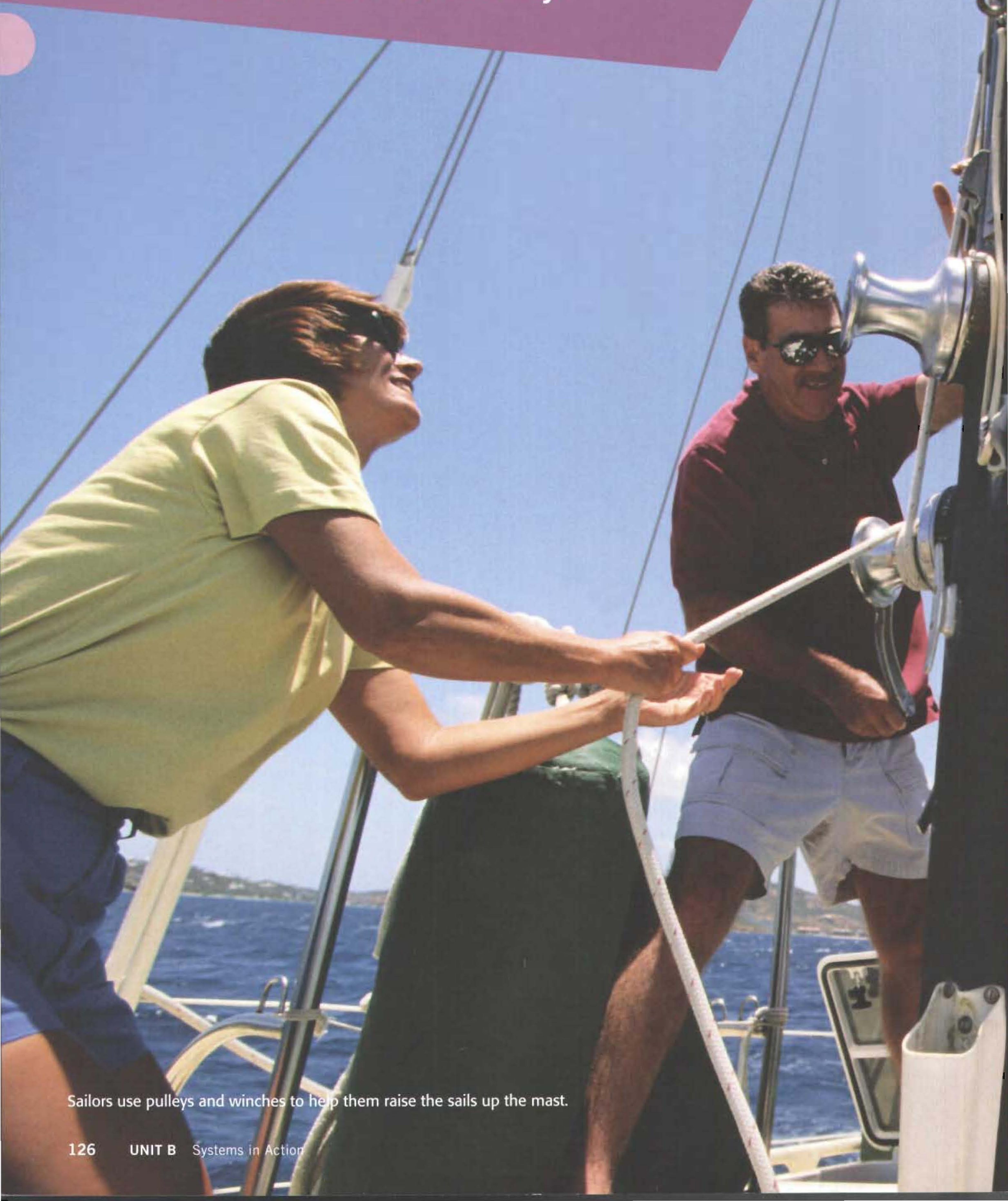
5.0 Mechanical systems involve machines that are designed to do work efficiently.



Sailors use pulleys and winches to help them raise the sails up the mast.

What You Will Learn

In this chapter, you will:

- analyze the uses of a variety of machines
- determine the mechanical advantage of a variety of machines
- determine the efficiency of a machine and suggest ways to increase its efficiency

Skills You Will Use

In this chapter, you will:

- manipulate simple machines in order to change their mechanical advantage
- design and construct a mechanism to perform a specified task

Why This Is Important

Every day you use a variety of mechanisms to perform tasks that require work to be done. Understanding the simple machines that make up these mechanisms allows you to complete the tasks efficiently.

Before Reading

Thinking Literacy

Predict-Read-Verify

Topics introduced in this chapter include:

- Simple Machines
- Ideal Mechanical Advantage
- Efficiency
- Increasing a Machine's Efficiency

Write down each of these topic titles and discuss what you think the topic means. Make a prediction about what you will learn.

Key Terms

- mechanism
- simple machine
- lever
- fulcrum
- pulley
- inclined plane
- screw
- wedge
- efficiency
- wheel and axle

5.0 Getting Started

Figure 5.1 A mountain bike has several different moving parts.

Figure 5.2 The gear-change lever on a mountain bike

Modern mountain bikes, like the one shown in Figure 5.1, allow the rider to climb steep hills and travel rough trails faster than by walking or running. But did you ever consider a mountain bike as a machine? A machine is any device that helps us do work.

A mountain bike is a mechanism. A **mechanism** is made up of several different types of machines that work together to perform a specific function. The bike is a complex mechanical system that is made up of many simple machines. A **simple machine** is a machine that requires the application of a single force to do work. You need only the pushing force when using an inclined plane (ramp) to move a cart into a delivery truck. Therefore, a ramp is a simple machine. Similarly, a lever uses only a single force to pry open a lid. Therefore, it is also a simple machine. Figure 5.2 shows the gear lever on a bicycle. Many different parts on the mountain bike move in different ways. Therefore, the bike consists of many simple machines.

A gear is a wheel with teeth around the edge that interacts with another toothed part of a device to change the speed, direction, or force of a transmitted motion. The sprocket or gear on the back wheel represents one of the bike's simple machines (Figure 5.3). At this location, the force and motion of the chain are transferred to the wheel. Mountain bikes allow the rider to change the distance between the chain and the axle. This is commonly called "switching gears." When the chain is mechanically moved from one sprocket to another, the mechanical advantage changes. When the rider needs to climb a steep hill, the chain is moved to a larger sprocket, increasing the mechanical advantage. When the rider needs less output force but wants to travel faster, the chain is moved to a smaller sprocket.

Figure 5.3 The mechanical advantage can be changed by moving the chain to different sprockets.

Simple machines (such as a ramp) and mechanisms (such as the mountain bike) both use forces to transfer energy. Machines are designed to transfer this energy as efficiently as possible. In this chapter, you will study several simple machines and their operation.

B23 *Quick Lab*

Locating Simple Machines on a Mountain Bike

A mountain bike is a mechanism that is made up of several simple machines. Different parts of the bike produce different kinds of motions. By analyzing where you find movement in the bike, you are identifying locations where a simple machine may exist.

Purpose

To find simple machines on a bicycle

Materials & Equipment

- bicycle
- pencil and paper

Procedure

1. As accurately as possible, make a sketch of a mountain bike.
2. On your sketch, draw circles around the locations on the bike where parts can move. These are the locations of simple machines.
3. Compare your diagram with a classmate's and discuss any differences. Using a different coloured pen or pencil, add any locations of simple machines that are different from those on your diagram.

Questions

4. How many locations of simple machines are on your diagram?
5. Were you surprised by the number of locations of simple machines on a bicycle?
6. Choose one of your simple machine locations. Describe the effect on the bike if that simple machine were not allowed to move.

5.1 Simple Machines and Mechanisms

Here is a summary of what you will learn in this section:

- Six types of simple machines are: lever, pulley, wheel and axle, inclined plane, screw, and wedge.
- Levers can be classified into three categories: first-class levers, second-class levers, and third-class levers.
- The ideal mechanical advantage of simple machines can be determined without measuring the input and output forces.
- Two or more simple machines that operate together form a mechanism.

Figure 5.4 Pyramids at Giza in Egypt. The Great Pyramid is the one in the middle. Notice how tiny the people are in the lower left!

The Great Pyramid of Giza, shown in Figure 5.4, was the tallest building on Earth until the 1300s. Built over 4500 years ago, the 150-m-high pyramid is still considered one of the Seven Wonders of the World. It took 20 years to assemble the 2.3 million blocks that were placed, one by one, to form this magnificent building. The granite and limestone blocks had masses between 1000 and 35 000 kilograms.

B24 *Starting Point*

Skills A C

Choose a Simple Machine

The following situations all require work to be done on an object. For each situation, suggest a tool, device, or machine that could be used to do the work.

- lifting a car to change a tire
- removing a lid from a can of paint
- undoing a tight bolt
- splitting a log for firewood
- moving a car from the lower level of a parking garage to a higher level
- raising a bucket of water in a well

Compare your list with another student's list. Did you both choose the same machine or device for each task?

The biggest question is, how did the Egyptians move these massive blocks of stone into place? Although there are no formal records, scientists believe that the early Egyptians used several simple machines. Long inclines (ramps) were built to raise the huge blocks. Some archeologists believe that the blocks were pulled up the ramps on skids (Figure 5.5). Others think that logs were placed under the blocks, like wheels under a cart, when they were pulled up the ramp. The workers set the blocks in place using long wooden and bronze levers.

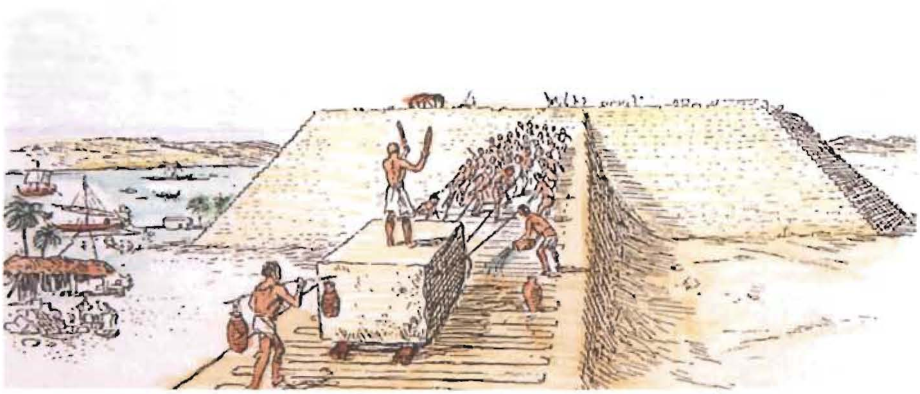


Figure 5.5 The massive blocks used to build this pyramid were positioned using simple machines.

Six Simple Machines

All machines, regardless of how complex, are made up of at least one of six simple machines, which are shown in Figure 5.6

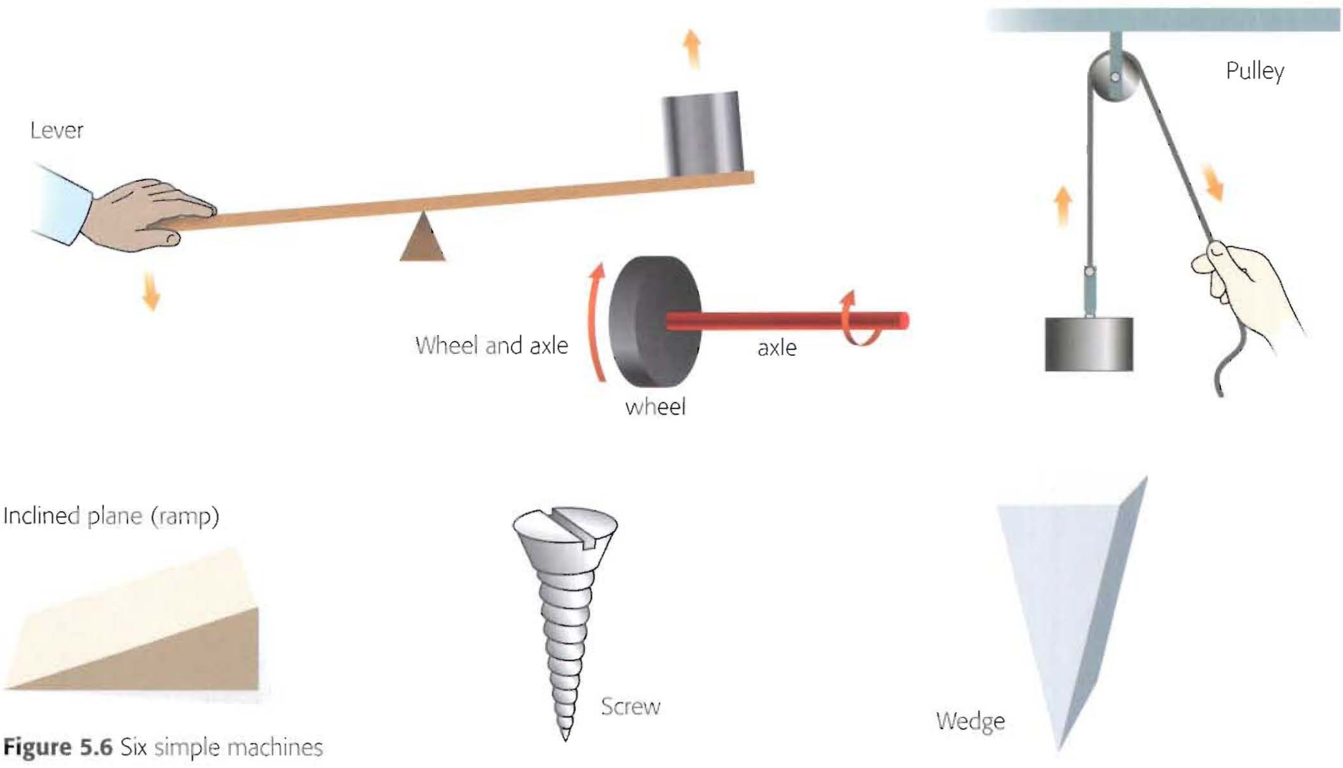


Figure 5.6 Six simple machines

B25 During Reading

Thinking Literacy

To Predict or to Infer?

