UNIT

D

Mechanical Systems

In this unit, you will cover the following sections:

1.0

Machines are tools that help humans do work.

1.1 Simple Machines—Meeting Human Needs

1.2 The Complex Machine—A Mechanical Team

2.0

An understanding of mechanical advantage and work helps in determining the efficiency of machines.

2.1 Machines Make Work Easier

2.2 The Science of Work

2.3 The Big Movers—Hydraulics

3.0

Science, society, and the environment are all important in the development of mechanical devices and other technology.

3.1 Evaluating Mechanical Devices

3.2 Technology Develops through Change

Exploring

The Da Vinci robotic arm allows surgeons to operate through small incisions. It also makes operating at a distance possible.

In July 2000, the first surgical robotic arm was approved for use in North America. Named "Da Vinci," this device helps surgeons perform operations inside people through very small incisions. This type of surgery is called "remote surgery" because the surgeon is not directly touching the patient. In fact, with this new system, the surgeon doesn't even have to be in the same room with the patient. The surgeon can do the operation from another location. The patient's local doctor needs only a connected computer, a video terminal, and the Da Vinci arm.

Mechanical Arm Provides More Control

The robotic arm is inserted through one small incision, and a tiny camera is inserted through a second incision. The surgeon then watches on a television screen to perform the operation. The Da Vinci robotic arm has a built-in "wrist" for flexibility. This feature and the size of the arm make it easier for surgeons to work on smaller tissues, such as nerves or blood vessels. With Da Vinci's help, surgeons can work in very small spaces and not worry about trembling from tired hands! The surgical robotic arm gives surgeons more control during surgery than ever before.

Benefits to patients include less recovery time for major operations. In the past, doctors had to make large incisions that would completely expose the organ they were operating on. The tiny incisions in a Da Vinci–assisted operation mean that the patient will heal more quickly.

The Da Vinci arm has a flexible mechanical "wrist" so that it can make the necessary movements for surgery.

A System of Components Working Together

Remotely controlled machines, such as the Da Vinci surgical system, rely on several smaller components and technologies in order to work. A computer controls the instruments as if the surgeon was controlling the very tip of the scalpel in person. The motions of the surgeon's hands are transferred to hydraulic pumps and electric motors that control the scalpel, drill, and scissors at the end of the robotic arm. The sensitivity of the tools is adjusted by combinations of miniature gears, levers, and pulleys.

The development of a complex machine such as a robotic arm is the result of teams of people working together. They use their knowledge of mechanical systems and apply the latest technology to solve problems.

Give it a TRY — **Activity**

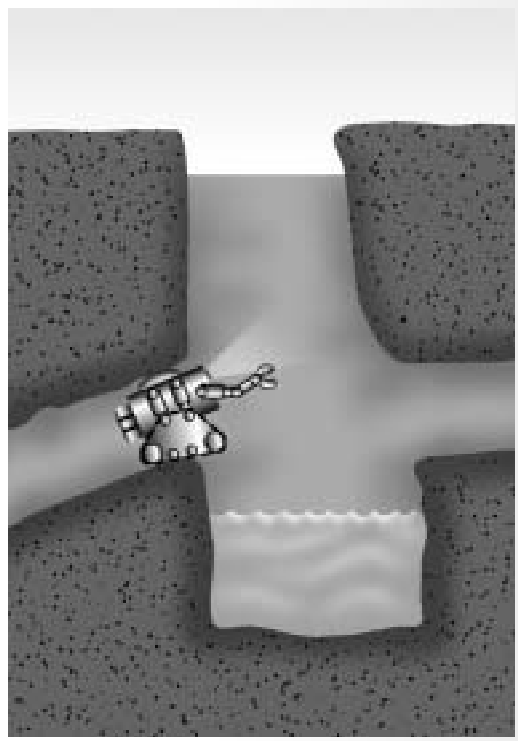
Emergency! (Toolbox)

Now you have an opportunity to work as part of a team in solving a problem. You and your group are part of the Emergency Robotic Environmental Response unit at RoboQuest Inc. An accident has just occurred. A robotic probe exploring a mining drainage pit has become wedged in a small passage. The probe is very heavy—about 100 kg. Your task is to retrieve the probe without damaging it. You can see from the diagram of the accident site that this will be a challenge.

Design a device that can help you extract the probe. Include the equipment listed below in your design:

- a mechanical arm
- steel beams about 2 m long
- an assortment of gears
- an assortment of pulleys with ropes

Before you start, read through Toolbox 3 to learn about problem-solving techniques.



The accident site

Focus On: Science and Technology

As you work through this unit, you will learn how machines help us do a variety of tasks. You will work with different mechanical systems to identify their components. You will also determine their impact on you and on the environment. Through this work, you will be able to understand better how science and technology are related. Scientific knowledge leads to the development of new technologies. In turn, new technologies lead to scientific discoveries.

The activities in this unit focus on your developing solutions to practical problems. Often these problems have more than one possible solution. You will learn to evaluate the options to find the best solution. You will also develop your problem-solving skills as you analyze working models of different types of machines to determine their strengths and weaknesses. At the end of the unit, you will use your understanding of mechanical systems and your skills in a final project. In this project, you will build a working prototype of a mechanical gripper device.

