Simple and Complex Machines

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Written by Ned Jensen

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KEY ELEMENTS USED IN THIS BOOK
The Big Idea: Machines help us do work more quickly, easily, and/or safely. Machines reduce the amount of force required to do work but often require working over a greater distance. Seven types of simple machines can be found in familiar devices. One or more simple machines may be combined to form a complex machine. Understanding how various machines work will help students to choose appropriate machines and use them properly.
Key words: axle, block and tackle, complex machine, distance, energy, first-class lever, force, friction, fulcrum, gear, hammer, inclined plane, knife, lever, lift, load, machine, pull, pulley, push, ramp, robot, screw, second-class lever, seesaw, simple machine, slope, third-class lever, tool, turn, wedge, weight, wheel, wheel and axle, work **Key comprehension skill:** Cause and effect *Other suitable comprehension skills:* Compare and contrast; classify information; main idea and details; identify facts; elements of a genre; interpret graphs, charts, and diagrams; using a glossary and boldfaced terms; using a table of contents and headings **Key reading strategy:** Summarize *Other suitable reading strategies:* Ask and answer questions; connect to prior knowledge; visualize; retell

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Introduction

How do you do **work**? How do you eat cereal or hit a baseball really far? How do you slice cheese for a sandwich or loosen the lid of a jar? You probably use tools.

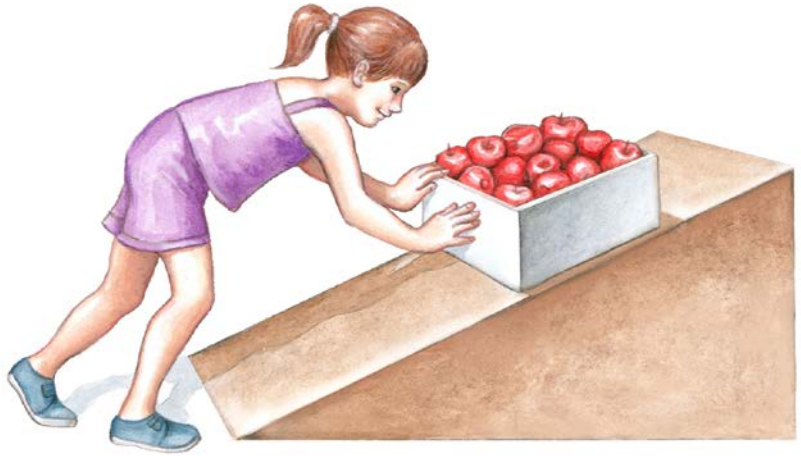
People have been making and using tools for millions of years. We create tools to make work easier to do. A **machine** is a device that uses energy to help you do work. Tools that have only a few parts are called **simple machines**. Hammers and knives are simple machines. Some machines combine several simple machines. Clocks and bicycles are **complex machines**. In this book, you will learn about machines and how they make work easier.

Do You Know?

Animals use tools, too! Apes use sticks to get ants out of anthills. Otters use rocks to crack open clamshells. Crows can make wire hooks to get food out of a tall, thin container.

In the introduction, you learned that machines make work easier. But what do we mean by work? In science, work is done whenever an object is moved over a distance. To move something, you must use **force**. The more force it takes to move an object, the more work is done. The greater the distance the object moves, the greater the amount of work it takes to move it.

Whenever you push, pull, turn, or lift an object, you are using force to move it. The amount of force it takes depends on the weight of the object. It takes a lot more force to move a large boulder than to move a small rock. Machines make work easier by reducing the amount of force, or effort, it takes to move an object, or **load**.

