CHAPTER 7

Simple Machines

Getting Ready...

- What is the relationship between work and energy?
- How do simple machines operate to make work easier?
- Why must we develop machines that are more energy efficient?
- Why is it a good idea to use renewable energy sources to operate machines?

Science Log

List three machines you use that work on a renewable source of energy. Explain how each of these machines makes life better for you. List any disadvantage of each machine.

Pyramids and statues of Easter Island are two marvels built with only the simplest of machines. Scientists still puzzle over how people could do this.

Over a million huge blocks of limestone were moved to build one pyramid. Blocks with masses over 1000 kg were raised 130 m.

Some statues on Easter Island weigh as much as four cars. The statues were moved kilometres across the island and raised into place. They were each then topped with another huge rock.

How could people in early societies accomplish this work?

They must have been experts with simple machines such as the lever, ramp, wheel and axle, and pulley. We use these same machines every day. In this chapter, you will see how much we depend on these simple machines.

You will also study the relationship between work and energy. You will investigate several simple machines and analyze how they make work easier. Finally, you will study the efficiency of machines. You will see that machines may make work easier — but there is a cost to us and to society.

and Energy Transfer

What You Will Learn

In this chapter you will learn:

- how work and energy are related
- how simple machines operate
- why it is necessary to develop more energy-efficient machines
- how to analyze the output of simple machines

Why It Is Important

- Both your personal budget and the global environment demand that machines be energy efficient. As you shift from non-renewable to renewable energy sources, you protect both. When you understand how simple machines work, you will have the wisdom of the ancients to help you make energy-efficient decisions.

Skills You Will Use

In this chapter you will:

- analyze the work of simple machines found around the house
- appreciate how many simple machines you use every day
- measure the relationship between work input and work output
- identify simple machines as force-multipliers or distance-multipliers
- investigate efficient machines that rely on renewable energy

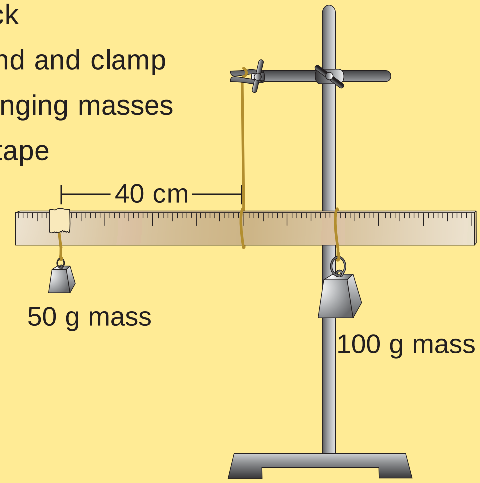
Starting Point ACTIVITY

Keeping Things in Balance

In this activity, you will investigate factors that balance or bring a teeter-totter into **equilibrium**.

What You Need

metre stick
retort stand and clamp
box of hanging masses
masking tape
string



Step 5

What to Do

1. Tie a metre stick so that it hangs, balanced, from a clamp on a retort stand. See the illustration.
2. Tape a 50 g mass 40 cm from the balance point of the stick.
3. Hang a 50 g counterweight at the other end of the stick. Move the 50 g mass until the stick is in balance.
4. Record the distance from the centre of the metre stick to the position where the 50 g mass balances the metre stick.
5. Remove the hanging counterweight. Repeat Steps 3 and 4, using a 100 g mass, a 200 g mass, and a 500 g mass. Record your observations.

7.1 All Kinds of Energy

READING Check

What is energy?

We usually think of **energy** in terms of fuel. You can see from the figures on this page, however, that there are many kinds of energy. We need a definition of energy that includes all of these. What do sound, light, a moving baseball, and a nuclear power plant have in common?

The answer is that they all make things move. They can all do work. Energy is the ability to do work.

Figure 7.1 The bungee jumper has stored *potential energy* due to her position above the surface of Earth. As she falls, she gains the energy needed to stretch the bungee cords.

Figure 7.2 The baseball has *kinetic energy* due to its motion.

Figure 7.3 The stove element is a source of *heat* or **thermal energy**.

Figure 7.4 The outlet is a source of *electrical energy*.