As you work through this unit, use the following four questions to guide your learning about mechanical systems:

1. **How is energy transferred in mechanical devices?**
2. **How do mechanical devices provide for the controlled application of force?**
3. **How do mechanical devices work efficiently and effectively to meet human needs?**
4. **What are the social and environmental impacts of mechanical devices?**

1.0 Machines are tools that help humans do work.

Key Concepts

In this section, you will learn about the following key concepts:

- systems and subsystems
- transmission of force and motion
- simple machines

Learning Outcomes

When you have completed this section, you will be able to:

- describe examples of mechanical devices used in the past to meet particular needs
- describe an example of how a common need has been met in different ways over time
- analyze a mechanical device by describing how different parts contribute to its overall function and identifying the parts that are simple machines
- identify the sources of energy for some familiar mechanical devices
- identify linkages and transmissions in a mechanical device and describe their general functions

Since farming began over 7000 years ago, humans have been creating ever more sophisticated tools and machines. Machines help people use energy more effectively. In other words, a **machine** is a device that helps us do work.

The combine harvester shown here was developed to make harvesting crops easier and quicker for farmers. Early combines were pulled by horses or tractors. Later they were motorized, and today they are computerized and air-conditioned as well. Developments in technology for control systems, motors, materials, and other areas have all contributed to the design of these new combines.

In this section, you will learn about simple machines and how they help people perform tasks. You will learn that simple machines can work together in a system to form a complex machine. You will also discover how linkages and transmissions transfer energy in machines.

1.1 Simple Machines—Meeting Human Needs

The earliest machines were very simple devices. For example, people used levers to pry rocks out of the ground. Then they used a ramp to help them raise the rocks as they built walls and other large structures. Each machine was designed to meet specific needs, such as lifting rocks or splitting wood. Although each machine was different, they all had one thing in common. These first machines depended on people or animals for their source of energy.

Working with a partner, try to determine what tasks the historic machines in Figure 1.1 were used for and how they worked. Look for clues in the pictures, or research the names of the machines to find out what needs these machines were designed to meet. Also, try to determine the approximate time periods when these machines were used.

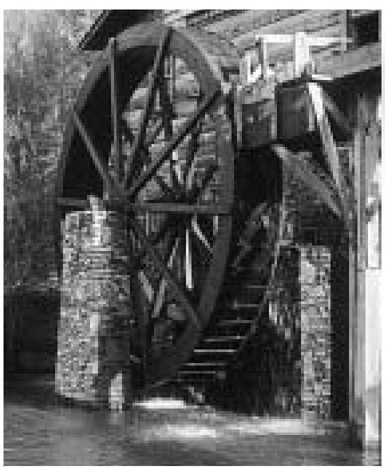


Figure 1.1a) Mill wheel

Figure 1.1b) Nutcracker

Figure 1.1c) Plow

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Roman Aqueducts

Thousands of years ago, Roman engineers developed a mechanical system for transporting water for many kilometres to supply major cities. These structures, known as aqueducts, were made up of three main parts:

1. pumps to raise the water into reservoirs and control the rate of water flow
2. sloped channels to carry the water to the cities
3. distribution systems in the cities to carry the water to central bathhouses and local reservoirs

The aqueducts were so well designed and constructed that many of them can still be seen today in Europe, more than 2000 years after they were built!

Meeting the Same Need in Different Ways

One of the most basic human needs is fresh water. You have running water in your home because of a combination of mechanical systems. These systems move water from its source, through a series of pipes, to your tap. Pumps powered by electricity keep the water moving.

Before pumps were available, people used gravity to move water. Water was stored in large, raised tanks. Gravity caused it to move down from the pipes through tanks to where it was needed in the community.

In the past, one of the most common ways of raising water into these tanks was a type of water wheel called a *sakia* (also called a Persian wheel). A sakia has a series of buckets attached to a long rope, which is draped over a large wheel. Animals such as donkeys, camels, or cows turned the wheel, which raised the buckets of water.

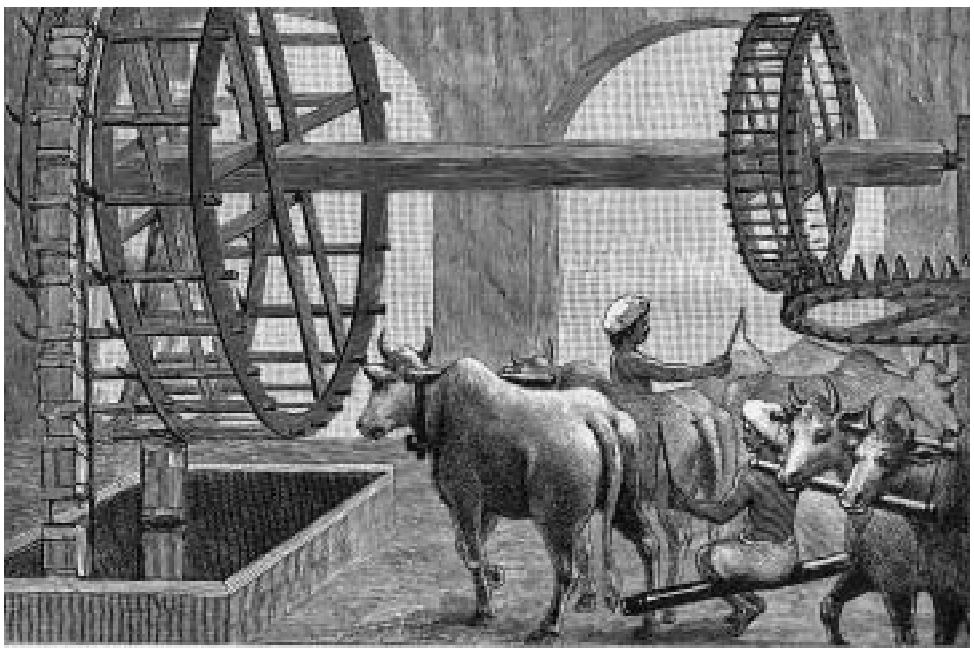


Figure 1.2 A sakia can be used to haul water out of a well for storage in large tanks or for irrigation.