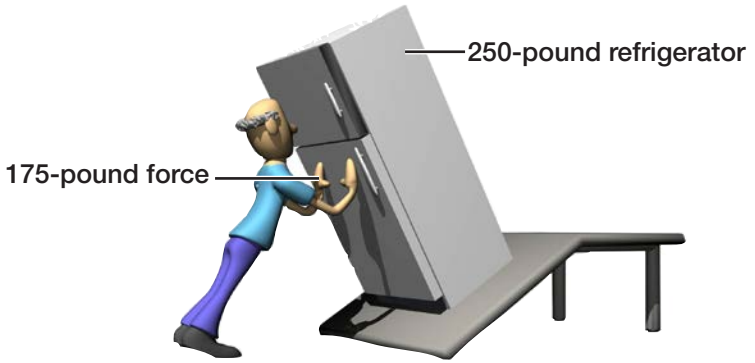


Both ramps do the same amount of work. The top ramp requires twice as much force as the bottom ramp, but the bottom ramp covers twice as much distance. Which ramp would you rather use?

But there is a trade-off when you use a machine to reduce the force it takes to do work. The trade-off is that you have to apply the force over a greater distance. Most machines help you do work by spreading out the force over a larger distance.

Types of Simple Machines

There are only a few types of simple machines. Some have no moving parts, and others have only a few. Below are the seven simple machines you will read about in this book.



Inclined Plane

The **inclined plane** is a very simple machine. It has no moving parts! It is a surface with a slope, or incline. Inclined planes are used to change the height of an object. A common inclined plane is a **ramp**.

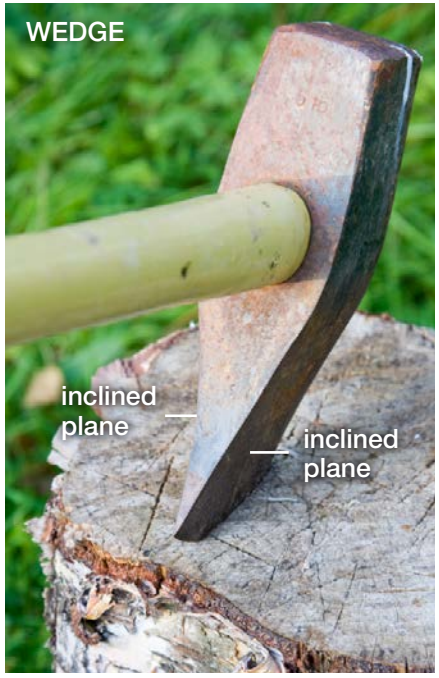
Furniture movers use ramps because it takes less force to slide a heavy box up an inclined plane than to lift it straight up into a truck. It would take a certain amount of work to lift a box three meters. But if you use a ramp that is six meters long to raise the box three meters high, it takes only half the work! The longer the ramp and the gentler the slope, the less force is needed to move the load. But remember the trade-off. The gentler and longer the slope, the farther you have to push or pull the load.

Do You Know?

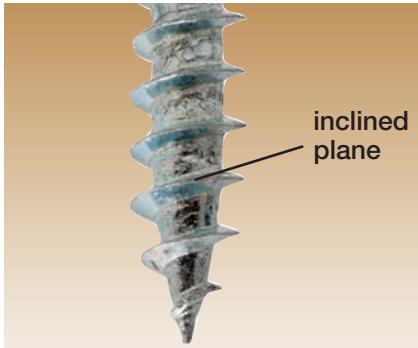
Over 3,000 years ago, the Egyptians used inclined planes to build pyramids. They used long ramps to move heavy stones uphill.

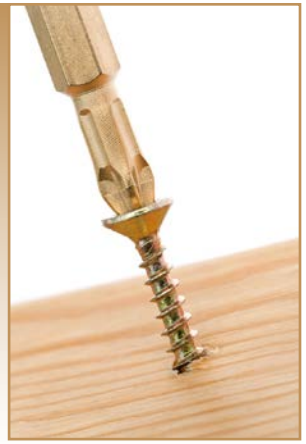
Wedge

A **wedge** is really just two inclined planes that meet. Instead of helping you move things to a different level, a wedge helps you push things apart. The blade of a knife is a wedge. Your front teeth are also wedges. Wedges cut through things by moving them apart. The narrower or sharper the wedge, the easier it is to move things apart.