Figure 7.5 The light bulb emits *light energy*.

Figure 7.6 The speaker is a source of *sound energy*.

Figure 7.7 Some chemicals have stored *chemical energy*.

Figure 7.8 Enriched uranium used in a nuclear power plant has *nuclear energy*.

Find Out ACTIVITY

SKILL CHECK

Initiating and Planning

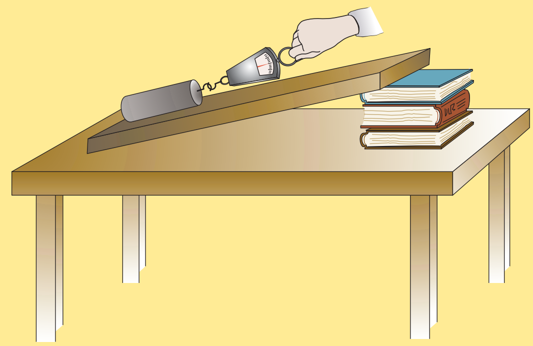
✷ Performing and Recording

✷ Analyzing and Interpreting

Communication and Teamwork

Wheelchair Ramps, Switchbacks, Propellers, and Screws

An inclined plane or ramp is the simplest kind of machine. As you complete this activity, you will find out if lifting or using an inclined plane makes work easier. As you complete the activity, think about how ramps, switchbacks, propellers, and screws use this physics.



What You Need

Newton spring scale

smooth, flat board (10 cm wide, 50 to 100 cm long)

smooth block of 2x4, 30 cm long (with a hook screwed into one end)

6 textbooks of uniform thickness

metre stick

string

What to Do

1. Use a loop of string to tie the spring scale to the block of wood.
2. Let the block hang freely. Lift the block from the desk top to the height of the stack of three books. As you lift, note the force recorded on the spring scale. Record that force.
3. Record the height, in metres, from the desk to the top of the stack of books.
4. Incline the board from the desk to the top of a stack of three books, as in the illustration.
5. Place the block of wood at the bottom of the ramp, as shown in the diagram.
6. Pull the block of wood up the ramp slowly. As you do this, note the force reading on the Newton scale. Record the effort used.
7. Add another three books to the stack. This will put the ramp at a different angle. Repeat Steps 2–6. Record your observations.

What Did You Find Out?

1. In each trial, how does the force used to slide the block up the inclined plane compare with the force needed to lift the block to the same height?
2. What effect does increasing the angle of the ramp have on the force needed to slide the block up the ramp? Justify your answer.
3. "You can't gain for losing" is true in science, too. What are you gaining with a ramp? How are you losing?
4. Discuss changes you could make to improve this machine.

Extension

5. How do wheelchair ramps, switchbacks, propellers, and screws use an inclined plane to do work?

READING Check

In what two ways are joules and newton-metres related?

What Is Work?

In science, a **force** is a push or pull. **Work** is done when a force moves an object. You were doing work when you pulled or lifted the block of wood to the top of the pile of books.

The amount of work done is recorded in various ways.

- A **newton-metre** (N•m) is the work done when one newton of force is used for a distance of one metre.
- A **joule** (J) is the standard way of reporting work done. One joule is equal to one newton-metre.

Work = force × distance
or
$W = F \bullet d$

Force is measured in newtons (N).
Distance is measured in metres (m).

To find out the amount of work done, multiply the distance something moved by the amount of force it took to move it. The formula will help you remember. Use this knowledge to calculate how much work was done in the Find Out activity on page 131.

