever

Can you find the fulcrum in this pair of pliers? It's in the middle, between the effort force and the load. The effort force is the force you apply when you squeeze the handles. The load is the item you will grab with the "nose" end of the pliers. A first-class lever, such as pliers, has the effort force at one end, the load at the other end, and the fulcrum between them.

Second-Class Lever

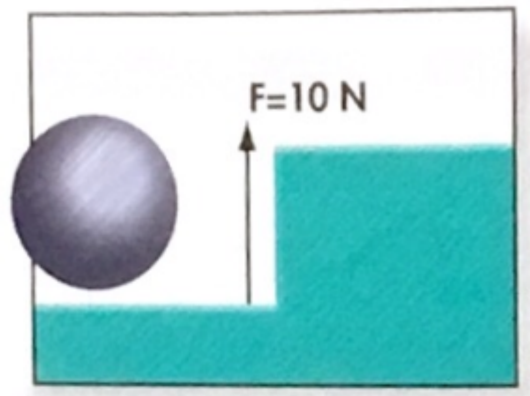
A second-class lever, such as a nutcracker, has the effort force at one end, the fulcrum at the other end, and the load in the middle. The fulcrum of the nutcracker is at the closed end, where the two bars connect. The effort force is the force you apply when you squeeze the handles. The load is the nut you want to crack.

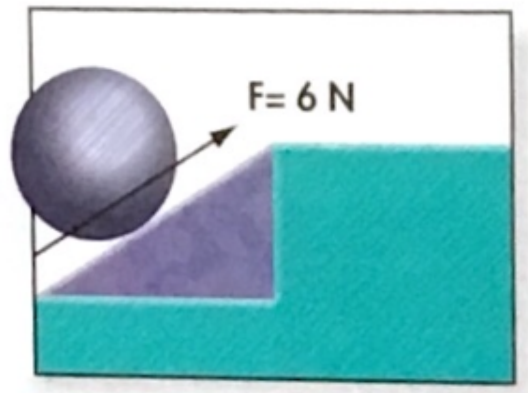


Third-Class Lever

You probably don't think of crab claws as levers. Can you find the fulcrum? It is the joint that connects the two halves of the claw with the crab arm. The effort force is the force the crab applies with muscles in the middle of its claw. The load is the tasty morsel the crab pinches and grabs with the sharp ends of its claw. A third-class lever, such as the crab claw, has the fulcrum at one end, the load at the other, and effort force in the middle.

1. ✓ Checkpoint How do first-class, second-class, and third-class levers differ?
2. Health in Science Your elbows and knees are types of fulcrums. Sometimes, these parts of the body must handle strong forces applied in activities such as sports. Find out how you can protect knees and elbows when doing sports activities such as playing ball or riding a bike. Use the Internet or your library. Make a list of helpful hints.





Inclined Plane

Would you rather carry a heavy box up a flight of stairs or use a ramp? A ramp is another type of simple machine called the inclined plane. An inclined plane is a slanted surface. A ramp makes moving a load from a low place to a higher place easier.

The inclined plane offers a trade off between distance and force. You can see in the diagrams that moving a load up a ramp takes less force than lifting it straight up. But the load travels farther up the ramp. In both cases, you do the same amount of work.

This winding road on a mountainside is an inclined plane. Cars must travel quite a distance to get to the mountaintop, but they can go there more easily than driving straight up.

The Wedge

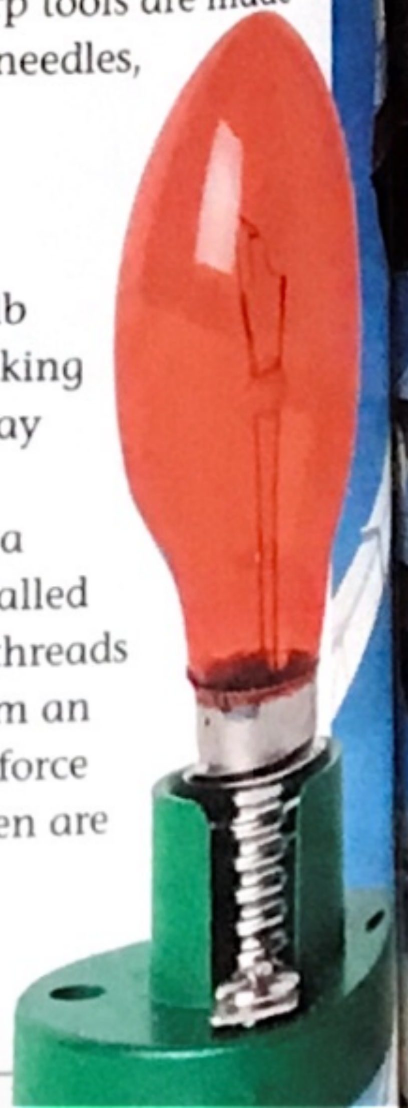
Not all inclined planes are as simple as a ramp. The left picture on the bottom of the page shows the part of a ship called the prow. The prow is a wedge. A wedge is a simple machine made of one or two inclined planes. The slanted edges of the inclined planes come to a point. To do its work, the wedge must be moving. A force directed at the flat end of the wedge drives the point forward. The inclined planes of the wedge change the direction of the force.