A wedge can split a piece of wood.





An inclined plane wraps around the center of a screw. As the screw turns, it moves into the object.

Screw

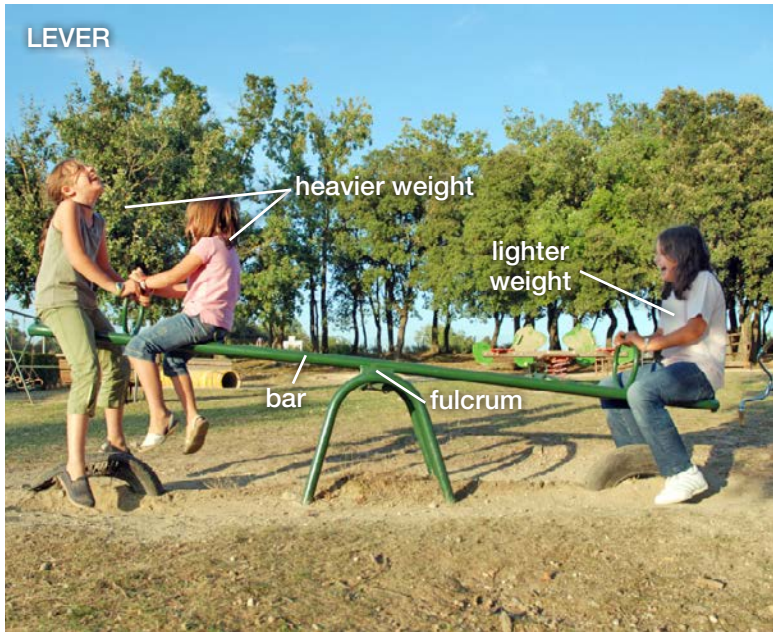
A **screw** is an inclined plane wrapped around a rod. The thread on a screw is the inclined plane. As you turn a screw, the thread makes it easier to force the screw into wood or metal. Screws usually hold two things together, such as two pieces of wood.

Screws of many sizes are used to hold things together.

Lever

A **lever** is a machine that can lift heavy things. A lever consists of a board or bar that rests on a turning point called the **fulcrum**. The board pivots, or rotates, on the fulcrum.

If you've ever been on a seesaw, you've used a lever. On a seesaw, it is possible to balance with someone who is much heavier than you are. If you move farther from the fulcrum, and the heavier person moves closer to the fulcrum, you can balance the heavier person's weight.