At the start of this chapter, you made a prediction about what you think you will learn based on what you already know. As you read, you will be able to confirm whether or not your prediction was correct.

Making an inference is related to predicting. As you read, you add what you already know to clues in the text. Making an inference, however, involves the reader using these clues to form a logical conclusion. This conclusion may not be directly confirmed until the end of the text.

Draw a three-column chart labelled "It Says," "I Say," and "And So" to help you form inferences as you read Section 5.1. What inferences can you make based on the section title? What inferences can you make about the ancient Egyptians?

Levers

If you have ever used a rake, played on a teeter-totter, or swung a baseball bat, you have used a lever. A **lever** is a rigid bar that is supported at one point. This point on the lever is called the **fulcrum**. There are three classes of levers, classified by the locations of the fulcrum, the input force, and the output force.

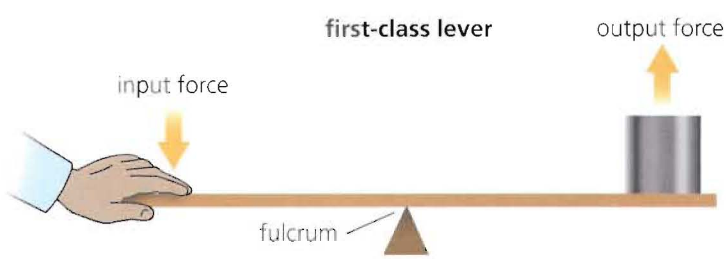
Three Classes of Levers

Using a pry bar to remove the lid of a paint can is an example of a first-class lever (Figure 5.7(a)). The fulcrum is the part of the pry bar that is touching the rim of the can. That part of the pry bar is stationary; it does not move. The input force is at your hand, pushing down on the pry bar handle. The output force is at the tip of the pry bar, pushing the lid of the paint can upward. A **first-class lever** always has the fulcrum between the input and output forces (Figure 5.7(b)). As well, the output force is always in the opposite direction to the input force.

Figure 5.7 When used to open a paint can, a pry bar (a) is an example of a first-class lever, which has the fulcrum between the input and output forces (b).

(a)

(b)



Removing the cap from a soft-drink bottle requires a different class of lever, called a **second-class lever** (Figure 5.8(a)). In this situation, the fulcrum is the very end of the opener that remains in contact with the bottle cap. The force used to open the cap, the output force, is between the fulcrum and the input force (Figure 5.8(b)). In a second-class lever, the input and output forces are in the same direction.

(a)

(b)

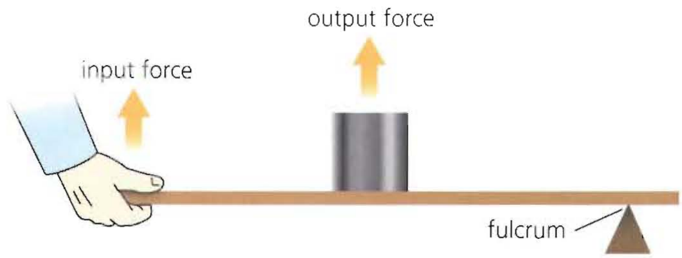


Figure 5.8 A bottle opener (a) is an example of a second-class lever, which has the output force between the fulcrum and the input force (b).

Using a garden rake or shooting a puck with a hockey stick are examples of the **third-class lever** (Figure 5.9(a)). If you hold the top of the rake stationary with your left hand (the fulcrum) and move the rake with the right, your right hand is the input force. The head of the rake applies an output force to the leaves. The third-class lever has the input force between the fulcrum and the output force, and the input and output force are in the same direction (Figure 5.9(b)).

A third-class lever always produces a mechanical advantage less than 1. That is, the output force is always less than the input force. Instead, a third-class lever is useful because the distance and speed of the output end of the lever are greater than at the input end. Swinging a baseball bat or hockey stick are all examples of creating speed with a third-class lever.

(a)

(b)

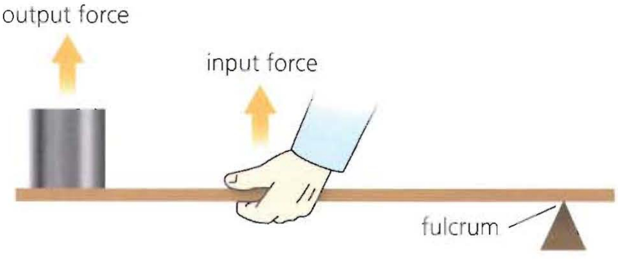


Figure 5.9 A garden rake is an example of a third-class lever, which has the input force between the fulcrum and the output force.

Ideal Mechanical Advantage of a Lever

As with all machines, the mechanical advantage can be calculated by dividing the output force by the input force. But you would have to measure these forces by conducting an experiment. Sometimes it is enough to find the ideal mechanical advantage. When the amount of friction is relatively small, calculating the ideal mechanical advantage can provide a good approximation of the machine's actual mechanical advantage. You do not have to conduct an experiment to measure the forces. Remember from Chapter 4 that the ideal mechanical advantage assumes that no friction is involved in the transfer of energy using forces.

The ideal mechanical advantage (IMA) of a lever can be calculated by dividing the length of the input arm (L_{in}) by the length of the output arm (L_{out}).

$$\text{Ideal Mechanical Advantage} = \frac{\text{length of input arm}}{\text{length of output arm}}$$

$$\text{IMA} = \frac{L_{in}}{L_{out}}$$

Suggested Activity
B27 Inquiry Activity on page 141

The length of the input arm is the distance between the location of the input force and the fulcrum. The output arm length is the distance between the fulcrum and the output force (Figure 5.10).

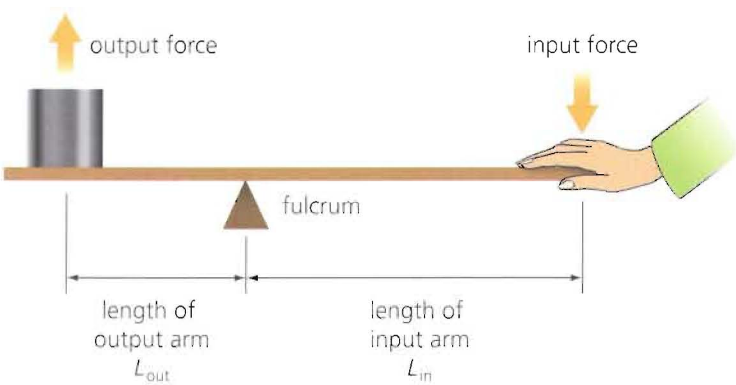


Figure 5.10 The ratio of the length of the input arm (L_{in}) to the length of the output arm (L_{out}) is the ideal mechanical advantage of a lever.

For example, Jasmine tries to lift a rock using the lever shown in Figure 5.11. What is the ideal mechanical advantage of this lever?

$$\text{IMA} = \frac{L_{\text{in}}}{L_{\text{out}}}$$

$$= \frac{1.5\ \text{m}}{0.5\ \text{m}}$$

$$= 3.0$$

This lever has an ideal mechanical advantage of 3.0.

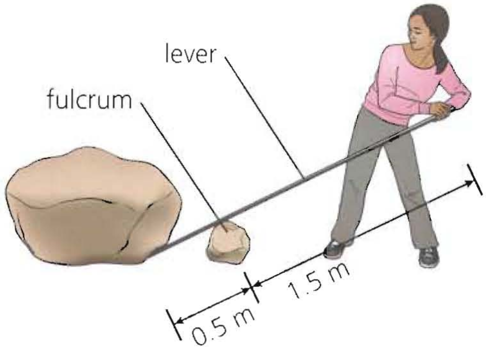


Figure 5.11 When the length of the input arm is greater than the length of the output arm, that lever has an ideal mechanical advantage greater than 1.

Take It **Further**

Levers come in three types: first-class, second-class, and third-class. The human body contains each of these three types of lever. Give an example of a location in the human body for each of these three types of lever. Make a sketch of the fulcrum and forces for each example. Begin your search at ScienceSource.

B26 Learning Checkpoint

Three Classes of Levers

Figures 5.12, 5.13, and 5.14 each display a common lever. Do the following for each figure:

1. Sketch the lever involved.
2. Label the fulcrum, input force, and output force.
3. Identify the lever as a first-class, second-class, or third-class lever.

Figure 5.12

Figure 5.13

Figure 5.14

Human Levers

Many movements of the human body can be explained by comparing them with levers. For example, levers give us the ability to throw a ball (Figure 5.15). The solid rod of a lever can be compared to the bones in your forearm. When a person throws a ball overhand, the elbow acts as the fulcrum of a first-class lever and the triceps muscle applies the input force. The output force is the force that the hand applies to the ball. Since the length of the input arm (the distance between the elbow and the triceps muscle) is less than the length of the output arm (the distance from the elbow to the ball), the mechanical advantage when throwing a ball is less than 1.

The process of throwing a ball also involves other levers in the human body, such as at the shoulder and wrist.

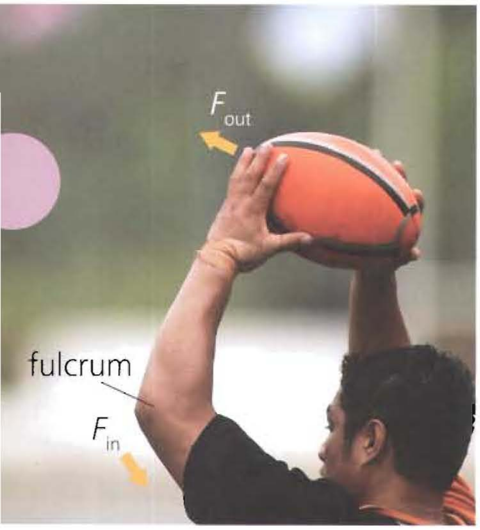


Figure 5.15 Bones and joints act as levers.

Pulleys

If you have ever raised a flag on a flagpole or hung clothes on a clothesline, you have used a pulley. A **pulley** consists of a grooved wheel with a rope or cable looped around it (Figure 5.16). The pulley is free to spin. A pulley can change the direction of the force or increase the output force, depending on whether the pulley is fixed or movable.

Fixed pulleys change only the direction of the force. When the input force is applied downward on the rope, the output force is in the upward direction (Figure 5.17). Since the output force is the same size as the input force, a fixed pulley has an ideal mechanical advantage of 1.

If one end of the rope is fixed and the pulley is allowed to move, you have a movable pulley. The movable pulley in Figure 5.18 is supported by the rope at two locations. At each of these locations, the tension in the rope applies an upward force on the pulley. Each segment of rope that applies a force on the pulley is considered a support rope. If you pull the rope with an input force of 5 N, the rope applies this force to the movable pulley in two locations. Therefore, the output force is 10 N. This gives an ideal mechanical advantage of 2.

Figure 5.16 A fixed pulley

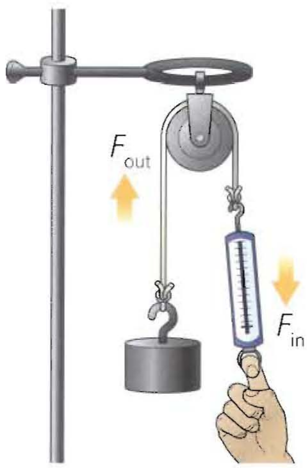


Figure 5.17 A fixed pulley showing the input and output forces

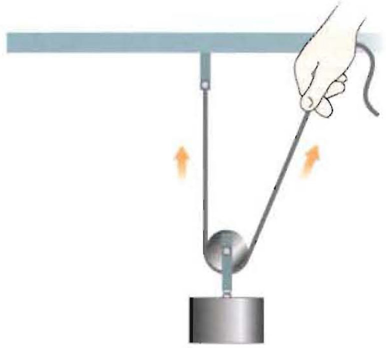


Figure 5.18 This movable pulley has two support ropes and therefore an ideal mechanical advantage of 2.

Ideal Mechanical Advantage of a Pulley System

The ideal mechanical advantage of a pulley system is equal to the number of support ropes. A combination of fixed and movable pulleys can produce various mechanical advantages. Figure 5.19 shows a pulley system with one fixed and one movable pulley. By counting the number of support ropes, you find that the ideal mechanical advantage for this pulley system is 3.

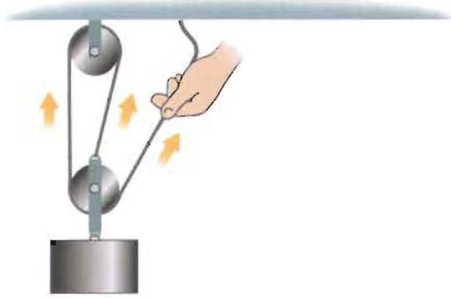
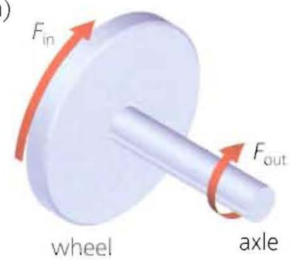


Figure 5.19 This pulley system has an ideal mechanical advantage of 3, since it has three support ropes.

Wheel and Axle

Could you tighten a screw with a screwdriver that had no handle? The screwdriver handle is part of a simple machine called a wheel and axle. The **wheel and axle** consists of a shaft or axle that is attached to a larger disk, called the wheel (Figure 5.20(a)). When you use a screwdriver to tighten a screw, the handle is the wheel and the shaft is the axle (Figure 5.20(b)). Doorknobs and the pedals on your bicycle are also examples of wheels and axles.