Archimedes Invents a More Efficient Way

Although the sakia worked well in lifting water, people were always looking for more efficient ways to do this task. One of these methods was invented by the famous Greek scientist and mathematician Archimedes. His device used a large screw inside a tube. One end of the tube is placed in water. When the screw turns, it raises water up to the top of the tube. Called an Archimedes screw, this device can move large volumes of water or other substances. Originally it was powered by hand. Today it is powered by gasoline or electric motors.

Hundreds of years later, the famous Italian scientist Leonardo da Vinci designed a water lift using two Archimedes screws to raise water up to a storage tank in a water tower. His original plans are shown in Figure 1.3. The Archimedes screw is still in use today. Figure 1.4 shows a modern example of an Archimedes screw being used to move grain into a truck.

Figure 1.3 Leonardo da Vinci's design for using two Archimedes screws to raise water up into a water tower.

Figure 1.4 The spiral motion of the slowly turning screw moves the grain into the truck.

Simple Machines

The earliest machines, known as simple machines, are still used today. A **simple machine** is a tool or device made up of one basic machine. In their work, engineers must be aware of the strengths and limitations of each type of simple machine. This knowledge enables them to design combinations of these machines to do complicated tasks.

Before you read about the advantages and disadvantages of each simple machine, make a chart in your notebook similar to the one below. Fill in your chart as you read about the different machines.

Simple Machine	Advantages	Disadvantages
lever		

There are six simple machines that help us do work: the lever, inclined plane, wedge, screw, pulley, and wheel and axle. Each one is used for specific tasks. Each has its own advantages and disadvantages.

Lever

The **lever** is a rigid bar or plank that can rotate around a fixed point called a *pivot* or *fulcrum*. Levers are used to reduce the force needed to carry out a task such as pulling a nail, opening a bottle, hitting a baseball, and cutting paper. With a lever you can move a larger load than you could without using it. However, to do that, you must move a greater distance than the load does.

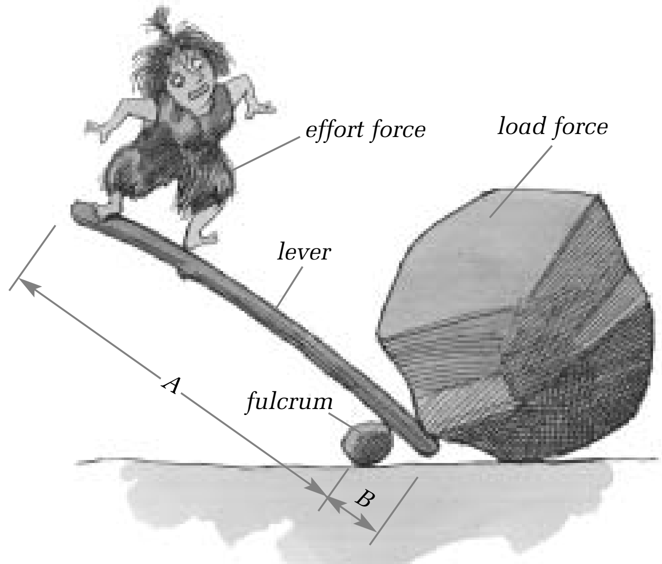


Figure 1.5 The lever is one of the simplest and oldest tools ever used by humans. This drawing shows one way that levers help to move objects. In this example, part A of the lever is seven times longer than part B. This means the force needed to move the object will be one-seventh of the force needed to move the object without using the lever. But look how much farther the person applying the force has to move compared with the distance the rock will move.

Levers can be labelled in three different ways, according to the location of the fulcrum and the load being moved. Figure 1.6 shows the three kinds or classes of levers. A *first class lever* has the fulcrum between the load and the point where the effort is exerted to move the load. A *second class lever* has the load between the effort and the fulcrum. A *third class lever* has the effort between the load and the fulcrum.