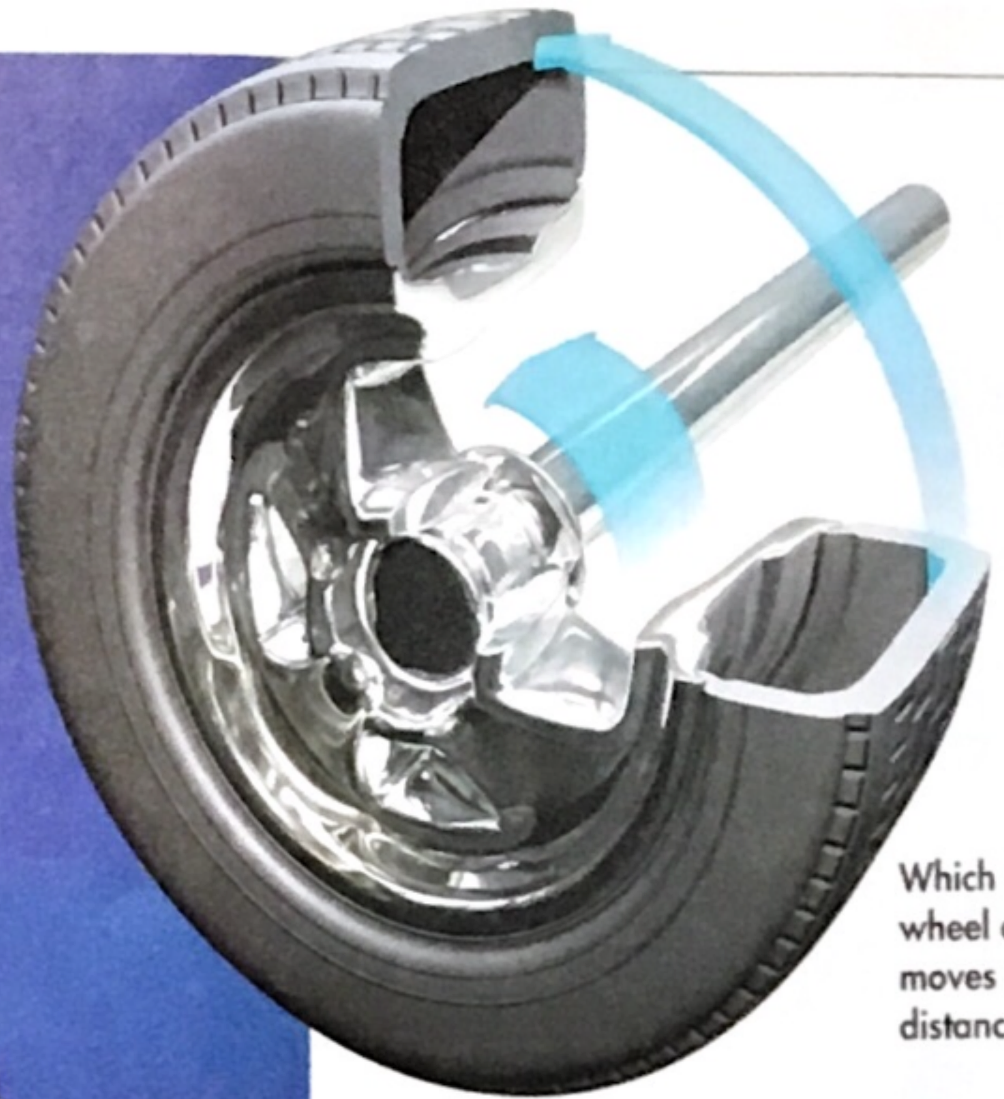
A wedge can be used for splitting wood or for digging in the ground. Many sharp tools are made of inclined planes—saws, knives, needles, and axes.