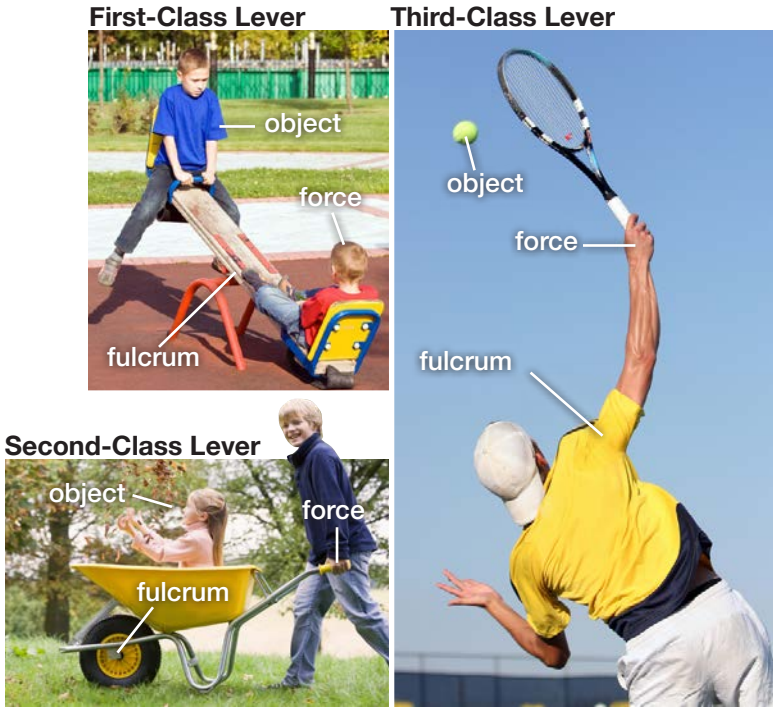


When the fulcrum is close to an object, the object can be lifted more easily but not as high.

With the fulcrum far away from an object, the object is harder to lift, but it can be lifted higher.

With a seesaw, the fulcrum is at the center. But a fulcrum can be placed just about anywhere along a lever. You can change the location of the fulcrum to make your job easier. The closer the object is to the fulcrum, and the farther the force is from the fulcrum, the easier it is to move the object. As a result, you will need less force to move it. In the diagram, the top lever takes half as much force to move the object as the bottom lever does.

There are several kinds, or classes, of levers. In a first-class lever, the fulcrum is between the force and the object being lifted. The seesaw is a first-class lever. In a second-class lever, the object is between the force and the fulcrum. A wheelbarrow is a second-class lever. In a third-class lever, the force is between the fulcrum and the object. A tennis racket is a third-class lever. The fulcrum is the player's shoulder, the lever is the person's arm plus the racket, the object is the ball, and the force is the hand moving the racket.



Wheel and Axle

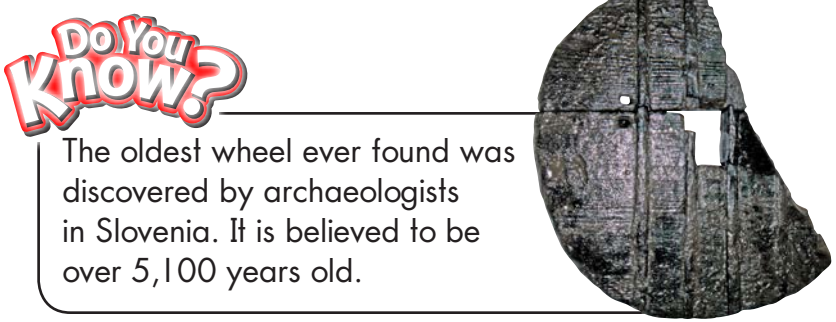
A **wheel and axle** is another simple machine. It consists of a **wheel** attached to a rodlike **axle**. When the wheel turns, the axle also turns.

The wheel is wider than the axle. When a force is used to turn the wheel, the force is transferred to the axle. Since the wheel turns a longer distance, the force at the axle is greater. This allows it to move heavy objects. A doorknob is a wheel and axle. It makes opening a door easier. Wheels and axles are used in many complex machines, such as cars and bicycles.