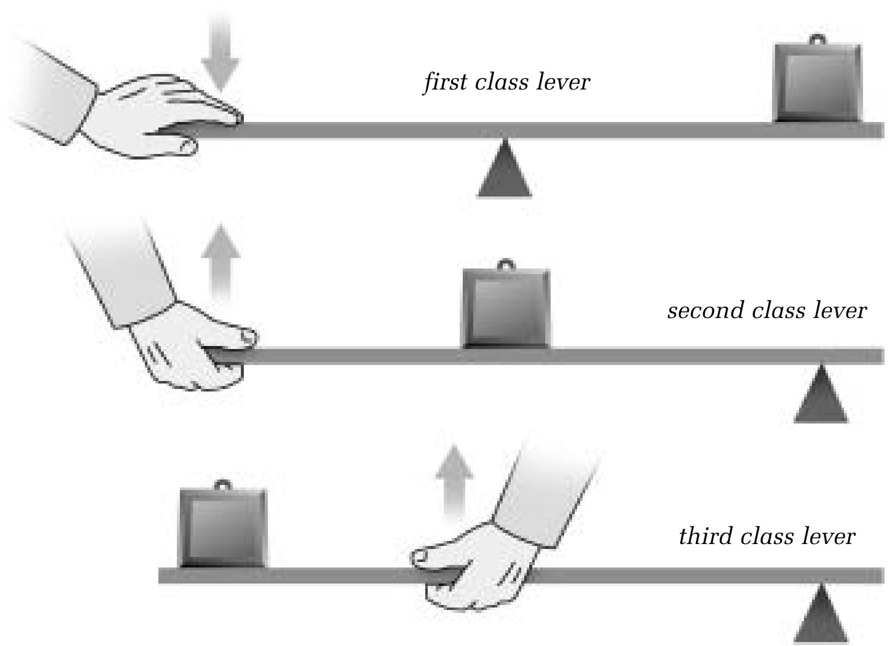


Figure 1.6 Different ways of using a lever

Inclined plane

Imagine that you had to lift a very heavy box from the floor onto a table. You would have to exert a large force to lift it straight up from the floor onto your desk. An **inclined plane** or ramp would make it easier for you to move the box up onto the desk. An inclined plane makes it possible to lift heavy objects using a smaller force. However, you have to exert the force over a larger distance, compared with lifting the object straight up. As well, a ramp is generally useful only for small inclines. The steeper the angle of a ramp, the harder it is to control the motion of an object as it moves up or down the ramp. Examples of inclined planes include loading ramps on buildings and wheelchair access ramps.

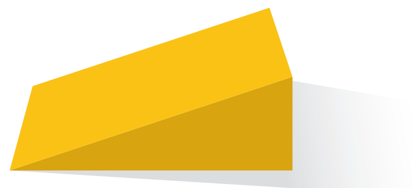
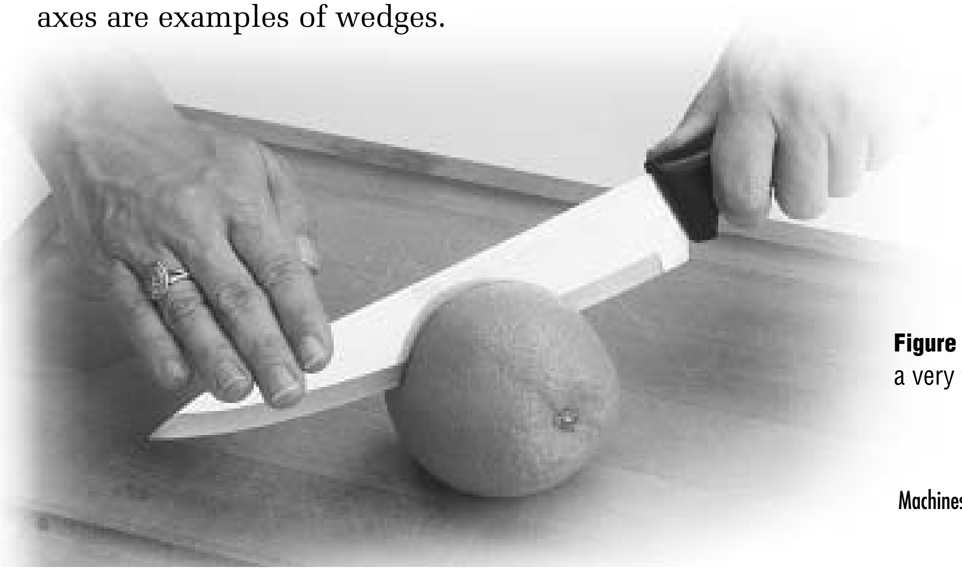


Figure 1.7 An inclined plane or ramp can help move large, heavy objects that are too heavy to lift straight up.

Wedge

A **wedge** is similar in shape to an inclined plane, but it is used in a different way. The wedge machine is forced into an object. By pressing on the wide end of the wedge, you can exert a force on the narrow end so it splits an object apart. The wedge increases the force that you apply on the object. But it moves a greater distance into the object than the split it causes. Unlike the ramp, a wedge can be used only in one direction: to push objects apart. Knives and axes are examples of wedges.



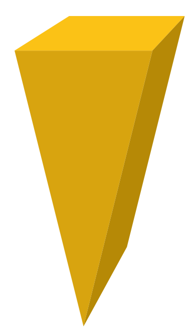


Figure 1.8 A knife blade is a very thin wedge.

Screw

A **screw** is a cylinder with a groove cut in a spiral on the outside. Using a screw helps you increase the force you use. It can penetrate materials using a relatively small force. A screw can also be used for converting rotational (turning) motion to linear motion (motion in a straight line). You saw an example of this earlier in the pictures of the Archimedes screw. Figure 1.9 shows how the screw moves in a spiralling motion. This is the rotational motion. However, the screw is also moving the water along a line from point A to point B. Most screws will move objects very slowly.

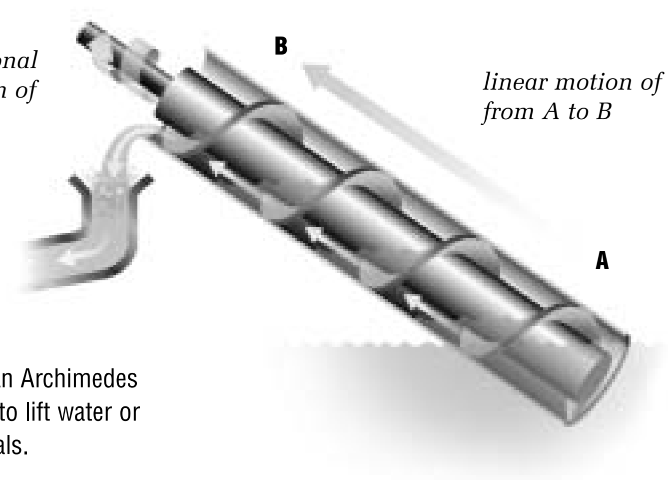


Figure 1.9 An Archimedes screw helps to lift water or other materials.