The ship's prow is a wedge. It helps the ship move more easily through the water.

The Screw

The bottom part of this light bulb is a modified inclined plane. Thinking of a screw as an inclined plane may seem strange. But a screw is an inclined plane that is wrapped in a spiral. The ridges on a screw are called threads. If you could unwind the threads of a screw, you would see they form an inclined plane. A screw decreases force and increases distance. Screws often are used as fasteners.





Which part of the wheel and axle moves the greater distance?

Wheel and Axle

Did you ever ride on a Ferris wheel similar to the one in the picture? If you did, you were riding on a simple machine called a wheel and axle. A wheel and axle is made of a wheel with a rod joined at the wheel's center. You can see in the picture how much larger the diameter of the wheel is than that of the axle. The wheel turns through a much greater distance than the axle. But the smaller turn of the axle is much more powerful.

A wheel and axle can increase a force or increase the distance through which a force acts. Think about a water faucet in the shape of a wheel that you turn with your hand. The force you put into turning the faucet changes into a larger force in the tiny axle, which opens up the water valve. Can you imagine what it would be like to turn on the faucet if it consisted of just the axle without the wheel?

1. **Checkpoint** Explain how a wedge and a screw are related to the inclined plane.
2. **Cause and Effect** You want to move a heavy box up the four front steps of your home. You decide to use a ramp. How will using the ramp affect the distance the box must be moved?

Pulley

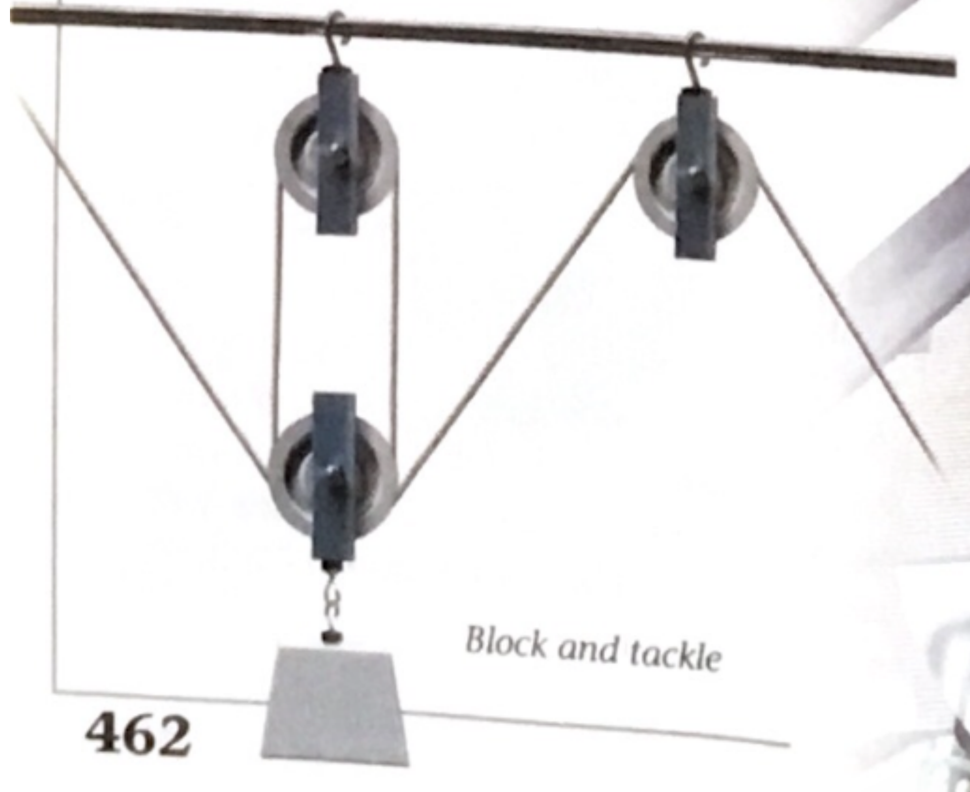
A pulley is a grooved wheel with a rope or chain around it. A load is attached to one end of the rope and the effort force is applied to the other end. There are two types of pulleys: fixed pulleys and movable pulleys. A fixed pulley stays in one position as the wheel spins. It lets you pull down on one end to lift up the load on the other end. It changes the direction of the force, but it doesn't reduce the effort force you must use. A downward pull on the rope causes the load to move upward.