(a)



(b)

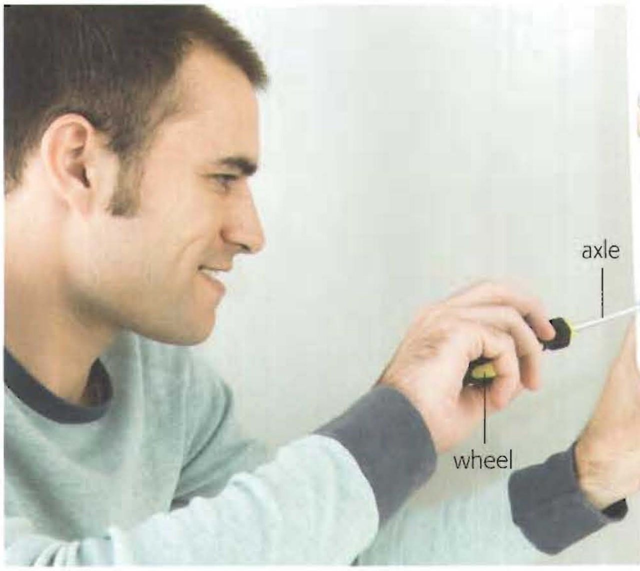


Figure 5.20 (a) A wheel and axle.
(b) A screwdriver is an example of a wheel and axle.

Ideal Mechanical Advantage of a Wheel and Axle

Both the wheel and the axle rotate around the centre of the axle. If an input force acts on the wheel, then the output force provided by the axle produces an ideal mechanical advantage greater than 1. This is because the input force is farther from the centre of the axle than the output force is. Using a screwdriver to turn a screw is an example of using a wheel and axle to increase output force. The input force acts on the handle, and the output force is at the head of the screwdriver.

Figure 5.21 Since the input force is applied closer to the axle than the output force on the rim, this bike wheel has an IMA less than 1.

Sometimes the input force is applied to the axle. The wheels on a car or bicycle turn because of the input force applied to the axle (Figure 5.21). In this case, the mechanical advantage is less than 1 since the input force is closer to the centre of the axle than the output force is.

If the input force is applied to the axle, the ideal mechanical advantage can be calculated by dividing the radius of the axle (r_a) by the radius of the wheel (r_w).

$$\text{Ideal Mechanical Advantage} = \frac{\text{radius of the axle}}{\text{radius of the wheel}}$$

$$\text{IMA} = \frac{r_a}{r_w}$$

If the input force is applied to the wheel, the ideal mechanical advantage can be calculated by dividing the radius of the wheel (r_w) by the radius of the axle (r_a).

$$\text{Ideal Mechanical Advantage} = \frac{\text{radius of the wheel}}{\text{radius of the axle}}$$

$$\text{IMA} = \frac{r_w}{r_a}$$

Figure 5.22 When you turn on the tap, you put force on the handle, which is a wheel. This turns the axle, which opens the tap.

For example, the handle of a garden tap of radius 3.0 cm is connected to a shaft of radius 0.50 cm (Figure 5.22). What is the ideal mechanical advantage of this wheel and axle?

$$\text{IMA} = \frac{r_w}{r_a}$$

$$= \frac{3.0\text{ cm}}{0.50\text{ cm}}$$

$$= 6.0$$

Inclined Planes

Sometimes the force needed to lift an object up a height is greater than we can safely apply. For example, when a hill is too steep for a car to travel in a straight line, a zigzag road is built with a gentler slope (Figure 5.23). A sloping surface on which an object can move is called an **inclined plane**. A ramp (for example, a wheelchair ramp) is another name for an inclined plane. The ramp reduces the force needed to move the wheelchair, but the distance the wheelchair must travel to get to the top of the ramp has increased.

Figure 5.23 By decreasing the slope of the road, the car travels a greater distance but with less required force.

Ideal Mechanical Advantage of an Inclined Plane

If you have to lift an object a vertical height, you can use an inclined plane or ramp. While the ramp increases the distance the object must travel, as shown in Figure 5.24, the amount of force you need is less than if you lifted the object straight up. The ideal mechanical advantage of an inclined plane is the ratio of the length of the slope (l) to the height of the ramp (h).

Suggested Activity
B28 Problem-Solving Activity on page 142

$$\text{Ideal Mechanical Advantage} = \frac{\text{length of ramp}}{\text{height of ramp}}$$

$$\text{IMA} = \frac{l}{h}$$

For example, an object is raised 1.0 m (vertical distance) by pushing it along a loading ramp 6.0 m long. What is the ideal mechanical advantage of this ramp?

$$\text{IMA} = \frac{l}{h}$$

$$= \frac{6.0\text{ m}}{1.0\text{ m}}$$

$$= 6.0$$

Figure 5.24 An inclined plane allows you to use less force over a greater distance.

The Screw

Figure 5.25 A screw is an inclined plane wrapped around a rod.

A **screw** is simply an inclined plane wrapped around a rod (Figure 5.25). This continuous inclined plane, starting at the tip, is called the "thread." The length of the thread is much greater than the length of the screw. As with the inclined plane, this difference in length gives the screw mechanical advantage. The screw's thread allows it to penetrate into hard wood with minimal force. Many food jars have threads similar to the screw. The threads on the lid and the top part of a jar hold the lid firmly in place.

The Wedge

When we use an inclined plane, the object is pushed or pulled along the inclined plane. A **wedge** is an inclined plane that travels through the object or material. For example, a wedge can be used to split firewood (Figure 5.26). The longer and narrower the wedge, the greater its mechanical advantage. Needles, knives, and your front teeth are all examples of wedges.

Figure 5.26 A wedge is an inclined plane that moves through the object.

Mechanisms

Many of the machines that you use every day consist of several simple machines working together to perform a task. A mechanism is two or more simple machines working together. At the beginning of this unit you learned that a **mechanical system** is a group of physical parts that interact with each other and function as a whole in order to complete a task. Therefore, mechanisms are mechanical systems. Bicycles and cars are obvious mechanisms. Even simple scissors can be considered a mechanism since they consist of a lever and a wedge (Figure 5.27).

Figure 5.27 Scissors are a mechanism.

B27 *Inquiry Activity* Toolkit 2

SKILLS YOU WILL USE
- Measuring
- Controlling variables

Measuring the Mechanical Advantage of Simple Machines

Question

What factors affect the mechanical advantage of a lever and an inclined plane?

Materials and Equipment

- spring scale
- 1.0-kg mass
- wooden board
- metre stick
- support stand
- string

Procedure

Part 1 – The Lever

1. Copy Table 5.1 into your notebook.

Table 5.1 The Lever

Trial	Length of Input Arm (cm)	Length of Output Arm (cm)	Input Force (N)	Output Force (N)	MA	IMA
1	45	25		9.8		
2	35	25		9.8		
3	25	25		9.8		
4	15	25		9.8		

2. Support a metre stick from a support stand using a string attached to the 50-cm location on the metre stick.
3. Attach a 1.0-kg mass to the 25-cm location (25 cm from fulcrum) and a spring scale to the 95-cm location (45 cm from fulcrum).
4. Measure the force required to slowly lift the mass. Record this input force in Trial 1.
5. By moving the location of the spring scale, repeat steps 3 and 4 for the remaining trials shown in the table.
6. Calculate the mechanical advantage (MA) and ideal mechanical advantage (IMA) for each trial.

Part 2 – The Inclined Plane

7. Copy Table 5.2 into your notebook, with space for four trials.

Table 5.2 The Inclined Plane

Trial	Length of Ramp	Height of Ramp	Input Force (N)	Output Force (N)	MA	IMA
1				9.8		
2				9.8		

8. Stack some books on your table. Using the wooden board, set up a ramp from your desk to the top of the stack of books. Measure the length and the vertical height of the ramp. Record these measurements in Trial 1.
9. Attach your spring scale to the mass at the base of your ramp and slowly pull the mass up the ramp. Record this input force in Trial 1.
10. Lower the height of the ramp and repeat steps 8 and 9. Repeat for a total of four trials.
11. Calculate the mechanical advantage and ideal mechanical advantage for each trial.

Analyzing and Interpreting

12. Which simple machine produced the largest mechanical advantage?
13. In general, how does the size of the ideal mechanical advantage compare to the mechanical advantage?

Skill Builder

14. For the inclined plane, which variables in the experiment did you control to ensure that this was a "fair" experiment?

Forming Conclusions

15. For each of the simple machines, explain what variables can be manipulated to change the mechanical advantage.

B28 Problem-Solving Activity

Toolkit 3

SKILLS YOU WILL USE
- Modelling
- Explaining systems

Best Machine for the Job

Recognize a Need

Have you ever thought of becoming an engineer? Engineering is the application of science to develop solutions and design structures that are useful to people. For example, you might need to lift a large mass to the top of a skyscraper.

Problem

Design and construct a mechanism made from simple machines that will move a 1.0-kg mass from the floor to the top of your desk using the smallest input force.

Materials & Equipment

- spring scale
- various simple machines
- string
- 1.0-kg mass

Criteria for Success

- The final design must include at least one simple machine.
- The input force must be applied by your hand.
- Your design must allow for continual measurement of the force applied by your hand.
- The mechanism must be able to move the mass from the floor to the surface of the desk in a safe manner.

Brainstorm Ideas

1. Which simple machines would be best suited for this task?
2. What variables in each machine can you control to maximize the mechanical advantage?
3. What materials will you use?

Make a Drawing

4. On a single piece of paper, start your sketch by first drawing the floor and the table. Add the starting location of the 1.0-kg mass.
5. Sketch your design for your mechanism. Label the simple machine(s) involved in your design. Your design must show the location of the spring scale used to measure your input force.
6. Be sure to show your drawing to your teacher before going any further.

Test and Evaluate

7. Construct your mechanism.
8. As you operate your mechanism to move the mass, note the maximum force measured by the spring scale. Record this value.
9. The output force required to lift a 1.0-kg mass is 9.8 N. Calculate and record your mechanism's mechanical advantage.
10. Suggest ways of improving your mechanism's mechanical advantage.

Communicate

11. Share and compare your design and mechanical advantage with your classmates' results. Did anyone have a similar design? How did their results compare with yours? What do you think is the best design for this problem?
12. Present your findings to the class or in a form suggested by your teacher.

5.1 CHECK and REFLECT

Key Concept Review

1. Match each photograph below to one of the six simple machines.

(a)

(b)

(c)

2. State the class of lever for each of the levers in the chart. The locations are shown below the chart.

	Location 1	Location 2	Location 3
Lever A	fulcrum	input force	output force
Lever B	output force	fulcrum	input force
Lever C	fulcrum	output force	input force

3. Two ramps of different lengths are used to lift furniture into the same truck. Which ramp requires less force?

4. Explain the difference between a mechanism and a simple machine.

Connect Your Understanding

5. A metre stick is used as a lever. If the input force is applied at 0 cm and the output force is exerted at 100 cm, what is the ideal mechanical advantage if the fulcrum is at 75 cm?

6. As the mechanical advantage of a simple machine is increased, how does the distance of the input force compare to the distance of the output force?

Practise Your Skills

7. Draw a simple diagram for the lever involved in the photograph below. On the diagram, label the input force, output force, and fulcrum.
   (a) State the class of lever involved.
   (b) Is the mechanical advantage of this lever greater than 1 or less than 1?

For more questions, go to ScienceSource.

B29 *Thinking about Science, Technology, and Society*

Think Before You Buy

When shopping for a mechanism, how do you decide which one to buy? How do manufacturers try to get you to buy their product?

Consider This

Choose a mechanism that you have recently purchased.

1. What did the advertisements say and what images did they use to convince you to buy this product? How do these images attract you (or not) to buy their product?
2. List the criteria you used when deciding which mechanism to purchase.

5.2 Efficiency

Here is a summary of what you will learn in this section:

- The work done by a machine is less than the work put into the machine.
- The efficiency of a machine can be calculated by dividing the output work by the input work.
- A machine's efficiency can be increased by reducing the friction that produces heat.

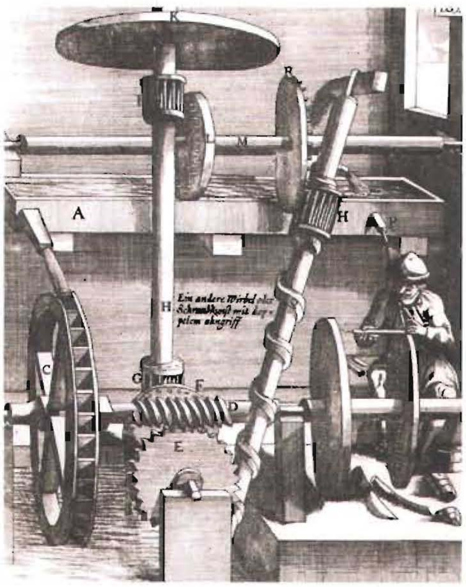


Figure 5.28 An attempt at a perpetual-motion machine

Can you imagine a machine that runs forever without using any energy? A perpetual-motion car would run without having to be refilled with gas. Over the years, inventors have tried to invent perpetual-motion machines with no success. Such a machine would break the laws of physics.

Figure 5.28 shows a water-screw perpetual-motion machine from the 1600s. Water in the trough falls and turns the water wheel, which is connected to gears that turn a screw. The turning screw carries the water back up to the trough, and the whole process, in theory, should repeat itself. However, this machine soon comes to a grinding halt.

The gravitational potential energy of the water in the trough cannot provide enough energy to turn the screw to return the same amount of water back to the trough. Some of the water's original stored energy is transformed into other forms of energy, such as heat, that this machine cannot use to lift water.

B30 *Starting Point*

Skills A C

Work Can Be a Drag

When you lift an object, it gains gravitational potential energy. Regardless of what machine you use to lift the object, the output work (W_{out}) is the same.

What to Do

1. Pull a cart slowly up a ramp using a spring scale. Record the amount of force required.
2. Turn the cart over so that the wheels are not touching the incline. Repeat step 1.