Pulley

A **pulley** consists of wire, rope, or cable moving on a grooved wheel. Pulleys may be made up of one or many wheels and can be fixed in place or movable. They can be linked together in systems for moving and lifting objects. Pulleys help you lift larger loads than you could lift on your own.

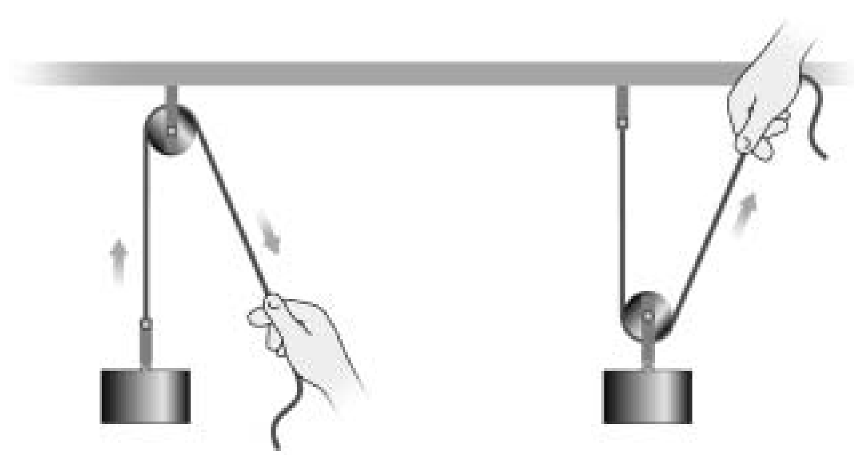


Figure 1.10 Two types of pulleys

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Early Tools

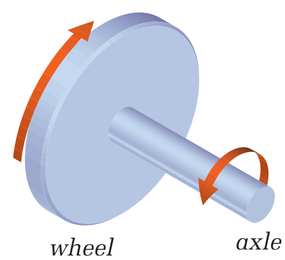
Many of the tools used by Canada's earliest inhabitants were simple machines. Using resources available in your library or on the Internet, identify a tool that was used by Aboriginal peoples in Canada before the year 1800. Once you have identified a tool, determine what needs the tool met, and the simple machine(s) it contained.

Figure 1.11 Pulleys make it possible to lift large, heavy loads.

Wheel and Axle

The **wheel and axle** is a combination of two wheels of different diameters that turn together. A longer motion on the wheel produces a shorter but more powerful motion at the axle. The steering wheel and steering column in a car together form a wheel and axle. That combination is one example of using a wheel and axle to increase the size of a force. The drawback is that you have to turn a greater distance (a larger wheel) to apply the force. A wheel and axle can also be used to increase speed. Wheels on bicycles are examples of using this simple machine to increase speed. The rider exerts a large force to turn the axle, which causes the bicycle's wheel to turn. The rider moves faster on the bicycle than without it.

Figure 1.12 A doorknob is a wheel-and-axle machine. Which part is the wheel and which part is the axle?



Inquiry
Activity

The Right Machine for the Job

Materials & Equipment
- 30-cm string
- 1-kg mass
- 20-N spring scale
- ramp
- 60-cm string
- pulley system
- metre-stick
- 10-cm string
- pivot or fulcrum

Before You Start ...

Have you ever tried to lift a very heavy object? Did you need to have another person help you, or maybe you used a lever or a ramp to help you? These devices are both simple machines. In this activity, you will investigate a variety of simple machines and determine which machine is best suited for lifting a mass.

The Question

Which simple machine requires the least amount of force to lift a 1-kg mass?

Procedure

Station 1. Lifting without a Machine

1. Tie a loop at one end of the 30-cm string, so the loop fits over the hook on the spring scale. Tie the other end of the string to the 1-kg mass.
2. Lift the spring scale just until the mass is hanging from the scale. Now slowly raise the load 10 cm. Measure and record the force needed to lift the mass.

Station 2. Lifting with a Ramp

3. Set up the ramp so that the highest point of the ramp is 10 cm above the top of the surface it's sitting on.
4. Place the mass on the bottom of a ramp and attach the loop of string to the spring scale again. With your hand at the top of the ramp, pull the mass steadily up the ramp. Measure and record the force needed to raise the mass.

Station 3. Lifting with a Pulley System

5. Tie one end of the 60-cm string to the mass. Place the mass on a table below the pulleys and thread the string between the pulleys.
6. Tie a loop at the loose end of the string and attach the string to the spring scale. Use the pulleys to raise the load 10 cm. Measure and record the force needed to lift the mass.

Figure 1.13 Step 4. Pull the mass steadily up the ramp.

Figure 1.14 Step 6. Use the pulleys to lift the mass up 10 cm.

Station 4. Lifting with a Lever

7. Place the metre-stick on the fulcrum so that the fulcrum is in the middle of the metre-stick. Hang the mass from one end of the lever. Use the 10-cm piece of string to make a loop and attach the spring scale to the opposite end of the lever. This end of the lever should be far enough above the table or the floor so you can use the spring scale to pull down on it.
8. Pull down the spring scale so the lever raises the mass at the other end. Record the force need to lift the mass.
9. Change the location of the fulcrum under the metre-stick and repeat step 8.

Figure 1.15 Step 7. The metre-stick is now acting as a lever.

Collecting Data

10 Record the force needed to lift the mass in each case.

11 Record your observations of the differences when you changed the position of the fulcrum under the metre-stick.

Analyzing and Interpreting

12 What was the most difficult method of raising the mass? What was the easiest method? Why do you think that is?

13 For the lever (the metre-stick):

a) What effect does the location of the fulcrum have on the force you must use to lift the mass?

b) What effect does the location of the fulcrum have on the distance that your hand moved and the mass moved?