Unlike a fixed pulley, a movable pulley is attached to the object being moved. As a force is applied to the load, the pulley moves along with the load. Movable pulleys decrease the force you must apply, but the force you use is applied over a greater distance. You must make both sides of the rope move in order to move the load.

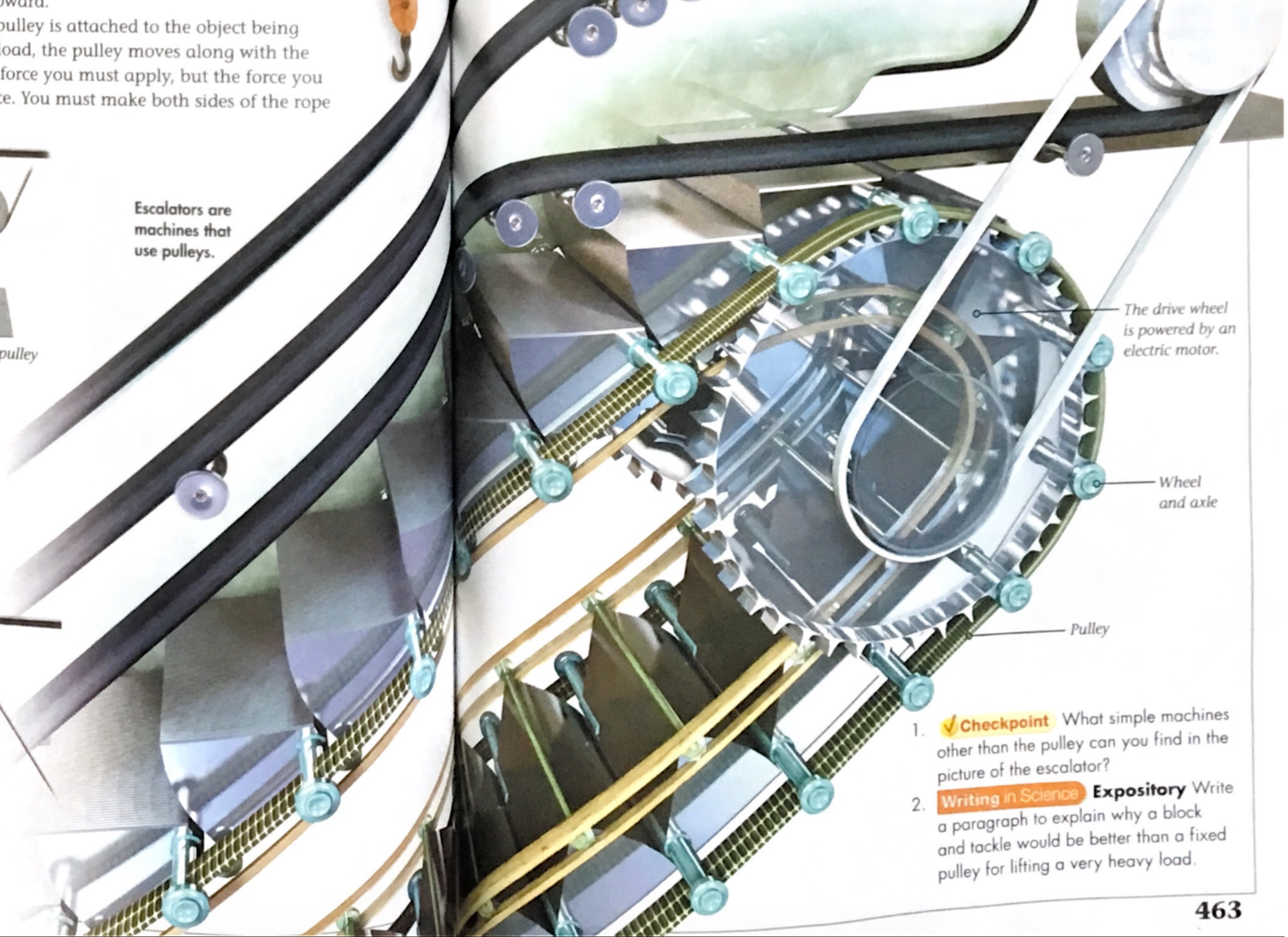
Fixed pulley

Moveable pulley

Several pulleys can be used with the same rope in a system called a block and tackle. Each pulley added to the compound system reduces the amount of effort required to lift the load. A block and tackle with a lot of pulleys could help lift a very heavy load, such as a piano.