Consider This

3. Which situation required a larger force? Since the length of the ramp was the same in both situations, which situation required more input work (W_{in})?
4. Both situations provided the same output work (W_{out}). Explain what happened to the extra energy needed with the larger input work (W_{in}).

Efficiency of Machines

Fuel-efficient cars and energy-efficient light bulbs are common topics in today's society. But what does it mean to be efficient? Perhaps you have been called an efficient worker. This generally means that you get jobs done without wasting time and energy. In science, the efficiency of a machine is determined by analyzing the energies involved.

The **efficiency** of a machine measures the useful work done by the machine compared to the work needed to operate it. **Useful output work** is the work that the machine is designed to perform. For example, a bicycle is designed to move forward. The bicycle's useful output work is determined by measuring the bicycle's forward motion (Figure 5.29). The input work is the work done by the person moving the pedals. For mechanisms such as the bicycle, the useful output work is always less than the input work. But where does the extra energy go?

Figure 5.29 The useful output work of the bicycle is determined by examining the forward motion.

Work Done by Friction

Whenever a machine is used to do work, parts of the machine are moving. For example, if a pulley is used to lift an object, not only does the object move, but parts of the pulley also move. A force of friction occurs where the pulley wheel rotates on its shaft. Since the force of friction is applied to a distance of motion, work is done by the friction force. Work done by the force of friction transforms input energy into heat when the pulley wheel turns (Figure 5.30). Therefore, extra work must be input into the machine to compensate for the work done by friction. For this reason, the useful output work of a machine is always less than the input work.

Highly efficient machines have less friction and therefore produce less heat from friction. More of the input work is changed into useful output work. An ideal machine would have no friction, and therefore all the input work would be converted to output work. Like the perpetual-motion machine, an ideal machine does not exist. Our current goal is to produce machines and mechanisms that are as efficient as possible, such as the solar-powered car in Figure 5.31 on the next page.

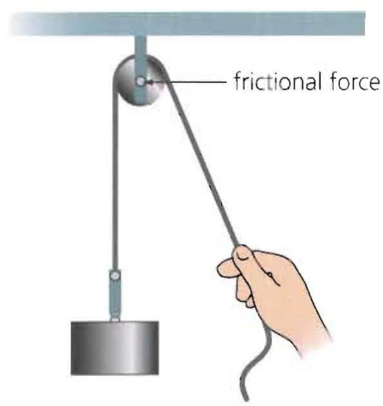


Figure 5.30 Friction between the wheel and its shaft produces heat when the pulley is used to lift the object.

Figure 5.31 The University of Waterloo team came fourth in the North American Solar Car Challenge in 2005. The 4000-km race lasted 10 days.

Calculating Efficiency

To calculate the efficiency of a machine, the useful output work (W_{out}) is divided by the input work (W_{in}). Efficiency is usually expressed as a percentage.

$$\text{Efficiency} = \frac{\text{useful output work (joules)} \times 100\%}{\text{input work (joules)}}$$

$$\text{Efficiency} = \frac{W_{out} \times 100\%}{W_{in}}$$

For example, a machine is capable of doing 35 J of work when 50 J of work is put into the machine. What is the efficiency of this machine?

$$\text{Efficiency} = \frac{W_{out} \times 100\%}{W_{in}}$$

$$= \frac{(35\text{ J}) \times 100\%}{(50\text{ J})}$$

$$= 70\%$$

This means that 70% of the work put into the machine goes into doing work that the machine was designed for. The other 30% of the input work goes into other forms of energy.

The efficiency of a machine can also be calculated by measuring the forces and distances. For example, a 500-N crate is moved up a 5.0-m-long ramp (Figure 5.32). What is the efficiency of this ramp if the person pushes with a force of 400 N in order to raise the crate a vertical distance of 2.0 m?

To calculate the efficiency, we must first calculate the useful output work and the input work. Remember from Chapter 4 that $W = Fd$.

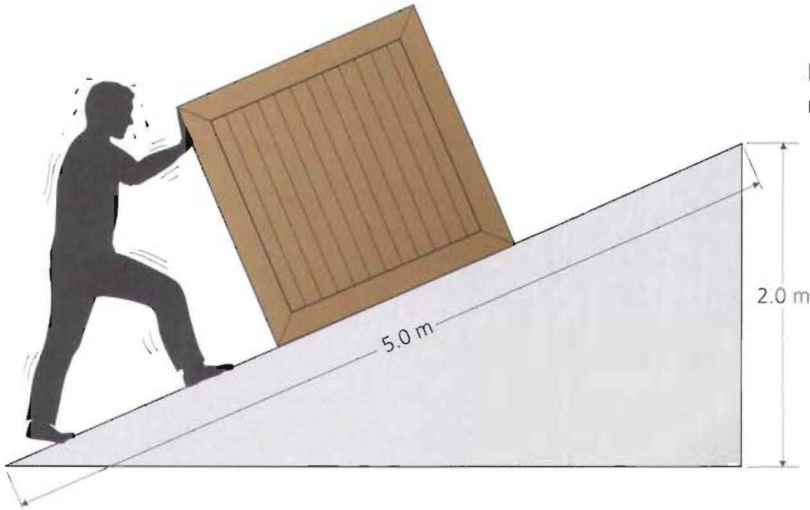


Figure 5.32 A 500-N crate is being pushed up the ramp with a force of 400 N.

Useful output work = (500 N)(2.0 m) = 1000 J

Input work = (400 N)(5.0 m) = 2000 J

Now we can use this work to calculate the efficiency.

$$\text{Efficiency} = \frac{W_{\text{out}} \times 100\%}{W_{\text{in}}}$$

$$= \frac{(1000\ \text{J}) \times 100\%}{(2000\ \text{J})}$$

$$= 50\%$$

This inclined plane is 50% efficient.

This ramp has a mechanical advantage greater than 1, which means that less force is required to lift the crate. Even though less force is required, some of the work done by the person is transformed into heat by the friction between the crate and the ramp. Therefore, the efficiency is not 100%.

Suggested Activity
B32 Inquiry Activity on page 149

Take It **Further**

In order to increase the efficiency of a machine, a lubricant can be used to reduce friction. Not all lubricants are liquids like oil. Find out which "dry" materials are used as lubricants. Find an example of a machine in which a dry lubricant is used. Begin your search at ScienceSource.

B31 *Learning Checkpoint*

Calculating Efficiency

You have to lift a mass to a higher location so that the mass gains 800 J of gravitational potential energy. You may use one of three different mechanisms given in the next column to lift the mass. Calculate the efficiency of each mechanism. Which one will you use?

1. You use an electric motor that requires 850 J of energy to lift the mass.
2. You pull the rope of a pulley, which is attached to the mass, a distance of 6.0 m with a force of 150 N.
3. You push the mass 10 m up a ramp with a force of 140 N.

Table 5.3 The Efficiencies of Some Common Mechanisms

Mechanism	Efficiency (%)
Electric generator	99
Olympic track bike	98
Mountain bike	85
Hybrid-diesel car	45
Electric car	44
Hybrid-gasoline car	36
Conventional gas-powered car	22
Solar cell	10

The Efficiency of Common Mechanisms

When a mechanism does work, its energy is transformed from one form to another or transferred from one object to another. A car transforms the chemical energy stored in its fuel into several other forms of energy, such as kinetic energy, sound energy, light energy, and thermal energy. Since the main purpose of a car is transportation, the useful output work of the car would be the work done to provide motion (kinetic energy).

We can measure the efficiency of any mechanism that transfers energy Table 5.3 gives the efficiencies of some common mechanisms.

How to Increase Efficiency

The efficiency of any machine is not 100 % because some of the input work is used to compensate for the work done by friction. When you use a pulley, you may hear the pulley squeak (sound energy) and the pulley wheel may become warm (heat). These result from the work done by friction. If you reduce the frictional force, you increase the efficiency of a machine. The best way to reduce friction is to add a lubricant, such as grease or oil, to any surfaces that rub together. Lubricants fill the gaps between the two surfaces, making it easier for those surfaces to slide past each other. Because water is also a good lubricant, wet floors are more slippery than dry floors (Figure 5.33).

Figure 5.33 Water, like oil and grease, acts like a lubricant to decrease the amount of frictional force.

For some devices, the thermal energy produced during the energy transfer cannot be decreased by a lubricant. A good example is an incandescent lamp, which operates at 175 °C (Figure 5.34). At this temperature, only 5 % of the electrical energy is transformed into light energy. The rest becomes heat. Lubricating the filament of the lamp would not increase its efficiency. Compact fluorescent lamps (CFLs) are designed to operate at a much lower temperature, around 30 °C. At this temperature, less electrical energy is converted to heat. Therefore, the CFL has a higher efficiency than traditional incandescent lamps.

(a) (b)

Figure 5.34 (a) Incandescent light bulb, (b) Compact fluorescent light bulb

Toolkit 2

SKILLS YOU WILL USE
- Initiating and planning
- Evaluating information

Increasing Efficiency

No machine is 100% efficient since extra work must be input to the machine to compensate for the work done by friction. To increase the efficiency of a machine, you must decrease the amount of friction.

Question

What method will increase the efficiency of a simple machine, and by what amount is the efficiency increased?

Materials & Equipment

- spring scale
- inclined plane
- ruler
- mass
- material or process that will reduce friction

Hypothesis

Write a hypothesis about how the method you will use to reduce friction will change the efficiency of the simple machine.

Procedure

Part 1 – Measuring Efficiency

1. Copy Table 5.4 into your notebook. Give it a title.

Table 5.4

Output Force (N)	Output Distance (m)	Output Work (J)	Input Force (N)	Input Distance (m)	Input Work (J)	Efficiency (%)

2. Stack several books on your desk. Place the mass on your desk at the base of the stack. Using a spring scale, measure the force required to lift the mass straight up. Record this as the output force.
3. Using a ruler, measure the height from the desk to the top of the books. Record this distance as the output distance.
4. Calculate the work required to move the mass from the desk to the top of the stack of books. Record this value as the output work.
5. Place an inclined plane from the desk to the top of the stack of books. Using the spring scale, measure the force required to slide the mass up the incline. Record this value as the input force. Measure the length of your incline and record this as the input distance.
6. Calculate the work required to slide the mass up the incline to the top of the stack of books. Record this value as input work.
7. Calculate the efficiency of this inclined plane.

Part 2 – Increasing Efficiency

8. Suggest a process or material that you think will increase the efficiency of your inclined plane. Be sure to get your teacher's approval before going any further.
9. Copy Table 5.4 into your notebook. The values of output force, output distance, and output work are the same as in Part 1. Give this new table a title.
10. Apply your approved changes to the inclined plane and repeat steps 5–7.

Analyzing and Interpreting

11. Did your material or method increase the efficiency by as much as you expected?
12. Suggest what you might have done differently in order to increase the efficiency even more.

Skill Builder

13. Calculate the amount of heat produced in both Part 1 and Part 2.

Forming Conclusions

14. Answer the question at the beginning of this activity.

5.2 CHECK and REFLECT

Key Concept Review

1. Explain why a machine or a mechanism cannot have an efficiency of 100%.

2. If the efficiency of a machine increases, what happens to each of the following? (Use the words "increases," "decreases," or "stays the same" to describe the changes.)

(a) input work

(b) useful output work

(c) friction

(d) mechanical advantage

3. What is the mathematical relationship between efficiency, input work, and useful output work?

4. Explain how a lubricant affects the efficiency and the frictional forces of a machine.

Connect Your Understanding

5. A student does 25 J of work on the handle of a pencil sharpener. If the pencil sharpener does 20 J of work on the pencil, what is the efficiency of the sharpener?

6. A force of 900 N pushes a wedge 0.10 m into a log. If the work done on the log is 50 J, what is the efficiency of the wedge?

Practise Your Skills

7. Use the data below to rank machines A, B, and C from:

(a) highest to lowest mechanical advantage

(b) highest to lowest efficiency

Machine	Input Force (N)	Input Distance (m)	Output Force (N)	Output Distance (m)
A	5.0	10	20	2.0
B	10	25	50	3.5
C	20	6.0	27	4.0

For more questions, go to ScienceSource.

B33 *Thinking about Science, Technology, and Society*

Ontario's Bright Idea

The Ontario government has decided to ban the sale of incandescent light bulbs by 2012. It is estimated that by replacing the incandescent bulbs to the more efficient compact fluorescent lights (CFLs), Ontario will save enough energy each year to power 600 000 homes.

Consider This

With a small group or the whole class, discuss statements 1 and 2. Then answer question 3 by yourself.

1. Switching to CFLs will have both an economic and an environmental impact on Ontario.

2. Switching to CFLs will have both positive and negative impacts on Ontario.

3. Do you agree or disagree with the government's decision? Give reasons for your answer.

Mechanical Engineer

Figure 5.35 Some mechanical engineers design roller coasters for a living.

Are you fascinated with building things and with taking things apart to see how they work? Do you like solving puzzles? Would you like to invent a machine that is used by people all over the world? If you answered yes to any of these questions, perhaps you should consider becoming a mechanical engineer. Mechanical engineers use science and mathematics to design mechanical systems that meet societal and consumer needs. These mechanical systems include toys, cars, roller coasters, elevators, spacecraft — basically anything that moves.

Much of a mechanical engineer's work is designing and developing new mechanical systems. This process can usually be broken into four major steps. First, mechanical engineers must fully understand the societal or consumer requirements for the system they are developing. The second step is to design and test the various components of the product. Then, the components are integrated into the final design. The final step is to evaluate the effectiveness of the complete mechanical system. This final evaluation involves cost, reliability, safety, and impact on the environment.

Once these new systems are being used, mechanical engineers often supervise their operation. This may include supervising production in factories, determining the causes of component failure, or doing tests to make sure the system is operating efficiently.

Mechanical engineers require a good background in mathematics, physics, and chemistry. Two of the units in this textbook, Systems in Action and Fluids, are important if you decide to become a mechanical engineer. After high school, you will go to university to obtain a degree in mechanical engineering, or to college to become an engineering technician.