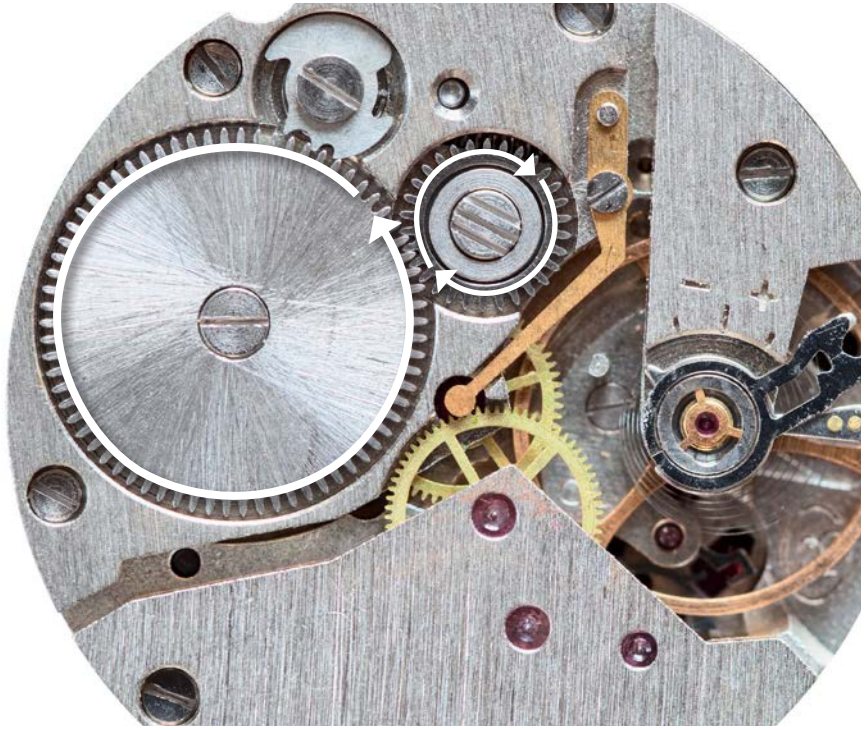
A wheel turns farther than the axle, but with less force.

A wagon with wheels creates less friction than a wagon without wheels.

Wheels also help move objects by reducing the amount of **friction**. Friction is a force that resists the movement of an object. Friction occurs whenever two surfaces rub against each other. The more surface that rubs together between the objects, the more friction there is, and the harder it is to move the objects past each other. A wheel only has one small part touching the ground at any time. This means that less of the object that could cause friction touches the ground. Imagine pulling a wagon without any wheels. The whole wagon would be on the ground, creating much more friction.



The oldest wheel ever found was discovered by archaeologists in Slovenia. It is believed to be over 5,100 years old.



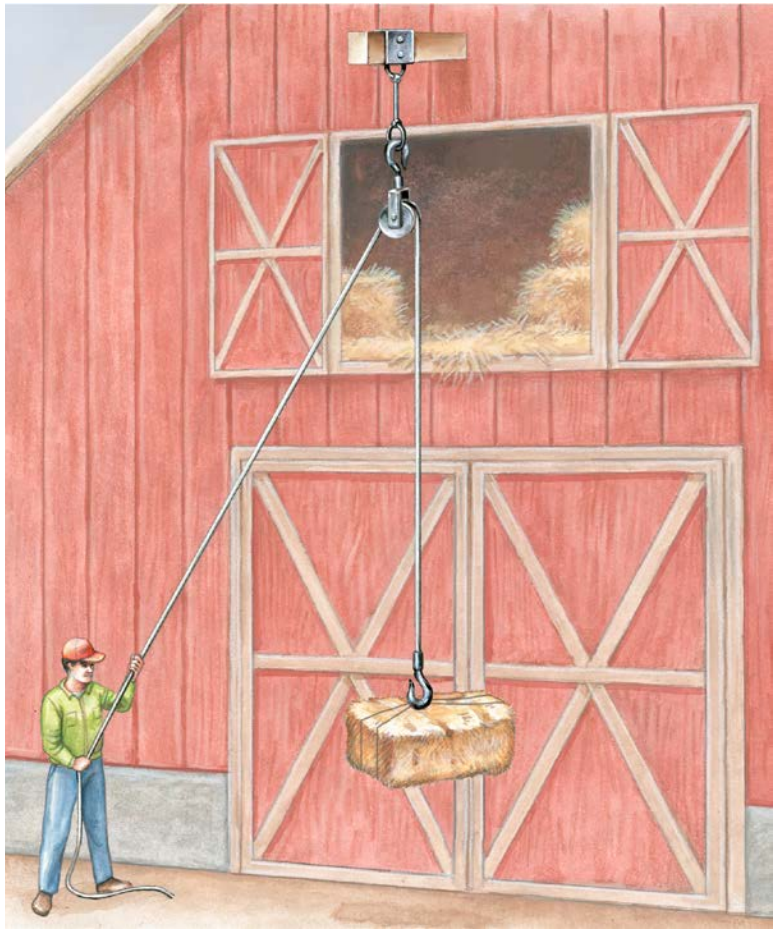
For every one time the large gear turns, the small gear turns more than once. The large gear has more force, while the small gear moves faster.