Block and tackle

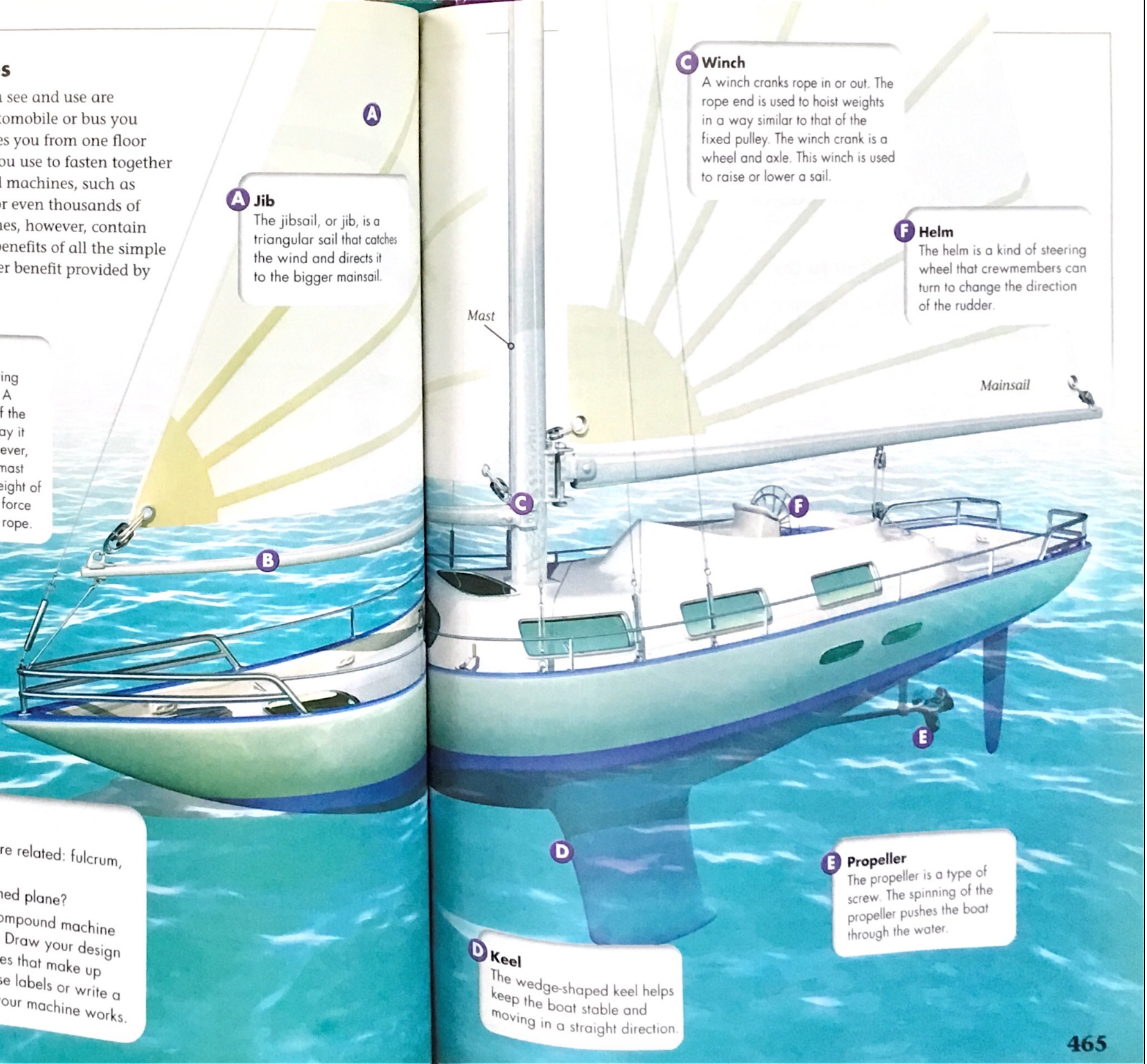


Escalators are machines that use pulleys.