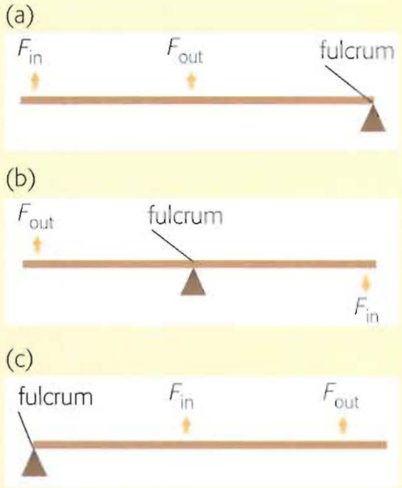
Mechanical engineers are hired by large corporations, government agencies, and engineering companies. These companies are looking for people who are "team players." Most engineering projects require the engineers to work with groups of clients, technologists, and other engineers. For this reason, engineers must have great communication and leadership skills.

Questions

1. What is the job description of a mechanical engineer?
2. Companies that hire mechanical engineers are looking for people who will be "team players." In your opinion, what characteristics should you have to be considered a "team player"?
3. Which two units in this textbook are closely related to the study of mechanical engineering?

5.0 Chapter Review

Assess Your Learning



Question 3

After Reading — Thinking Literacy

Making Connections

At the beginning of this chapter, you predicted what you might learn about simple machines, ideal mechanical advantage, and efficiency. How does the information you have read add to or change what you predicted about these topics?

You have also learned about making inferences. How is inferring the same as and different from predicting? Why might a writer give only essential details on a topic and expect the reader to infer meaning from this information? Share your ideas with the class.

Key Concept Review

1. Define "simple machine." K
2. Give an example each of a simple machine and a mechanism. A
3. Classify each of the levers in the illustration on the left as first-, second-, or third-class. K
4. For which class(es) of lever(s) are the input force and the output force K
   (a) in opposite directions?
   (b) in the same direction?
5. Describe the ideal mechanical advantage and the direction of the input and output forces for a fixed pulley. K
6. How does the output work compare to the input work for a machine that has an efficiency K
   (a) equal to 100%?
   (b) less than 100%?

Connect Your Understanding

7. To increase the mechanical advantage of a lever, should you increase or decrease the length of the output arm? A
8. Pedro and Brittany design a mechanical device that will move desks from one classroom to another on the floor above. They measure the forces and distances and calculate the input and output work. If their calculations show that the input work equals the output work, is their calculation correct? Explain. A
9. If you did Activity B23, you sketched locations on a mountain bike that involved simple machines. Using that sketch, label the type of simple machine at each location. C
10. A mechanical system is used to pull a tarp over a grass tennis court. On a clear, sunny day, the efficiency of the system is 55%. After a rainstorm, the efficiency is measured to be 65%. Explain why there is a difference in the efficiencies. A

ACHIEVEMENT CHART CATEGORIES
K Knowledge and understanding   T Thinking and investigation   C Communication   A Application

11. Each photograph on the right shows a common tool. Identify the type of simple machine each tool represents.

Question 11

Practise Your Skills

12. Plan an experiment to measure the ideal mechanical advantage of a three-hole punch.
   (a) What materials would you need?
   (b) What procedure would you use?

13. Calculate the IMA of a lever whose input force is applied 3 m from the fulcrum and whose output force is 0.5 m from the fulcrum.

14. A ramp that is 5 m long is used to raise an object 2 m vertically. Find the IMA of this ramp.

15. Using one or two pulleys, draw a mechanical system that has:
   (a) an IMA = 2
   (b) an IMA = 3

16. The handle of a screwdriver has a radius of 3 cm. If the shaft of the screwdriver has a radius of 0.5 cm, what is the IMA of the screwdriver when used to tighten a screw?

17. Wei uses a pulley system to lift a box. She pulls the rope a distance of 3 m, using a force of 50 N. If the work done on the box is 120 J, what is the efficiency of the pulley system?

Unit Project Link

In your Unit Task, you will design, construct, and test a mechanical system that uses only the energy stored in a spring-bar mousetrap. The mousetrap machine must have a function other than catching mice. What simple machines might you use in your project? How can you ensure that your design has maximum efficiency?

B34 *Thinking about Science, Technology, and Society*

Building a Modern Pyramid

The ancient Egyptian pyramids, like those shown in Figure 5.4 on page 130, were built over 4500 years ago. Archeologists believe that the workers mainly used ramps and levers when building them.

Suppose you wanted to build a similar pyramid using modern technology.

Consider This

In small groups or as a class, discuss the following questions.

1. What modern machines do you think would be used in the construction of the pyramid?
2. What developments in science and technology have resulted in these modern machines?

6.0 Systems have an impact on our society.

Automated assembly lines build many of the cars of today.

What You Will Learn

In this chapter, you will:

- identify various non-mechanical systems and describe the components of these systems that allow them to function efficiently
- examine alternative ways of meeting current needs and assess their impact on society and the environment
- determine how society and the environment have been affected by the automation of systems

Skills You Will Use

In this chapter you will:

- investigate the information and support that is provided to the consumer to ensure that a system functions safely and efficiently
- use criteria to evaluate a system

Why This Is Important

School systems, communication systems, transit systems, and health-care systems are just a few examples of systems that have both immediate and long-term effects on your life.

Before Writing

Thinking Literacy

Problem & Solution

Writers use different organizational patterns to communicate information to readers. Knowing these patterns helps readers "see" the relationship(s) among ideas. Much of the information in this chapter is presented in a Problem & Solution pattern. Think about a problem you have had and how you solved it.

Key Terms

- automated system
- non-mechanical system
- quantitative assessment
- productivity
- criteria
- qualitative assessment

6.0 Getting Started

Figure 6.1 A garbage truck is a mechanism used to collect waste products.

Here in Ontario, the City of Toronto alone produces about 500 000 tonnes of garbage every year. Mechanical systems, such as levers and hydraulics, are used to lift the waste bins and dump them into the truck (Figure 6.1). On the truck, other mechanical systems compact the materials to make more room in the truck.

However, it takes more than just mechanical systems to operate an efficient waste management program that reduces and recycles waste (Figure 6.2). The staff and the procedures used to collect and dispose of waste are part of the non-mechanical system involved in waste management. **Non-mechanical systems** include the procedures, processes, and people needed to perform a task.

A complete waste management program includes both mechanical and non-mechanical systems in its task to reduce, recycle, or dispose of waste. The non-mechanical system for waste disposal consists of several components. The city hires workers and buys trucks. Some workers develop a schedule of pick-up times and publish collection calendars for delivery to the public. Residents sort their waste into garbage, recyclables, and organic material (including leaf and yard waste) and put out the bins on the appropriate collection day for pick-up. The trucks offload recyclables at a recycling plant, the organic material at a compost-processing facility, and the rest of the waste at a landfill. Other workers operate the recycling plant and compost facility and maintain the landfill site.

Like mechanical systems, each component of a non-mechanical system plays a role in the successful completion of the task. In this chapter, you will study many types of systems and their impact on both the environment and society.

Figure 6.2 The workers, along with the procedures for collecting and handling recyclable products, represent some of the non-mechanical components of a recycling program.

B35 *Quick Lab*

Your School's Waste Management

Purpose

To examine how your school community manages its garbage

Materials & Equipment

- pen and paper
- resource person such as the custodian or principal

Procedure

1. On a single piece of paper, draw a T-chart with the headings "Non-recyclable" and "Recyclable."
2. Make a list of the types of garbage in your school. Remember: recyclable materials include metal cans, plastics, cardboard, paper, and organic materials.
3. Find out what materials your school recycles and put a checkmark beside those materials on your list.

Questions

4. Choose one item from your non-recyclable list. Describe what you think happens to this piece of garbage after you throw it away.
5. Choose one item from your recyclable list. Describe what you think happens to this item after you throw it away.
6. Suggest one change that you believe would improve the current system of waste management in your school.

6.1 Non-mechanical Systems in Society

Here is a summary of what you will learn in this section:

- As in mechanical systems, the components of a non-mechanical system interact to perform a task.
- Many non-mechanical systems are designed because of the needs of society.
- Information and support are required to keep a system working efficiently.

Figure 6.3 Students, desks, and books are just a few of the components that make up a school system.

In Chapters 4 and 5, you learned that mechanical systems use forces to do work and transfer energy. In this chapter, we will look at non-mechanical systems, which perform tasks without transferring forces. A non-mechanical system that you are familiar with is the school system (Figure 6.3). The school system involves more than just students and teachers. Principals, custodians, administrative staff, bus drivers, and school boards are all part of the system. The school system is not just people. It is also all of the objects such as books, desks, buildings, playgrounds, and equipment. Subjects (such as science), timetables, and even the rules are part of the school system.

In order for any system to perform its task successfully, the **components** of the system must interact. The components are the parts of the system. Most non-mechanical systems have an overall plan so that each component of the system has a purpose or role. For example, teachers, timetables, and books each have very different roles in the system, but each contributes to the overall success.

The school system is just one example of a non-mechanical system. Many other non-mechanical systems provide services to you, your community, your province, and your country.

B36 *Starting Point* — Skills P C

Non-mechanical Systems in Society

Non-mechanical systems usually include an organizational system that provides a service to some part of society. Work with a partner and brainstorm as many non-mechanical systems as you can think of. Keep this list for a future activity.

B37 During Writing

Thinking Literacy

A Problem, Its Causes, and Some Solutions

Society has many systems that improve our lives, but some may also cause problems. As you read, identify a problem in our society. What causes this problem? What solutions do we use to solve this problem? Develop a graphic organizer and record this problem, its cause, and its possible solutions.

Can you find any signal words on this page that tell you the writers used a "Problem & Solution" pattern to organize their ideas?

Systems Require Organization

In order for a non-mechanical system to function properly, the components of the system must work together in an organized manner. This organization is usually done by a person, a company, or a government, who oversees the operation of the system. Once all of the procedures and components are put in place, the system can perform the desired task.

Suppose the desired task is helping people travel without taking their own vehicles. Most cities in Ontario have organized a transportation system to perform such a task. Both mechanical and non-mechanical systems make up such a system (Figure 6.4). The mechanical components are the buses, trains, or subways. The non-mechanical components include the drivers, routes, and schedules (Figure 6.5). By themselves, none of these components could provide an adequate transportation system. Instead, the components interact in such a way that people are moved from one location to another efficiently and safely. If you were in charge, how would you organize such a transportation system?

One method may be to organize the non-mechanical components of the system first. You would design the bus routes that best meet the needs of the riders. A schedule of when the bus will arrive at each stop is next. Bus drivers must be informed of their routes and time lines. Finally, the mechanical system (the bus) is used to complete the task.

A transportation system is just one example of a non-mechanical system that is used to organize our society. The same analysis can be done with any system.

Figure 6.4 A transportation system involves both mechanical and non-mechanical systems.

Figure 6.5 Bus routes and schedules represent a non-mechanical component of a transportation system.

Figure 6.6 Day-care facilities like this are one component of the child care system.

Take It Further

As new products are developed to meet the needs of society, a system is needed to evaluate the safety of these products. The Canadian Standards Association (CSA) is a non-government association that tests and approves new products to make sure that they are safe for the consumer and the environment. Find out how the CSA evaluates consumer products. Begin your search at ScienceSource.

Systems Develop from a Need

Our society has many systems that improve our standard of living. You might wonder how non-mechanical systems become part of our society. Most are the result of a need.

A transportation system is just one example of a system that was developed in response to a need. Another example is child care. Over the past 40 years, the number of families with both parents working away from the home has increased. This meant that society had a need for a system that could take care of these parents' children. To meet this need, a child care system was developed (Figure 6.6).

In 2004, Ontario initiated its Best Start child care program. The demand for child care has continued to increase, and in 2007, the Ontario government added an extra $142.5 million to meet the demands of the child care system. In order for a system to continue to meet the needs of society, it must be evaluated and upgraded continuously.

Keeping the System Working Efficiently

Once a system is in place, it needs to be monitored frequently to make sure that it is meeting the needs of its consumers. A **consumer** is an individual who uses the goods or services provided by a system. In order for the system to work efficiently, the consumer must be provided with information and support on how to use it.

Suppose that you recently purchased a new computer system. The manufacturers of that computer system need to communicate to you, the consumer, how you can use that system. Often, the manufacturer provides an instruction manual (Figure 6.7), either as a booklet or on-line.

Not all systems work continuously without developing problems. When a problem arises, the consumer may need to get help. Most systems have a service component that deals with such problems. In the school system, your school counsellor might be one component that can help when you are having problems in school. Most companies offer "tech support" to make sure that you can get help if their product needs service.

Figure 6.7 Instruction manuals like this provide information to the consumer.

Assembly Not Included

Instruction manuals are one type of support that a manufacturer might provide to a consumer. In order for a manual to be useful, it must convey the information clearly and accurately.

Purpose

To evaluate assembly instructions

Materials & Equipment

- paper and pencils

Procedure

1. You have just bought a bookshelf at a furniture store. It came with the directions shown in the box at the right and a diagram to show you how it should be assembled (Figure 6.8).
2. Copy Table 6.1 into your notebook. Use it to record your evaluation of the instructions. Rate the Construction Steps as follows:
    - 4 = very good
    - 3 = good
    - 2 = satisfactory
    - 1 = unsatisfactory
3. In the Comments column, provide a reason for your rating. Include a least two suggestions for improving the directions.

Questions

4. Most instruction manuals contain both diagrams and written instructions. Explain why you think it is important to include both.
5. You used three categories when evaluating these assembly instructions. Which of these three categories do you think is most important to the consumer? Suggest another category that could be used in the evaluation.