Ramps Are Everywhere

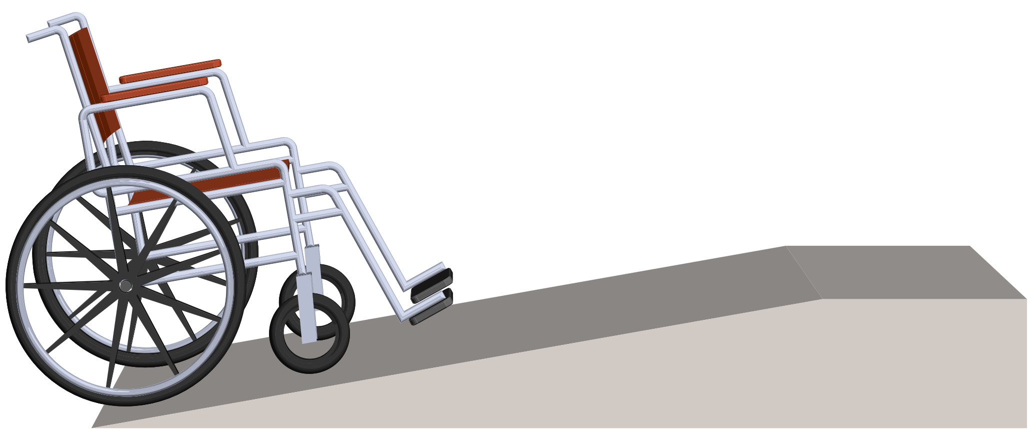


Figure 7.9 How do wheelchair ramps make things easier for wheelchair users?

Try This!

Which kind of screw is easiest to turn into wood: coarse or fine? Study the inclined plane on each screw. Make a prediction, and then try it.

Simple machines have one movement. The movement of an inclined plane is a slide.

The **inclined plane** or ramp is probably the oldest simple machine. Game trails and old paths use inclined planes, as do switchbacks. You use ramps when you bicycle. Going back and forth across a steep hill helps you climb with less effort.

You also use ramps in many hidden ways. The threads of a screw-top bottle are a form of ramp. So is the thread pattern on wood screws and metal bolts. These are circular inclined planes.

You Know You Are Working When ...

The scientific definition of work may surprise you. In science, work is done when *both* of the following occur.

1. A force is applied to an object.
2. The object moves — A person pushing against a solid wall is not working. The wall does not move. No work is being done.

Figure 7.10 No work is being done by the cyclist on a coasting bicycle. The bicycle is moving but the rider applies no force. Coasting is not work.

Figure 7.11 You *are* working when you pedal uphill. The bicycle is moving and you are applying force to the pedals to get the wheels to go around.

READING Check

How do you know when work is being done?

Using this definition, a person studying for an exam is not working. There is no force applied. No object is moved.

Check Your Understanding

1. In which of the following situations is work being done? Justify your answer.
   (a) A student lifts a stack of books from the floor to a desktop.
   (b) A student carries a gym bag down the hallway.
   (c) A student studies at a desk for two hours.
   (d) A student walks on a treadmill or pedals a stationary bicycle.
   (e) A student does push-ups.
2. What unit is equivalent to a newton-metre?
3. What is the difference between energy and work?
4. List five inclined planes that make work easier for you.

Key Terms

- equilibrium
- energy
- thermal energy
- force
- work
- newton-metre
- joule
- simple machines
- inclined plane

7.2 Just Prying into Things

Can you lift a 10 kg object vertically using five kilograms of effort?

You can if you use a lever, which is another simple machine. Levers are bars that pivot on a **fulcrum**. The object that the lever moves is the **load**. The force required to move the object is the **effort**. Look at Figure 7.12.

- The distance from the fulcrum to the load is the **load distance** (a).
- The distance from the fulcrum to the effort is the **effort distance** (b).

There are three classes of levers. You can tell what class a lever belongs to by where the parts are. In this section, you will look at the three kinds of levers and see where the various parts are located in each. As you go through, notice what happens to the effort distance and load distance when the fulcrum is moved.

Disc CONNECT

A simple machine is a machine with only one movement. A lever is an example of a simple machine. How do levers make us stronger? How do they allow us to move things faster? Are all levers the same? To answer these and other questions, load the student CD-ROM onto your computer. There are two applets on levers. Use **Levers 1** first, and then **Levers 2**, to find out about levers and how they make work easier.