1. **✓Checkpoint** What simple machines other than the pulley can you find in the picture of the escalator?
2. **Writing in Science** **Expository** Write a paragraph to explain why a block and tackle would be better than a fixed pulley for lifting a very heavy load.

Compound Machines

Almost all the machines you see and use are compound machines—the automobile or bus you ride in, the elevator that carries you from one floor to the next, even the stapler you use to fasten together your papers. Many compound machines, such as this sailboat, have hundreds or even thousands of parts. Even the largest machines, however, contain many simple machines. The benefits of all the simple machines add up to the greater benefit provided by the compound machine.



A Jib
The jibsail, or jib, is a triangular sail that catches the wind and directs it to the bigger mainsail.

B Boom
The boom's end can swing freely around the mast. A rope along the length of the boom controls which way it swings. The boom is a lever, with the fulcrum at the mast joint. The load is the weight of the sail above, and the force is applied by the guide rope.

C Winch
A winch cranks rope in or out. The rope end is used to hoist weights in a way similar to that of the fixed pulley. The winch crank is a wheel and axle. This winch is used to raise or lower a sail.

F Helm
The helm is a kind of steering wheel that crewmembers can turn to change the direction of the rudder.

E Propeller
The propeller is a type of screw. The spinning of the propeller pushes the boat through the water.

D Keel
The wedge-shaped keel helps keep the boat stable and moving in a straight direction.

✓ Lesson Checkpoint

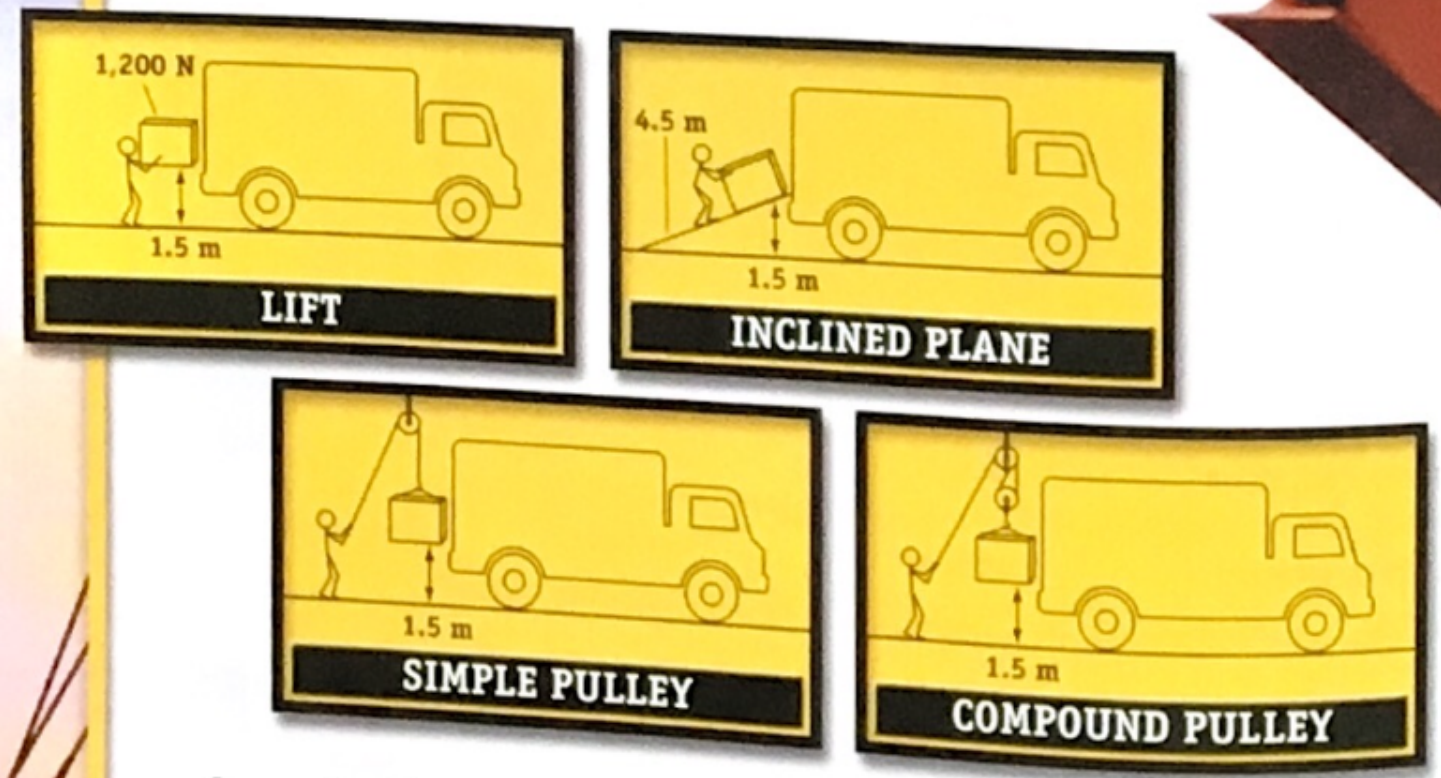
1. Explain how the following are related: fulcrum, load, effort force.
2. How is a screw like an inclined plane?
3. **Art in Science** Design a compound machine to perform a particular task. Draw your design and label the simple machines that make up your compound machine. Use labels or write a paragraph to explain how your machine works.