Construction Steps

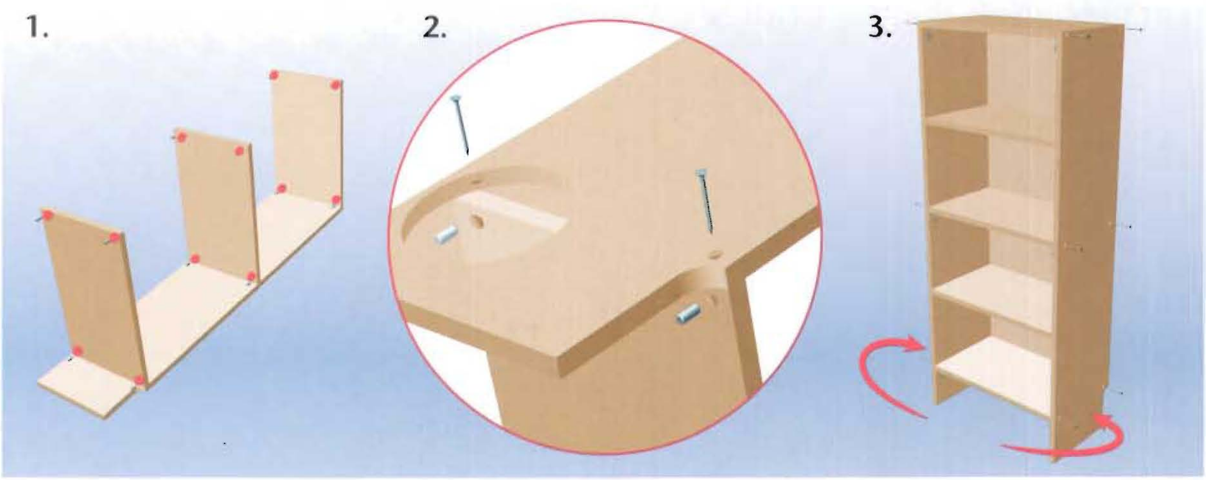
Assembling the bookcase

1. Locate the holes for insert A.
2. Screw connector B into insert A. There are 2 for each side.
3. Do the same for the other side.

Table 6.1

Category	4	3	2	1	Comments
Clarity of directions					
Thoroughness					
User-friendliness					

Figure 6.8 Bookcase assembly



B39 *Quick Lab*

Providing a Service to Society

Similar to mechanical systems, non-mechanical systems consist of several components that work together to perform a task or function. Often these components perform several tasks. At the beginning of this chapter, you created a list of different types of non-mechanical systems. In this activity, you will examine one system from your list.

Purpose

To examine a non-mechanical system that provides a service to society

Materials & Equipment

- paper and pencils

Procedure

1. With a partner, choose a non-mechanical system from the list you made earlier.
2. Write the name of your system at the top of a blank piece of paper.
3. Identify all of the components of this system that you can think of. Write the names of these components anywhere on the paper.
4. Draw lines between components that interact with each other. On each line, write a short description of how those components interact. Figure 6.9 shows a small example.

Questions

5. What societal need does the system you chose fulfill?
6. Some of your components may interact with more than one other component. Which component had the largest number of interactions?
7. If you removed the component that you identified in question 6 from the system, what might happen to the system?
8. Describe one part of the system that you believe is responsible for making sure the system works efficiently.
9. Suggest one improvement that you think would increase the effectiveness of this system.

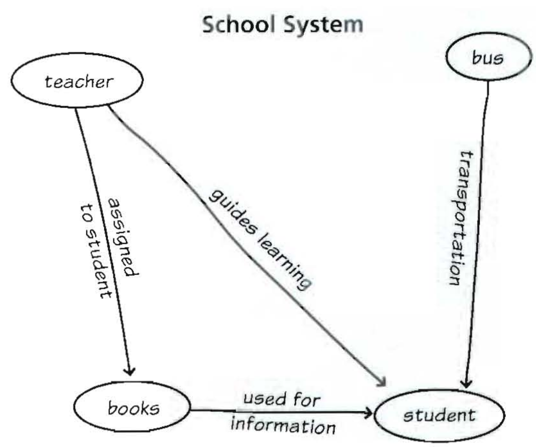


Figure 6.9

6.1 CHECK and REFLECT

Key Concept Review

1. In Canada, our government is considered a "democratic system." Is this a mechanical or a non-mechanical system? Explain.
2. Identify three components of the school system.
3. Explain what the concept "systems need organization" means to you.
4. What is the relationship between a need in society and a system?
5. Define "consumer."
6. In order for a system to work efficiently, what two services should be provided to the consumer?

Connect Your Understanding

7. Your company has been hired to install an automatic sprinkler system for a large park. The mechanical and non-mechanical components of the job are listed in random order below. Organize the components in the correct sequence.
   - Dig trenches to bury the water pipes.
   - Set the timer for the watering times.
   - Identify the areas that need watering.
   - Sketch a plan of the locations of the water pipes and sprinkler heads.
   - Connect the pipes to the water supply.
   - Connect the pipes to the sprinkler heads and bury them in the trenches.
8. What societal needs do you believe each of the following systems fulfills?
   (a) merchandise distribution system
   (b) provincial electrical system

Practise Your Skills

9. The photograph below shows part of a library system.
   (a) What societal need does a library system fulfill?
   (b) Identify the components of this library system.
   (c) Describe the interaction between any two components you have identified.
   (d) Describe one aspect of this system that keeps it working efficiently.

For more questions, go to ScienceSource.

B40 *Thinking about Science, Technology, and Society*

You: The Consumer

A consumer is a person who purchases the goods or services provided by a system. Many companies advertise their products to specifically attract teenage consumers.

With a group or the whole class, make a list of products that you think are intended for teenage consumers. Discuss the methods of advertising that companies use to make their products more attractive to teenagers.

6.2 Assessing the Impact of Automation and Alternative Systems

Here is a summary of what you will learn in this section:

- Increasing productivity allows a task to be accomplished faster or allows more tasks to be done at the same time.
- An automated system replaces human workers with machines that operate without human intervention.
- Automation has had an impact on our society, the environment, and our economy.
- The criteria for assessing a system include efficiency, safety, cost, and impact on the environment.
- When considering alternative ways of meeting the needs of society, we must assess both the current system and the proposed system.

Today you finally buy those shoes that you have been saving for. You may begin your search at the mall, involving many stores, styles, and prices (Figure 6.10). For some people, shopping is a dream come true, but others see it as a huge waste of time. If the only purpose for going to a mall is to buy shoes, then walking from store to store and trying on several styles seems very inefficient. There must be a way to be more productive.

Figure 6.10 A mall provides many options to the shopper.

B41 Starting Point

Skills A C

To Mall or Not to Mall: That Is the Question

Working with a partner or as a whole class, create a "Pros" and "Cons" list for shopping on-line versus shopping at a mall. Once the list is completed, classify each of the items as being:

- economic: deals with money issues
- environmental: has an impact on the environment (e.g., pollution)
- social: deals with the interaction of people

B42 *During Writing*

Thinking Literacy

Organizing Writing Ideas

The automation of the car industry has changed the way we live. The freedom of movement that comes with widespread use of the car has both positive and negative consequences.

Copy Table 6.2, leaving lots of room to add information. As you read this section, think about and record some of the positive and negative impacts of the increasing use of the car. For each negative impact, suggest a possible solution. Use this information to write a few paragraphs about the impact of the car. Use a Problem & Solution pattern for your writing.

Table 6.2 The Impact of the Car

Type of Impact	Positive Impacts	Negative Impacts	Solutions for Negative Impacts
Social			
Economical			
Environmental			

Productivity

Productivity is the amount of output that is produced per unit of time. If you can increase productivity, you can accomplish a task faster or do more tasks in the same amount of time. So how can you make the task of buying shoes more productive? One way would be to shop on-line (Figure 6.11), where you can search for different styles and even pay for your purchase. On-line shopping is much more productive because you do not waste time getting to the mall and walking from store to store.

Figure 6.11 On-line shopping may increase the productivity of shopping.

Increasing Productivity

In this unit we have studied how both mechanical and non-mechanical systems are used to do work or complete a task. Well-designed systems can improve productivity, allowing the work to be done faster or more tasks to be done at the same time.

Consider the amount of work required to dig a tunnel under a river or through a mountain. In 1854, construction of the Brockville Tunnel began under the City of Brockville, Ontario (Figure 6.12, next page). Workers used simple machines, such as shovels, picks, and ramps, to construct this 527-m-long railway tunnel.

Figure 6.12 The Brockville Tunnel, Canada's first railway tunnel, took more than six years to construct.

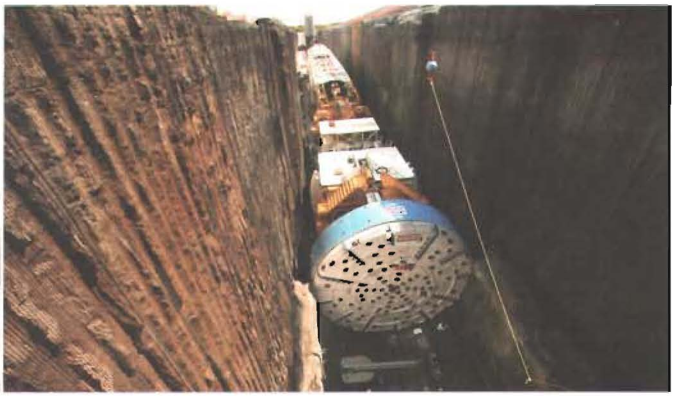


Figure 6.13 Modern tunnel-boring machines allow tunnels to be dug much faster than in the past.

In 2005, 150 years later, construction of the Niagara Tunnel began. This tunnel channels water under the City of Niagara Falls. Today, mechanisms such as the tunnel-boring machine (TBM) (Figure 6.13) have replaced the simple machines used on the Brockville Tunnel. If the Brockville Tunnel had been dug by the TBM used under Niagara Falls, it would have been completed in just over a month.

The building of the Brockville Tunnel employed hundreds of people for several years. Modern methods of tunnelling do not require the same number of workers. In situations like this, increased productivity has decreased the number of jobs available.

Often it is a combination of mechanical and non-mechanical systems that increase productivity. For example, some libraries now have self-checkout machines (Figure 6.14). These machines allow the consumer to scan the bar code to check out the items without waiting for a librarian. The mechanical system includes a scanner that is connected to a computer. By passing a laser light across the bar code, the scanner records the information on the computer's hard drive and a receipt is printed.

Figure 6.14 Consumers can check out their own books using this machine.

The non-mechanical part of the system includes the instruction sheet posted at each machine. The instructions help the library patrons use the machine to check out their books. These machines increase productivity because more books can be checked out in a given amount of time. Does this mean that we no longer need librarians? Librarians provide many services that are vital to the operation of a library, other than checking out books. However, when a system is implemented to increase productivity, there is always a danger that the quality of service will decrease.

Mass Production

In the past, many consumer goods were made by hand. For example, a small group of employees would build an entire car. Today, some high-quality furniture and musical instruments are still hand crafted (Figure 6.15).

Nowadays, many consumer goods are produced by a system called mass production, in which each employee repeatedly performs a small task as the item moves past on a conveyor belt (Figure 6.16). The system — from raw materials to final product — is called an assembly line. Each item is made faster and for less cost, and is very similar in design and quality.

Increasing productivity by mass production may also have negative consequences. Goods manufactured on an assembly line are often of a lower quality than hand-crafted items are.

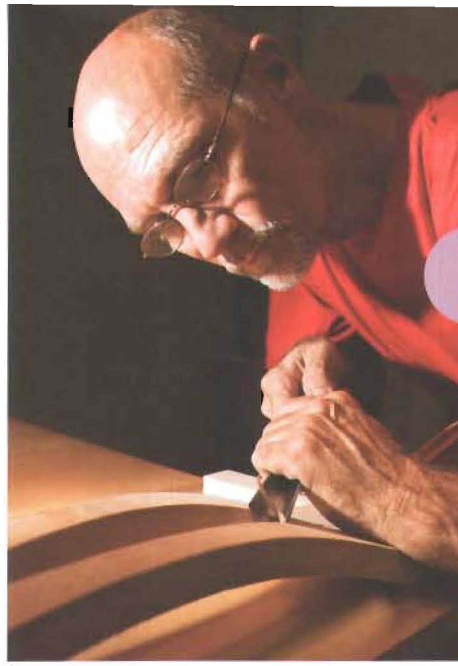


Figure 6.15 Hand-made products require many hours to complete.

Automated Systems

Another way to increase productivity is to replace the current system with an automated system. An **automated system** replaces human workers with machines that are controlled by a computer. Once the automated system is set up, the machines monitor and react to situations without human intervention. An automated system can be as simple as the thermostat that controls the heat in your home. Once it is set, the thermostat monitors the room temperature and reacts to control the temperature by turning the furnace on and off.

Automation is used for both simple tasks, like baking bread with a bread machine, and complex ones like assembling cars (see the chapter opener photo on page 154). Even professions such as farming have been automated. On modern poultry farms, thousands of chickens or turkeys are fed and watered by automated systems (Figure 6.17).

Figure 6.16 Many consumer goods are processed on an assembly line.

Figure 6.17 Many farms use automated feeding and watering systems.

The Impact of Automation

WORDS MATTER

The prefix "auto-" means self-operating. For example, "automobiles" are self-operating vehicles. "Automatic" means "working by itself," and an "automaton" is a human-like robot.

Over the past 20 years of computer development, many tasks traditionally done by workers have become fully automated. As with any change, this can be viewed both positively and negatively. To make up your own mind, you need to consider the social, economic, and environmental impacts that automation has on society. A social impact is how automation helps people live, work, and interact with each other in a society. Economic impacts of automation deal with the money aspects. Finally, environmental impacts include how automation affects both the biotic and abiotic elements of our ecosystems.