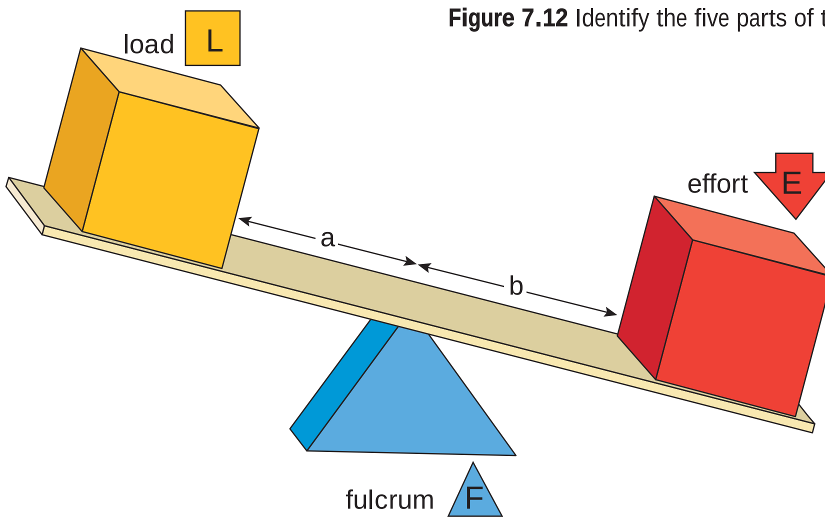


Figure 7.12 Identify the five parts of this lever.

First Class Levers

In a **first class lever**, the fulcrum is between the load and effort. You use a first class lever when you pry the lid off a paint can or use a long-handled fork to pick up a heavy load of hay or manure.

READING Check

Draw and label the parts of a first class lever.

Figure 7.13 This person is using a stick as a first class lever.

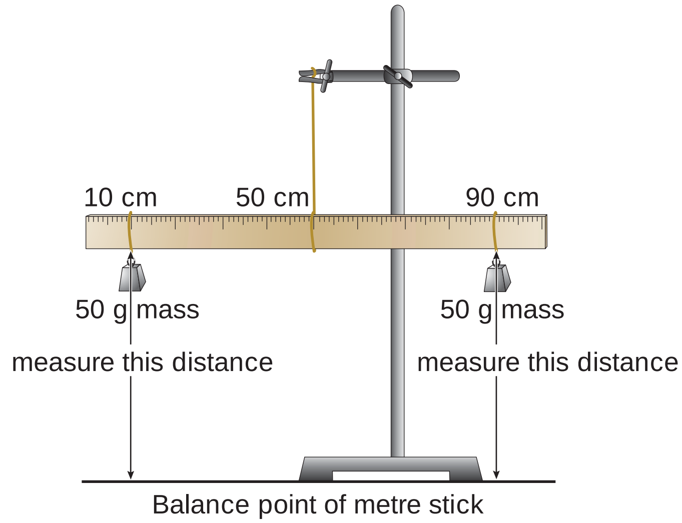
THINK & LINK

INVESTIGATION 7–A

SKILLCHECK

- Initiating and Planning
- ☼ Performing and Recording
- Analyzing and Interpreting
- ☼ Communication and Teamwork

A First Class Look Back



Think About It

In the Starting Point activity, you worked with a first class lever. Complete this investigation to find one advantage of first class levers. Your teacher will provide some analysis questions.

What You Need

metre stick
retort stand and clamp
box of hanging masses
string
ruler

What to Do

1. Refer to your notes from the Starting Point activity. Set up a table for recording results.

2. Set the teeter-totter up as you did to begin the Starting Point activity.

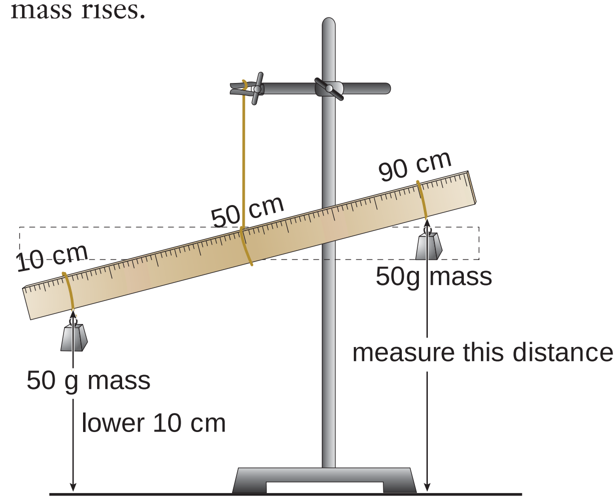
3. Place one 50 g mass 40 cm from the centre of the metre stick. Place the second 50 g mass on the other end of the metre stick, but also 40 cm from the centre.