Math in Science

Mathematics and MACHINES

We are surrounded by machines that make our lives easier. Scissors, doorknobs, and stairs are all examples of simple machines that we use regularly. Some of the same tasks could be accomplished with a variety of machines.

Suppose you need to load a heavy box (1,200 N) onto the back of a truck. You have several options for loading the box. First, you could lift it 1.5 m into the back of the truck. How much work would this take?



Remember: Work (in joules) = force (in Newtons) x distance (in meters).

W = 1,200 N x 1.5 m
W = 1,800 N x m
W = 1,800 J

In this case, the force is the weight of the box, in Newtons. The distance is the height of the truck bed from the ground.

The total work to lift the box would be 1,800 J.

You could also use a machine to load the box. You can choose a ramp (inclined plane), a simple pulley, or a compound pulley. These options are pictured for you on page 468. Friction works against all machines, so the actual force required is greater than what would be expected, but they can still make the job easier.

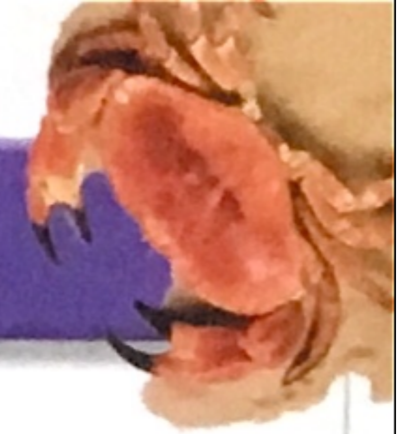
Answer each question. Use the pictures on page 468.

1. If the force required to load the box using the ramp is 440 N and the ramp is 4.5 m long, what is the amount of work done?
2. The work done to load the box using the simple pulley is 1,845 J. Compute the force needed. Considering your answer, how does a simple pulley help?
3. If you use the compound pulley, you will need to pull twice the distance but with less force. The force you need is equal to one half the weight of the box plus 25 N. What is the force needed?
4. If you are only able to exert a force of 550 N, which machine should you use? Which machine requires the most work to use?
5. Predict how the force needed would change if you used a ramp that is twice as long as the one pictured. Explain your answer.

Lab zone Take-Home Activity

Using a board or other long, flat surface, set up an inclined plane. Find a way to attach a rubber band to various objects that can be pulled up the inclined plane. As you pull an object up, try to maintain a constant speed. Measure the length of the rubber band as you are pulling. Experiment with objects of different weights and materials and change the angle of the incline. Record your results and use them to explain the advantages and disadvantages of using an inclined plane.

Chapter 16 Review and Test Prep



Use Vocabulary

compound machine (p. 456)	**load** (p. 458)
effort force (p. 458)	**machine** (p. 456)
fulcrum (p. 458)	**simple machine** (p. 456)
	work (p. 455)

Choose a term from the box that best matches each clue.