14 What feature of the lever made it easier to lift the load?

15 What change would you make to the ramp to make it even easier to raise the mass to a 10-cm height?

Forming Conclusions TOOLBOX

16 Using sentences and diagrams, describe how a simple machine increases the force that you apply to an object. Include the features of the simple machines in this activity as examples.

The Effects of Simple Machines

Simple machines can be used to obtain one of the effects shown below. Remember that a simple machine can increase the force that you apply, or change the direction of the force, but there is a cost. The force that you apply has to move farther than the load does.

1 *Changing the direction of a force (for example, a pulley on a flagpole)*

Figure 1.16 To raise the flag, you pull down. The pulley changes your downward pull to an upward pull on the flag.

2 *Multiplying force (for example, a screwdriver)*

Figure 1.17 A small force on the handle of the screwdriver becomes a large force in the shaft. This large force can then be used to undo screws that would be impossible to remove with your fingers alone.

3 *Increasing or decreasing speed (for example, scissors)*

Figure 1.18 To cut, you move the scissors' handles together. The scissors' blades cut the paper more quickly than you move the handles together. And they cut farther than the distance the handles move. Try it and see!

4 *Transferring force (for example, a staple remover)*

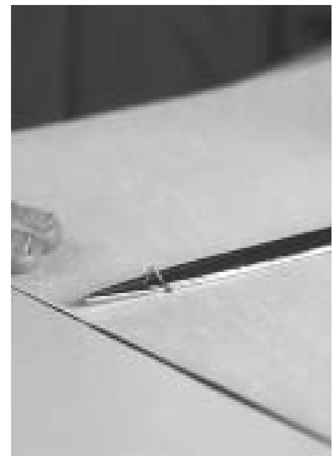


Figure 1.19 A lever like this staple remover transfers force to the object being moved. In this case, it is transferring the force from the student to the staple.

Check And Reflect

Figure 1.20 Question 4

1. Identify which simple machines you would use in each of the following situations:
   a) digging a deep hole
   b) moving a heavy rock from one side of your yard to the other
2. a) Give examples of energy sources used for modern machines, such as cars and sewing machines.
   b) Are the energy sources in question 2a) the same as those used in machines before the 1900s? Explain your answer.
3. When a simple machine increases the force you exert, what other factor changes?
4. One of the most important tools for pioneers in Canada was the axe. What two simple machines make up the axe?

1.2 The Complex Machine— A Mechanical Team

As time passed, people began living in larger communities. They needed to find ways to build larger buildings, provide running water, and develop transportation systems for moving people and goods. To do these and other tasks, they developed ever more complicated machines. They also found new ways to power these machines.

Within the last two centuries, scientists, engineers, and other inventors have developed machines that use sources of energy such as coal, oil, and electricity. These large supplies of energy, combined with new materials and new technologies, caused an industrial revolution. Large factories were now possible.

The first factories used powerful new machines to mass-produce goods. The newly invented steam engine transported these goods across countries in record time. People now had access to more food, clothing, tools, and raw materials than they ever had before, and their standard of living improved.

The development of new technologies has continued at a tremendous rate. Today we are almost completely dependent on machines. Think of the things that you enjoy doing that depend on a machine for delivering energy or for moving objects. Can you imagine how your life would change if you could *not* use machines?

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The Changing Bicycle

The bicycle is one of the most efficient machines ever invented to translate human energy into motion. The penny-farthing shown here was an early bicycle design. It had only levers for steering, and the wheel and axle for moving.

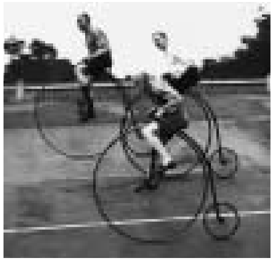


Figure 1.21 The invention of the steam engine led to the development of trains. Trains could travel faster than horses and haul much larger loads.

Complex Machines

Most of the devices that we use today are made up of several simple machines. These devices are called **complex machines**. A complex machine is a system in which simple machines all work together. A **system** is a group of parts that work together to perform a function. For example, the bicycle in Figure 1.22 is a system for moving a person.

Within the bicycle are groups of parts that perform specific functions, such as braking or steering. These groups of parts are called **subsystems**. The subsystems in a complex machine have just one function each. A subsystem usually contains a simple machine. All the subsystems work together to complete the task that the complex machine was designed to do.

The bicycle is a good example of a complex machine. Several subsystems work together to move you forward at different speeds, allow you to turn, and help you stop. Each subsystem uses a simple machine to help you do the task more easily. Figure 1.22 shows the major subsystems in a typical bicycle.

Figure 1.22 A bicycle is a complex machine made up of simple machines that work together. The whole bicycle is a system, made up of many subsystems.

Give it a **TRY** ACTIVITY

Analyzing a Mechanical Device

You are surrounded by a wide variety of machines, both big and small, in your daily life. Now you have an opportunity to look inside one of those machines and see how it works. You can use the one illustrated here or a device provided by your teacher.