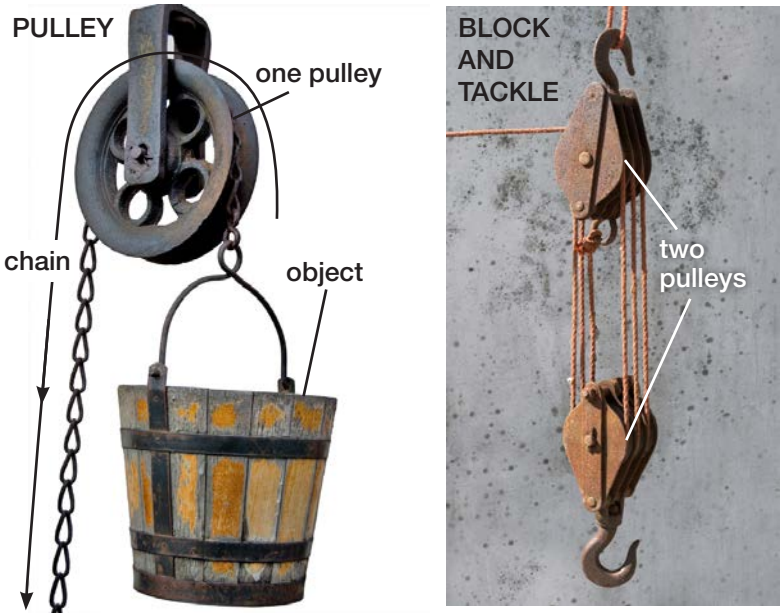
Gear

A **gear** is really just a wheel with teeth. Gears are used to transfer motion or force from one place to another. Gears attached to axles can be used to increase or decrease speed and to change the amount of force. A large gear will turn more slowly than a small gear it is connected to, but the large gear will turn with greater force.

Pulley

A **pulley** is a wheel with a rope. As the rope moves over the wheel, it changes the direction of the force. Look at the diagram. Pulling down on the rope, which is part of an attached pulley, raises the bale of hay on the other end of the rope.



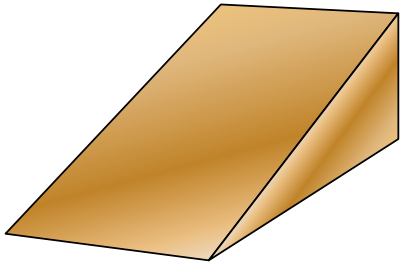
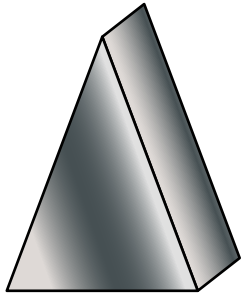
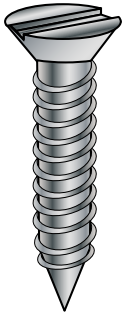