_____ **1.** Any device that helps people do work

_____ **2.** Has one or just a few parts

_____ **3.** The support on a lever

_____ **4.** The force applied to a lever by a person or another machine

_____ **5.** Has many parts; contains one or more simple machines

_____ **6.** The force of an object on a lever

_____ **7.** Using a force to move something

Explain Concepts

8. Explain how the scientific definition of *work* differs from the everyday meaning of *work*, as in "chores."

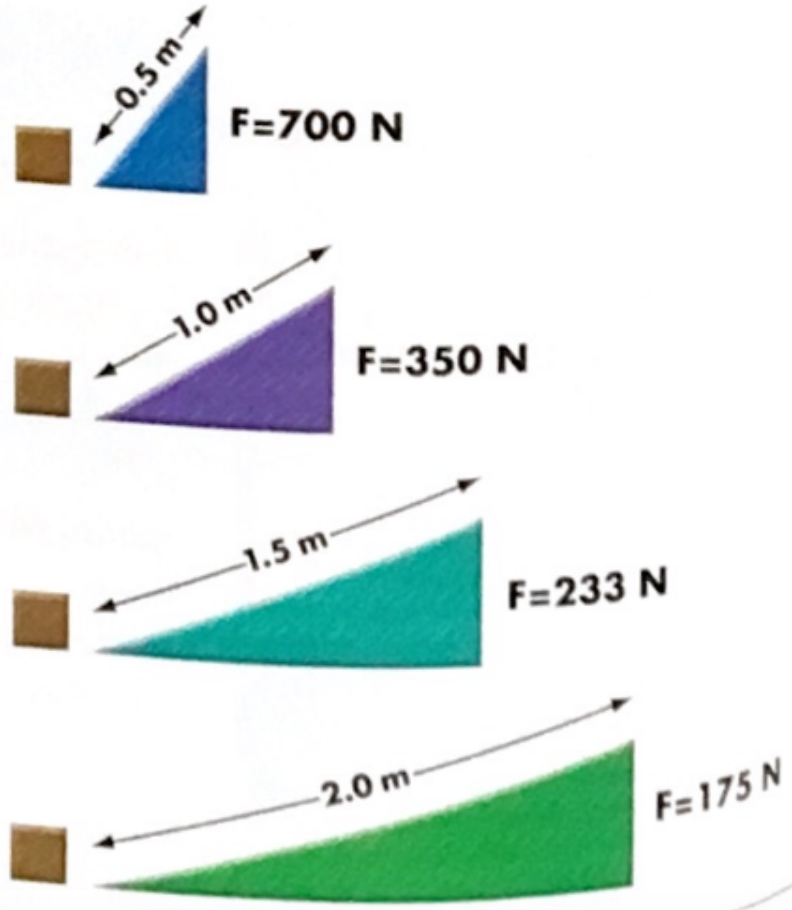
9. What are the six kinds of simple machines? Give an example of each.

10. Explain why the amount of work that a machine does is less than the amount put into the machine.

11. What are two ways to reduce the friction produced when parts of a machine move? Give examples.

Process Skills

12. Collect Data The pictures show how four different ramps were used to move a heavy box. Use the information to draw a force-distance graph. Then calculate the amount of work done with each ramp.



13. Classify Draw the three types of levers. Identify the fulcrum, effort force and load in each.

Cause and Effect

14. Lifting a load of 200 N with a single movable pulley requires 100 N of force. What would be the effect on the amount of effort force required to move the load if a block and tackle were used? Explain your answer.

Test Prep

Choose the letter that best answers the question.

15. How much work is done when a 5 N force moves a load 2 m?

Ⓐ 1 J
Ⓑ 2.5 J
Ⓒ 5 J
Ⓓ 10 J

16. Suppose you twist the lid of a pickle jar to tighten it. What simple machine are you using?

Ⓕ pulley
Ⓖ lever
Ⓗ screw
Ⓘ wheel and axle

17. A block and tackle is made from

Ⓐ a series of pulleys.
Ⓑ a wheel and axle.
Ⓒ two inclined planes.
Ⓓ two screws.

18. Which item is NOT a compound machine?

Ⓕ pliers
Ⓖ manual can opener
Ⓗ electric can opener
Ⓘ bicycle

19. Explain why the answer you chose for Question 15 is best. For each of the answers you did not choose, give a reason why it is not the best choice.

20. Writing in Science **Expository** Write directions for using a pulley to lift a very heavy load. Include a description of the kind of pulley to use.