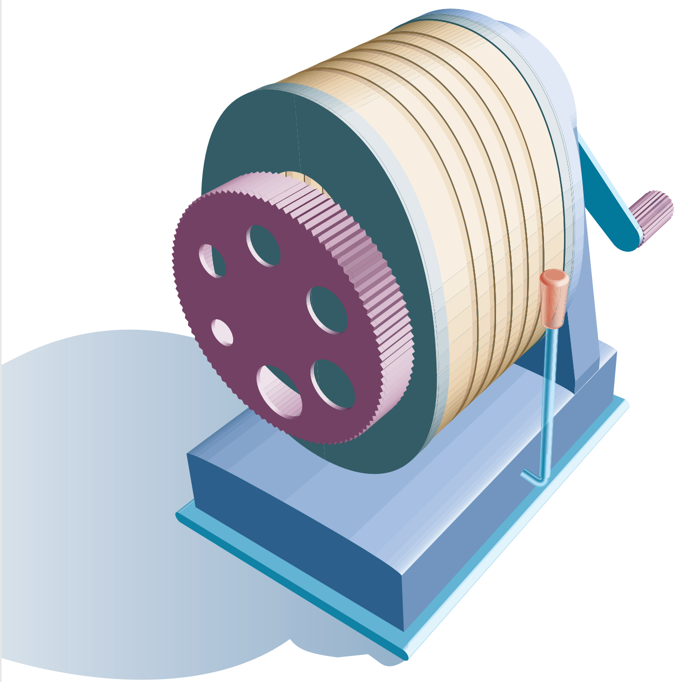


Figure 1.23 What is the function of this device?

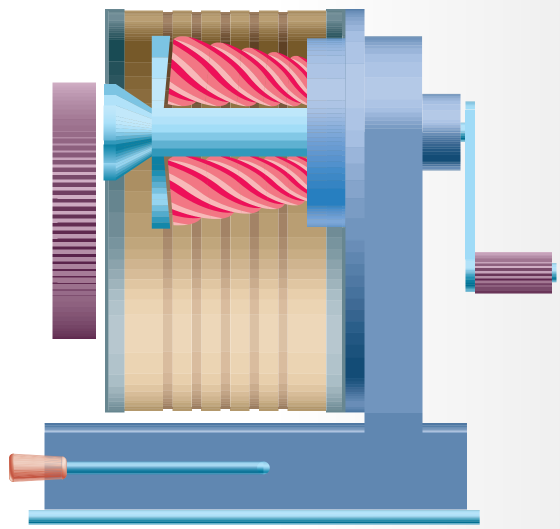
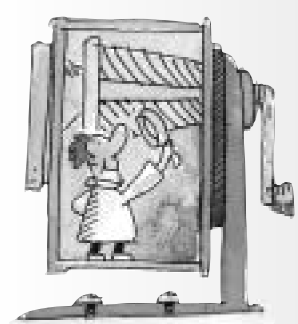


Figure 1.24 How does each subsystem contribute to the device's function?

Work with your partner to answer the following questions.

- What is the overall function of the device?
- How many individual subsystems can you identify in the device? Describe how each one contributes to the device's function.
- Do any of these subsystems contain a simple machine? If so, describe them.

Use a flowchart or diagrams to show how all the subsystems work together to make the device function.



Subsystems That Transfer Forces

Some of the subsystems in complex machines that produce motion play a role in the transfer of energy or force. In mechanical devices, these subsystems are called linkages and transmissions. Gears are often an important part of these subsystems.

Linkages

A complex machine moves an object by transferring energy from an energy source to the object. For a bicycle, you are the energy source. The bicycle's wheels are the objects that you must turn to make the bicycle move. The **linkage** is the part that transfers your energy from the pedals to the back wheel. In a bicycle, the chain is that linkage.

Many machines use high-tension belts instead of chains to rotate objects. You may have seen a belt used as a linkage in older car engines. This is the fan belt, which transfers energy from the engine to spin the cooling fan. The fan moves air through the radiator to keep the engine from overheating.

Chains or belts form a direct link between two separated wheels, so that when one turns, the other will turn in the same direction. If one wheel is larger, it will rotate more slowly, but with a larger force, than the smaller wheel. Chains have less chance of slipping than a belt, but belts are more flexible.

Figure 1.25 In a bicycle, the chain is the linkage that drives the gearwheels. When you shift gears, you move the chain from the larger gearwheel to the smaller ones or vice versa.

Transmissions

Most machines that move objects are more complex than a bicycle. They usually move much larger loads than just one person. These machines use a special type of linkage called a **transmission** to transfer the energy from the engine to the wheels. A transmission contains a number of different gears. This allows the operator to apply a large force to move objects slowly, or a smaller force to move objects quickly.

Transmissions are similar to the gears on a bicycle, except that they are designed to transfer much larger forces. In a car, for example, the driver can select a low gear to start the car moving, and then change to higher gears when driving on a highway.

In a low gear, the transmission connects a small wheel to a larger wheel, so the wheels rotate more slowly than the engine does. This increases the amount of power but reduces the car's speed. In a high gear, the transmission connects a large wheel to a smaller wheel, so the wheels rotate faster than the engine. This reduces the amount of power but increases the car's speed.

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Automatic and Manual Transmissions

What is the difference between an automatic transmission and a manual transmission in a car or truck? Which one is better? Which one costs more? Why?

GEARS

Gears are essential components of most mechanical systems. They consist of a pair of wheels that have teeth that interlink. When they rotate together, one gearwheel transfers turning motion and force to the other. The larger gearwheel rotates more slowly than the smaller gearwheel, but it rotates with a greater force. Gears can be used to increase or decrease speed in a machine. Both cars and bicycles use gears to change speed. Gears can also be used to change the direction of motion of a mechanical device like the eggbeater in Figure 1.26.

Figure 1.26 The gears on an eggbeater change the vertical motion of your cranking to the horizontal motion of the beaters.

Inquiry Activity

BICYCLE GEARS

The Question

What are the differences among three different gears on a bicycle?