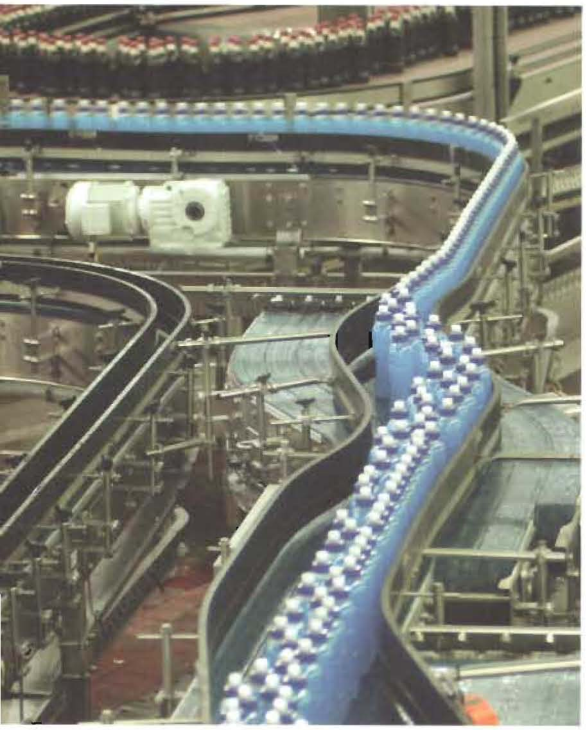


Figure 6.18 A fully automated bottling system.

Socially, many traditional jobs have been replaced by automated systems. Some people have lost their jobs to automation. However, automated systems have also been responsible for creating many new types of occupations. Thus, automated systems have changed the types of work that people do. Automated systems have definitely changed how society lives and works.

Economically, automating a system usually increases productivity. This means that the business can make the product at less expense and therefore can sell it at a lower cost. If automating a system reduces the number of employees required, this affects the economy of both the company and the community.

Environmentally, automating an assembly line may require an increase in the amount of energy used by the machines (Figure 6.18), which might have a negative environmental effect. Car manufacturers install an automated pollution control system in each car that decreases harmful emissions. This automated system has a positive environmental effect.

Take It **Further**

Automated teller machines (ATMs) replace some of the work done by a bank teller. A bank teller counts money visually. How do ATMs know the difference between a $10 bill and $20 bill? How do they count the correct amount of money? Begin your search at ScienceSource.

Assessing a System

When the needs of society change, the existing systems may no longer meet those needs. Either the existing systems must be changed or new systems must be developed. Before the changed system or the new system is put in place, the developers must evaluate the impact it will have on individuals, society, and the environment.

Using Criteria to Evaluate a System

Criteria (singular: criterion) are standard rules or tests on which a decision or judgement can be based. To assess systems, the developers often use the following criteria:

- efficiency
- safety
- cost
- environmental impact

Each of these criteria can be assessed quantitatively or qualitatively. A **quantitative assessment** involves analysis of numerical data. As we saw in Chapter 5 for a mechanical system, the quantitative efficiency is determined by:

Efficiency = (useful output work)/(input work)

Qualitative assessments are often made by observations. For example, "My car gets great gas mileage" is a qualitative assessment. Compare this qualitative assessment of the car's fuel efficiency with the quantitative assessment, "My car travels 10 km per litre of gas."

Assessing Systems for Transporting Groceries

Thousands of years ago, people grew or caught their food. They needed containers to transport the food to their villages and to store the food. Early containers were made from woven grass or twigs, animal skins, clay, and even animal organs (Figure 6.19). If we use the criteria listed above to assess these early containers, we might come to the following conclusions.

- Efficiency: Low since large amounts of time and effort were required to produce one container. It was also inconvenient to have to take the empty containers to the field.
- Safety: These containers were difficult to keep clean. As well, they did not provide protection against insects and rodents.
- Cost: Low since the materials were readily available in nature.
- Environmental impact: Low since the containers were made from natural materials and would decompose easily when discarded.

Figure 6.19 Sacks and baskets were used by our ancestors to carry things.

Figure 6.20 Paper grocery bags were used for many years.

From Paper to Plastic Bags

Society assessed these early containers as being inefficient, hard to store, and hard to keep clean. An efficiently produced, disposable bag was deemed a societal need. By the early 1900s, the system of making paper from wood products was well developed. Paper shopping bags soon replaced traditional methods of carrying groceries (Figure 6.20).

Applying the criteria to the paper bag, we find that paper bags were expensive to produce and not very strong. Since they were considered disposable, they were safe to use. Their environmental impact is questionable: the bags decompose easily, but paper is made from trees. For cost and efficiency, society wanted a cheaper bag that was light and strong, and could be given free to shoppers.

By the late 1970s, plastic shopping bags had almost totally replaced paper bags (Figure 6.21). It is estimated that Canada uses and discards about six billion plastic bags annually. Plastic bags are inexpensive to produce and can be re-used and recycled. However, they decompose extremely slowly.

Beyond Plastic Bags

The high efficiency of producing plastic bags and their low cost have made their use very appealing. Their safety is a concern, however, because of their potential to suffocate babies who play with them. Currently, society is again assessing our system for carrying groceries, mainly because of the impact of plastic bags on the environment. Most plastic bags are made of polyethylene, which is a type of plastic derived from oil. It is estimated that only about 1 percent of all plastic bags are recycled. The production, disposal, and environmental impact of plastic shopping bags must be considered when assessing our current system of transporting groceries.

Many shoppers are now bringing their own reusable bags every time they go to the store. The system for transporting groceries has gone full circle — from reusable containers, to disposable paper, to usually discarded plastic, and back to reusable containers.

Figure 6.21 Most stores use plastic bags now.

DI Anchor Activity

B43 Decision-Making Analysis

Toolkit 4

SKILLS YOU WILL USE
- Gathering information
- Summarizing information

My Opinion of Automation

Issue

Many jobs and tasks that used to be done by people are now being done by automated systems. Choose a job or task that has been automated and decide if this automation has had a positive or negative effect on society.

Background Information

The number of jobs that have become automated continues to grow. Jobs that have been automated include:

- phone-answering systems
- automated teller machine (ATM) (Figure 6.22)
- assembly lines (in manufacturing)
- autopilot on commercial airplanes
- checkouts at libraries or stores
- ticket-dispensing machines at movie theatres (Figure 6.22)
- farming (poultry, dairy, hydroponics)

Analyze and Evaluate

Choose any job that has been automated. Your task is to look at the positive or negative impacts the automation of that job has had on society, and decide whether the automation was positive or negative on the whole. Research evidence to support your argument. You will present your findings as either a report or a class presentation. Your teacher will provide more details about how to present your information.

As you research, answer the following questions.

- How was this task accomplished before it was automated?
- How is this task accomplished with automation?
- What is the social impact of this automation?
- What is the economic impact of this automation?
- What is the environmental impact of this automation?

1. Use the following resources for your research.
   - Go to ScienceSource to begin your search for information.
   - Look in print materials such as magazines, newspapers, and books for information on the automated job you have chosen.
2. Summarize the information you find in a short report for presentation. Be sure to include only information that supports your viewpoint or refutes the opposite view.

Figure 6.22 It seems like everything is automated these days!

6.2 CHECK and REFLECT

Key Concept Review

1. How does increased productivity change:
   (a) the time it takes to complete a task?
   (b) the number of tasks performed in a certain amount of time?
2. Explain what is meant by an automated system. Give two examples of automated systems.
3. What four criteria are often used when assessing a system?
4. Indicate which of the following is a qualitative assessment and which is a quantitative assessment.
   (a) 45 percent efficient
   (b) makes your clothes whiter

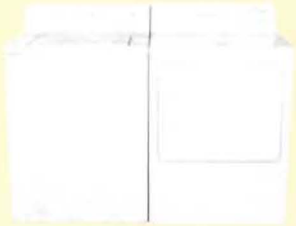
Connect Your Understanding

5. Baking bread at home can now be automated. Just add the ingredients to a bread machine and press a button (photo at right). Identify the mechanical and non-mechanical systems involved in this automation.

6. Use an example to explain how automating a system can have both positive and negative effects on society.
7. Explain how increasing the efficiency of a system can have a positive effect on society.
8. Give two reasons why people look for alternative ways of meeting the current needs of society.
9. Suppose the government passed a law saying, "Everyone must use an electric toothbrush." Use the four criteria to assess this change in the system of brushing your teeth.

Practise Your Skills

10. Explain why you think the figure below displays an automated system. List some positive and negative aspects of automating how we wash and dry our clothes.



For more questions, go to ScienceSource.

B44 *Thinking about Science, Technology, and Society*

Automating Your School's Recycling Program

At the beginning of this chapter, you examined the recycling program in your school. Suggest one component of this system that could be automated. Predict what effect this automation might have on your school community. If possible, predict the social, economic, and environmental impacts.

Making Connections

Jay Ingram

Jay Ingram is an experienced science journalist and is the host of *Daily Planet* on Discovery Channel Canada.

The Trebuchet

Imagine it is 1304. You are a Scottish soldier defending Stirling Castle against the English. You've hung in for months as the English siege machines battered the castle walls with balls made of stone and lead. You are completely surrounded and you're running out of food. If all that weren't bad enough, the King of England, Edward I, has just ordered his chief engineer to build a massive trebuchet, called the Warwolf.

A trebuchet (pronounced treb-you-shay) is a mechanism, but its heart is a strange lever with one arm longer than the other. The short arm has a gigantic weight at the end. The long arm is pulled down to the ground and held there. Imagine a teeter-totter with a very large man sitting on the short end and a gang of kids holding down the long end. When they let go, the man comes crashing to the ground. The trebuchet is like that, except that the large man is replaced by a giant weight and the kids by a trigger.

There is one more thing. The long arm has a sling attached to it: a long cord with a stone ball cradled in a net at the end. When the trigger is released, the weight falls. The long arm of the lever swings up like lightning, whipping the sling and its ball overhead. At just the right moment, the sling releases the stone ball and it goes flying toward the target.

What's most amazing about trebuchets is this: they're ancient machines, yet they were capable of amazing power and accuracy. They could throw weights of up to 1000 kg more than 200 m. They were also much more accurate than other launching devices, such as catapults.

Fifty men took three months to build the Warwolf, but in the end, it didn't play a part in the English victory. The Scots surrendered before it was even used. However, King Edward refused to accept their surrender until the Warwolf had flung a few of its 140-kg weights at the castle wall and bashed it in. That was the trebuchet's specialty: breaking down walls.

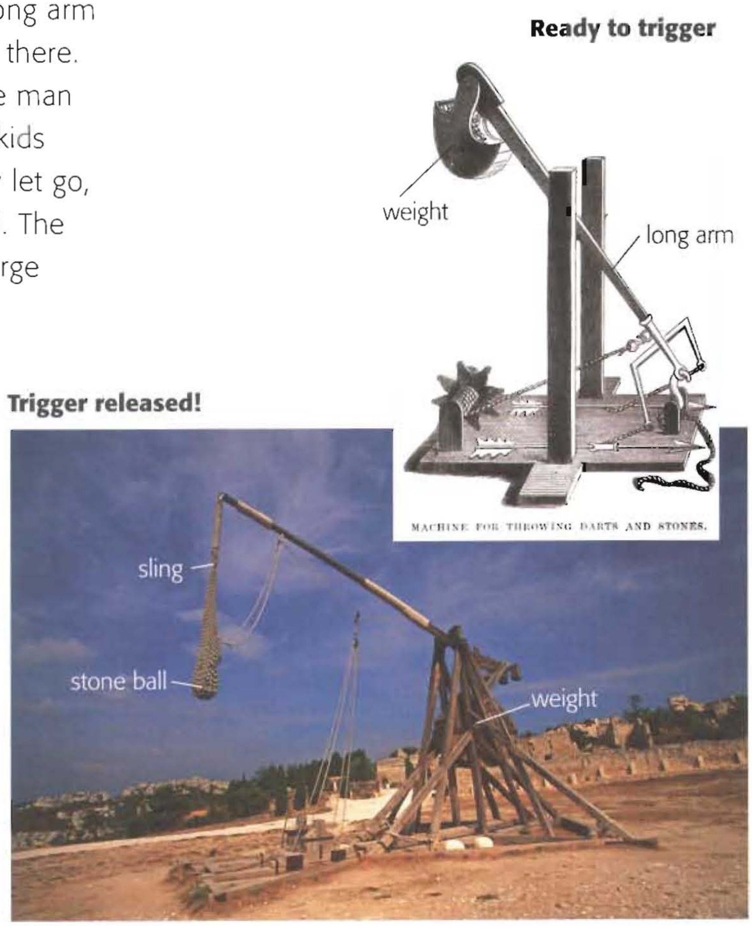


Figure 6.23 An old diagram of a trebuchet and a recently built one.

6.0 Chapter Review

Assess Your Learning

Key Concept Review

1. List three non-mechanical components of the school system.
2. The postal service is a system for delivering mail. Who are the "consumers" of this system?
3. What are two methods of support used to keep a system operating safely and efficiently?
4. Explain how an automated system is different from a non-automated system.
5. A bakery bakes 35 loaves of bread every hour. If the productivity of the bakery increases, how does the time to bake 35 loaves change?
6. Identify each of the following as a qualitative measurement or a quantitative measurement.
   (a) The water is at 66°C.
   (b) The creek had a strong current.

Connect Your Understanding

7. Your younger brother is given a toy that requires some assembly. Are the instructions for assembly a mechanical or a non-mechanical component of the toy system? Explain.
8. Often, a system is developed to meet a need of society. Identify the needs that resulted in the development of the following systems:
   (a) home alarm system
   (b) irrigation system
9. One year ago, a company stated: "We make 100 widgets every day." If the productivity of the company has increased in the past year, what statement(s) might the company make now?

After Writing *Thinking Literacy*

Reflect and Evaluate

Exchange your "Problem & Solution" writing piece with a classmate. Take some time to read your classmate's work. Provide each other with descriptive feedback, such as, what two things did he or she do well?

Did you learn something new about the impact of cars? Did you find new solutions to the negative impacts? Finally, share tips for writing a good "Problem & Solution" piece with the class.