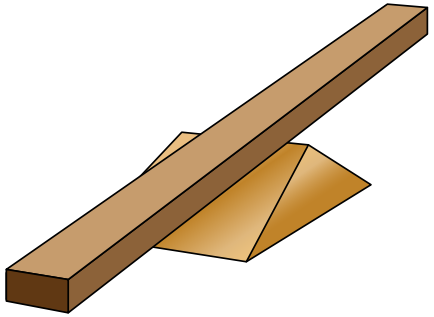
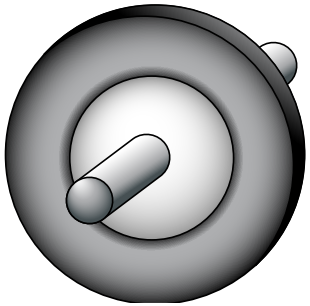
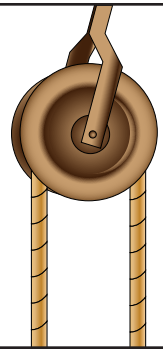
A pulley changes the direction of the force. Pulling down raises the load. In a block and tackle, the rope moves farther, but it takes less force to lift the load.

Pulleys can also be used to decrease the amount of force needed to move objects. Putting two or more pulleys together reduces the force needed to lift a load. A group of two or more pulleys is called a *block and tackle.* But as with all simple machines, there is a trade-off when you use a block and tackle. Adding pulleys to reduce force means that you have to pull the rope farther to lift the load. If you add enough pulleys to reduce the force by four times, you must pull the rope four times farther.

Simple Machine Summary

The table below shows the seven major simple machines and their uses.

Simple Machine and Use	Drawing
Inclined Plane To raise or lower heavy objects	
Wedge To split things apart	
Screw To hold things together	

Lever To lift heavy things	
Wheel and Axle To reduce friction and make it easier to move something	
Gear To reduce the force needed to move something	
Pulley To lift heavy objects	

Complex Machines

Most big machines are combinations of simple machines. For example, a wheelbarrow is a combination of a lever and a wheel and axle. A bicycle uses wheels and axles with pulleys and gears. A can opener uses a wedge, a lever, and a gear.

We use complex machines to do repetitive, difficult, complicated, or dangerous tasks. Electric mixers mix batter over and over, so we don't have to beat it with a spoon. Cranes lift big containers and help build roads and skyscrapers. Robots make computer chips, build cars, and dig through rubble. Each of these machines uses energy to make work easier.

Some machines do things that people can't. Robots can handle heat, pressure, and radiation that would hurt or kill a person.

Robots like this one might explore the seas on Jupiter's moon Europa.

That's why we send robots to explore space and into the deepest parts of the sea to study hot spots on the ocean floor.

Conclusion

We use many different machines to help us do work every day. Machines can be simple, with just one or a few parts. The inclined plane, wedge, screw, lever, wheel and axle, gear, and pulley are all simple machines. Many machines combine several simple machines. These complex machines help us do tasks that are difficult, repetitive, dangerous, or just boring. All machines help us move things by using either less force over more distance or more force over less distance. What machines have you used today?

Glossary

axle a pin or pole around which a wheel revolves (p. 14)

complex machines any devices made up of more than one simple machine; compound machines (p. 4)

force the strength or energy that moves an object (p. 5)

friction the force that builds up when two objects rub against each other (p. 15)

fulcrum the point around which a lever pivots or turns (p. 11)

gear a toothed wheel that connects with another toothed object to change speed or direction; a type of simple machine (p. 16)

inclined plane a slanted surface that makes it easier to move an object between a lower level and a higher level; a type of simple machine (p. 8)

lever a rigid bar that pivots or turns around a fulcrum; a type of simple machine (p. 11)

load something that is lifted or carried (p. 5)

machine any device that uses energy to help a person do work (p. 4)

pulley a circular lever, usually a wheel with a rope around it; a type of simple machine (p. 17)

ramp a sloped path used to move things between a lower level and a higher level (p. 8)

screw an inclined plane wrapped around a rod, often used to hold things together; a type of simple machine (p. 10)

simple machines any basic devices that work with the use of a single force (p. 4)

wedge a simple machine with one narrow or pointed end and one wide end, used to separate two objects or parts (p. 9)

wheel a round object that turns around a central point (p. 14)

wheel and axle a round object that turns around a pin or pole; a type of simple machine (p. 14)

work the act of moving something (p. 4)

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