Materials & Equipment

- multi-geared bicycle
- spring scale
- metre-stick or measuring tape

Caution!
Turn the pedal slowly and keep your fingers away from the wheel spokes and gears.

Procedure

1. With your group, observe the two sets of gears on the bicycle—front and rear. The rear set has more gears than the front one does. The gears are made up of flat, toothed disks called sprockets.
2. As a group, decide which three gears you will study. Count the number of teeth on the front and rear sprockets for each gear. Record this information in your table.
3. Measure the distance from the centre of the rear wheel to the edge of the tire. This is the radius of the rear wheel.
4. Measure the distance from the centre of the front sprocket to the outer-most point of the pedal. This is the radius of the circle that the pedal makes when it moves.
5. Attach a spring scale to the pedal. Apply just enough constant force to turn the pedal for one complete revolution. How much force is required to turn the pedal one turn? Record your result.
6. How many times did the back wheel turn for one turn of the pedal? Record your result.
7. Repeat steps 5 and 6 for the other two gears. Record your results.

Figure 1.27 The gears on a bicycle are divided between the front and the rear.

Collecting Data

8 Record your observations in your notebook in a table like the one below.

Gear	Front sprocket: No. of teeth	Rear sprocket: No. of teeth	Radius of rear wheel	Radius of pedal	Force needed for 1 pedal turn	No. of back wheel turns
Lowest gear						
Middle gear						
Highest gear						

Analyzing and Interpreting

9 For each gear, divide the number of teeth on the front sprocket by the number of teeth on the rear sprocket. Record your results in your notebook.

10 Find the circumference of the circle the pedal makes when it goes through one turn. To do this, multiply the radius of the pedal's circle by 2π or 6.28. This is the linear distance the pedal travels in one turn. Record your result in your notebook.

11 Find the circumference of the rear wheel by multiplying the wheel's radius by 2π or 6.28. This is the linear distance the wheel travels in one turn. Record your result in your notebook.

12 For each gear, determine how far the rear wheel travelled with one complete turn of the pedal. This can be calculated by multiplying the circumference of

How Gears Work

Almost any device that contains spinning parts uses gears. If you look inside a VCR, you'll see gears. You may have an electric meter with a clear plastic cover on the outside of your house. Take a look in it and you will see many different sizes of gears.

Gears are important in mechanical systems because they control the transfer of energy in the system. For example, in a bicycle, they control the transfer of energy from the rider to the wheels. They allow the rider to control and change the speed at which the wheels turn. In a car or other motorized vehicle, they control the transfer of energy from the engine to the wheels.

Gear wheels work together in gear trains of two or more wheels, like the one shown in Figure 1.28. The gear that has a force applied to it from outside the gear train is the driving gear. It then applies a force to the other gear, called the driven gear.

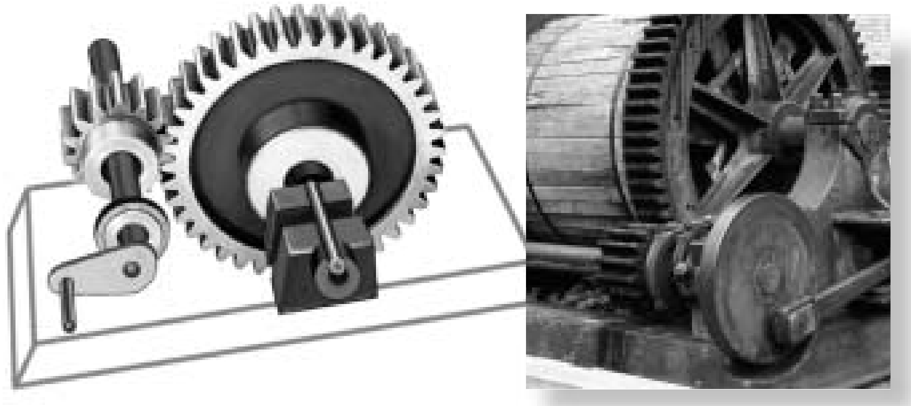

Figure 1.28 A gear train

How Gears Affect Speed

If the driving gear is larger than the driven gear, the turning speed in the system increases. When you rotate the large gear once, it rotates the smaller gear several times. Think about the gears in an eggbeater like the one shown in Figure 1.26. When you turn the crank, you rotate the large gear, which is the driving gear. It rotates the smaller gears attached to the beaters through four complete turns. This makes the beaters move much faster than the handle, so you can beat the eggs more quickly.

Gears like these that increase the speed of rotation in a device are called multiplying gears. Reducing gears decrease the turning speed in a device. In reducing gears, the driving gear is smaller and has fewer teeth than the driven gear, as shown in Figure 1.29.

In a bicycle, gear wheels do not mesh directly with each other. They are joined by the chain, which provides the linkage between the different sizes of gear wheels. When you shift gears, you move the chain from one gear wheel to another. In this way, you can change how fast you go when you pedal.

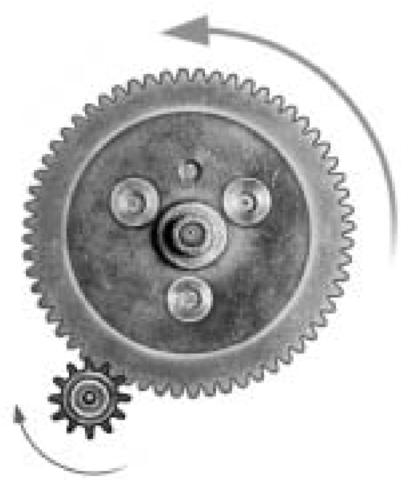

Figure 1.29 Reducing gears decrease turning speed in a device.