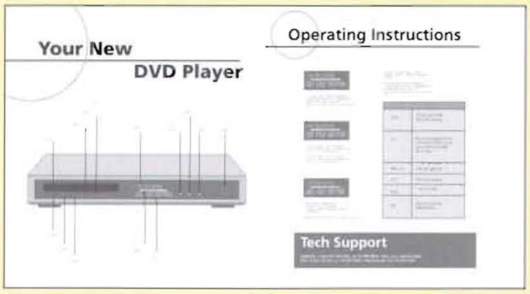
ACHIEVEMENT CHART CATEGORIES
Knowledge and understanding · Thinking and investigation · Communication · Application

10. The Sweet Tooth chocolate company produces one-of-a-kind handmade chocolates. To increase productivity, they decide to automate chocolate making. Suggest two positive and two negative impacts that might result from the automation of this company.

11. Explain how the furnace thermostat in your home or school is an example of an automated system.

Practise Your Skills

12. You have just purchased a new DVD player. You also received an owner's manual, shown at the right. Identify at least two properties of this owner's manual that are designed to help you operate this DVD player efficiently.

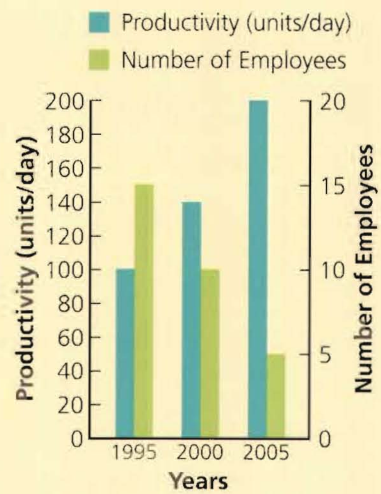


Question 12

13. The histogram to the right displays a company's productivity and the number of employees during a 10-year period. Use the histogram to answer the following.
    (a) Describe the changes from 1995 to 2005:
        (i) in productivity
        (ii) in the number of employees
    (b) What is the relationship between productivity and the number of employees?
    (c) Suggest a possible reason for these changes.

Unit Task Link

In your Unit Task, you will design, construct, and test a mechanical system that uses only the energy stored in a spring-bar mousetrap. The mousetrap machine you design must have a function other than catching mice. What is the need being met by your device? Using the four criteria, assess your mechanical system.



Question 13 Productivity and number of employees in 1995, 2000, and 2005

B45 *Thinking about Science, Technology, and Society*

Assessing the Change

Pollution caused by motor vehicles is a problem in all parts of the world. To address this problem, your local government decides to ban the use of any vehicle with a motor in your city or town.

Consider This

With a classmate or as a whole class, use the four criteria on page 169 to assess this new system of transportation.

UNIT B Summary

4.0 Mechanical systems use forces to transfer energy.

KEY CONCEPTS

- A force is a push or a pull on an object
- $W = F \times d$
- A machine is a mechanical system that makes doing work easier.
- $MA = \frac{F_{out}}{F_{in}}$
- Ideal mechanical advantage (IMA) assumes that the machine has zero friction.

CHAPTER SUMMARY

- The force of gravity (weight) is the product of the object's mass and the Earth's gravitational field.
- Work is done when a force causes something to move and energy is transferred.
- Machines make work easier by increasing the force applied to the object, by increasing the distance over which the force is applied, or by changing the direction of the force.
- The amount by which a machine can multiply the input force is called its mechanical advantage (MA).

5.0 Mechanical systems involve machines that are designed to do work efficiently.

KEY CONCEPTS

- A simple machine requires the application of a single force to do the work.
- Two or more simple machines that operate together form a mechanism.
- $Efficiency = \frac{W_{out}}{W_{in}}$
- Machines can be made more efficient by reducing friction.

CHAPTER SUMMARY

- The six types of simple machines are the lever, pulley, wheel and axle, inclined plane, screw, and wedge.
- The IMA of simple machines can be calculated as the ratio of lengths, the ratio of radii, or the number of support strings.
- The efficiency of a machine measures the useful work done by the machine compared to the work needed to operate the machine.
- Friction causes the input work to be transformed into heat, thus decreasing the efficiency of the machine.

6.0 Systems have an impact on our society.

KEY CONCEPTS

- A non-mechanical system is a procedure or process designed to perform a task.
- Systems develop from a need.
- Automating a system may have social, economic, and environmental effects.

CHAPTER SUMMARY

- Information and support are required to keep a non-mechanical system working efficiently.
- Productivity is the amount of output that is produced per unit of time.
- Automated systems replace human workers with machines that react without human intervention.
- The criteria for evaluating a system include efficiency, safety, cost, and environmental impact.

UNIT B Task

Mousetrap Machines

Getting Started

Successful machines carry out their functions consistently and efficiently. The best mechanical systems use the minimum component materials and are surprisingly simple in design.

The humble mousetrap evolved from an idea that was patented well over 100 years ago. Its job is simple: the instantaneous, painless, and humane dispatch of small rodents. The design that you can buy in any housewares store is virtually unchanged from the first working prototype.

Can you identify the components of this system? What is the role of each component? How do these parts work together to accomplish the desired result?

Your Goal

A spring-bar mousetrap will be your only source of power. You will design, construct, and test a mechanical system that uses the energy stored in the spring, to perform a task other than killing mice.

What You Need to Know

You have learned that systems are designed for specific functions. In this task, the mousetrap will power a system with a different function. How will you design your system so that the components work together to accomplish your new function? Check online at ScienceSource for mousetrap machine ideas or construction tips.

Review your notes dealing with mechanical advantage. Your chapter investigations will help you study the input and output forces acting on your system. Consider efficiency and friction in order to improve your initial prototype.

Steps to Success

1. As a class and under the strict guidance of your teacher, review the safe handling of a mousetrap.
2. Give your teacher a plan of your intended system (either CAD or technical drawing). Your teacher will give you the "proceed order" on your job.
3. Decide on the performance criteria that will determine if you have succeeded in your quest.
4. Construct your prototype. Keep an inventory of all materials used (including amounts) in a fabrication log.
5. Record in the log any problems or changes in plans as they occur.
6. Test your prototype's performance. Record your findings in your log. Modify components to determine the effect upon the system. Can you improve on the performance by changing one or more features? (Be sure to change only a single component each time.)
7. Present your final prototype, along with the design plans and fabrication log, in a gallery tour format. Be prepared to show the system in action.

How Did It Go?

8. Did your machine accomplish its stated function? Defend your answer using your results.
9. When you tested your machine, what component(s) worked as intended? Which did not?
10. Can you explain the problems that arose? Could they have been avoided?
11. Which component, when modified, caused the greatest change in performance of the system?
12. If possible, calculate the efficiency of your system.

UNIT B Review

Key Terms Review

1. Create a concept map that illustrates your understanding of the following terms. Begin with the term "Systems." (K)
   - automated system
   - efficiency
   - energy
   - force
   - ideal mechanical advantage
   - inclined plane
   - lever
   - mass
   - mechanical advantage
   - mechanical system
   - mechanism
   - non-mechanical system
   - productivity
   - pulley
   - simple machine
   - weight
   - work

Key Concept Review

4.0

2. What is a mechanical system? (K)
3. Give an example of a force that is classified as a: (K)
   (a) contact force
   (b) action-at-a-distance force
4. Your friend steps on a bathroom scale and states, "I weigh 40 kg." Explain why this statement is incorrect. (K)
5. What is the difference between force and work? (K)
6. State the two classifications of energy. (K)
7. In what three ways can a machine make work easier? (K)
8. Describe the difference between mechanical advantage (MA) and ideal mechanical advantage (IMA). (K)

5.0

9. What is the difference between a simple machine and a mechanism? (K)
10. Identify six simple machines. (K)
11. Make sketches of a first-class, second-class, and third-class lever. Be sure to label the input force, output force, and fulcrum on each diagram. (K)
12. What type of simple machine is each item below? (A)
    (a) inline skates
    (b) your jaw
    (c) screwdriver
    (d) hammer
13. Explain why machines are not 100 percent efficient. (K)
14. What is one method of increasing the efficiency of a machine? (K)

6.0

15. You just purchased a new stereo system. What two services might the stereo company provide to ensure that the system works safely and efficiently? (K)
16. Define "increased productivity" in terms of the number of tasks and the amount of time. (K)
17. Explain how a telephone answering machine could be considered an automated system. (A)
18. What is the difference between a qualitative and a quantitative assessment? (K)

ACHIEVEMENT CHART CATEGORIES
(K) Knowledge and understanding (T) Thinking and investigation (C) Communication (A) Application

19. What four criteria are often used when assessing a system?

Connect Your Understanding

20. A person travels to a distant planet that has a greater gravitational field than Earth. Describe the person's change in weight and mass.

21. Fouad pushes on a wall with a force of 75 N for one hour. Is he doing any work on the wall? Explain.

22. In a short paragraph and using examples, compare the scientific definitions with the everyday uses of the terms "work," "energy," and "efficiency."

23. If you increase the efficiency of a simple machine, does the:

(a) MA increase, decrease, or remain the same?

(b) IMA increase, decrease, or remain the same?

24. An Olympic track bike has an efficiency of 98 percent. By comparison a mountain bike has an efficiency of 85 percent. Suggest reasons for the Olympic bike's greater efficiency.

25. You need to lift a box 1 m to put it in a truck. Lifting the box straight up requires a force of 100 N. On the other hand, you could push the box up a 5-m-long ramp. This requires a force of 30 N.

(a) Which method of raising the box requires more work?

(b) Which method do you think would be easier? Why?

26. A cafeteria is a system designed to allow people to purchase a meal.

(a) List five components of a cafeteria system.

(b) Explain how each of the five components contributes to the system.

(c) List one factor that contributes to the system operating safely and one factor that contributes to the system working efficiently.

(d) Suggest how automation could be used to provide the same service.

27. What part of this unit did you find most difficult? What could you do to improve your understanding of that part?

Practise Your Skills

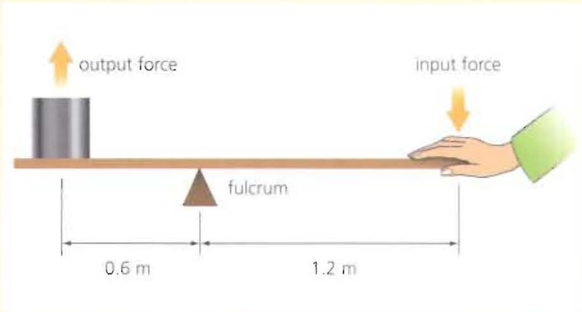
28. If the Earth's gravitational field is 9.8 N/kg, what is the force of gravity on a 5-kg mass?

29. Michelle uses a force of 50 N to push a table 2.5 m across the floor. How much work did Michelle do on the table?

30. Calculate the mechanical advantage (MA) for each situation in the chart below.

	Input Force (N)	Output Force (N)	Mechanical Advantage (MA)
(a)	5	25	
(b)	15	5	
(c)	12	12	

31. Calculate the ideal mechanical advantage (IMA) of the lever shown below.



Question 31

32. A pulley system lifts a 500-N weight a distance of 1.5 m. Marina pulls the rope a distance of 9.0 m, exerting a force of 100 N.

(a) What is the MA of this pulley system?

(b) What input work did Marina do on the rope?

(c) What useful output work did the rope do on the weight?

(d) What is the efficiency of the pulley system?

Question 34

33. A box weighs 20 N. Sketch a pulley system that will lift this box using an input force of 10 N or less.

Revisit the Big Ideas

34. A family currently uses a gas-powered lawnmower to cut their grass. They are thinking about switching to a human-powered push mower, like the one shown below left. Use the four criteria on page 169 for assessing a system to evaluate the new lawn-cutting system.

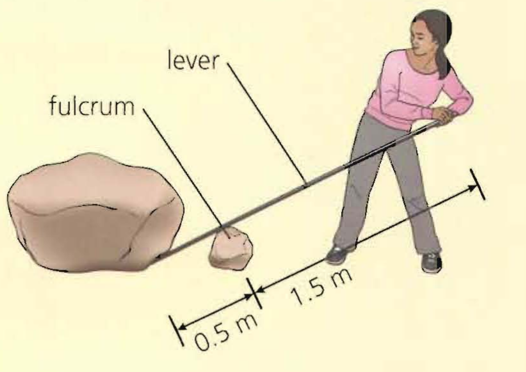
35. Explain the difference between a mechanical system and a non-mechanical system.

36. What does "Systems develop from a need" mean?

37. Using the illustration below, make a sketch of the lever.

(a) On your sketch, label the input force, the output force, and the fulcrum.

(b) How could you move the smaller rock to increase the mechanical advantage of the lever?



Question 37

ACHIEVEMENT CHART CATEGORIES
Knowledge and understanding · Thinking and investigation · Communication · Application

38. The following are components of a school system. Identify each component as either mechanical or non-mechanical.

(a) timetables

(b) staplers

(c) water fountains

(d) fire drill procedures

39. Suggest one positive and one negative outcome of increasing productivity.

40. A box lifted from the floor to a desk gains 300 J of gravitational potential energy. Calculate the efficiency of each machine used to move the box.

(a) An electric motor uses 400 J to lift the box.

(b) The rope on a pulley, attached to the box, is pulled a distance of 3 m using a force of 150 N.

(c) You push the box 5 m up a ramp using a force of 90 N.

B46 Thinking about Science, Technology, Society, and the Environment

Rethinking the Engine

Imagine that you are listening to a group of inventors in the 1880s describing their development of the internal combustion engine. This is the type of engine used in most cars today. During the discussion, you realize that they have not considered any of the social or environmental issues associated with the engine.

Consider This

With a classmate or as a whole class, discuss the following questions.

1. What need of society does the engine fulfill?
2. What are the social impacts of producing an internal combustion engine?
3. What are the environmental impacts of producing an internal combustion engine?
4. Why do you think the inventors in the 1880s ignored the social and environmental aspects of their invention?