Adjust the distance of the 50 g mass on the left side until the system is in balance. Measure and record the distance from the desk top to the bottom edge of the ruler directly above each mass.

5. Slide the 50 g mass on the left side 1–2 mm away from the centre until the teeter-totter is just out of balance.

Controlling the end of the teeter-totter, allow the left side to lower 10 cm.

7. Measure and calculate how far the other 50 g mass rises.



Repeat Steps 3 to 7 using:
- a 100 g mass on the right side 20 cm from the centre
- a 200 g mass on the right side 10 cm from the centre

First Class Levers Around the House

Try This!

Hand brakes on bicycles and motorcycles are first class levers. Sketch a brake handle. Label the fulcrum, effort, and load.

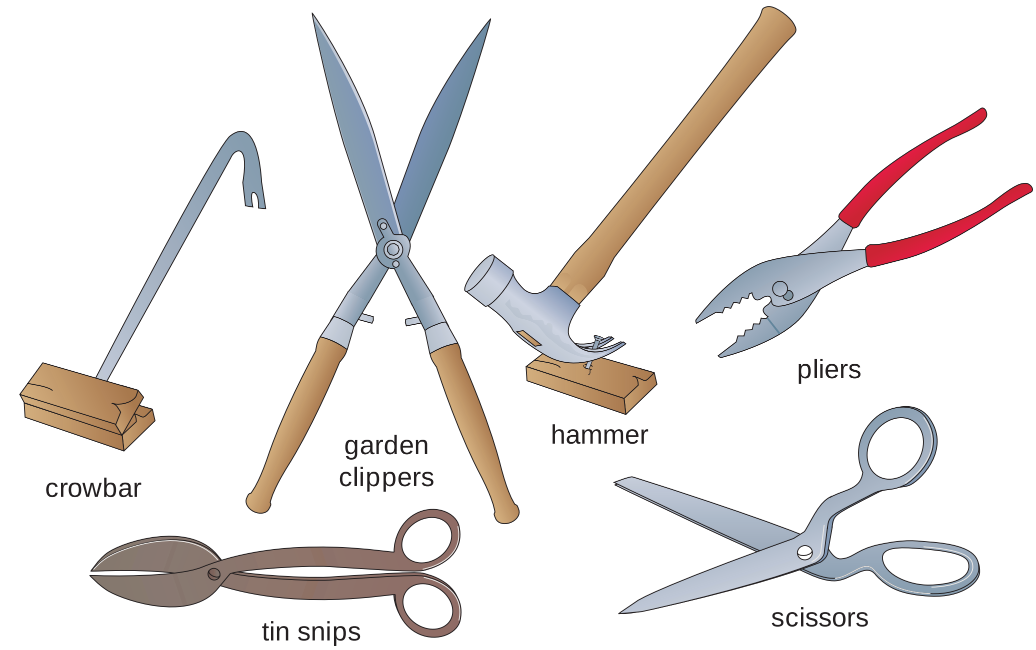


Figure 7.14 Many common household tools are examples of the first class lever. Identify the fulcrum, load, and effort for each.

READING Check

Sketch one household tool that is a first class lever. Label the fulcrum, load, and effort. Explain how you can increase the effort.

First class levers are used for lifting, prying, and cutting. In a pair of scissors, for example, the fulcrum is the screw that holds the scissor blades together. Your hand gives the effort. Cutting is the load. Pliers work in much the same way. In this simple machine, the effort applied to the handles is used to grip or hold the load.

Other examples are all around you. Put a piece of paper in a binder or clipboard and you have used a first class lever. Most light switches and lawnmower speed controls also use first class levers. Watch how many you use at home tonight.

Second Class Levers

A wheelbarrow is an example of a **second class lever**. In this type of lever, there is a bar with the fulcrum at one end, an effort at the other end, and a load in between. Sketch how you can use this kind of lever to lift heavy objects.

Some can openers, bottle openers, and nutcrackers are second class levers. Others are first class levers. Check any you have around the house and see if you can classify them.

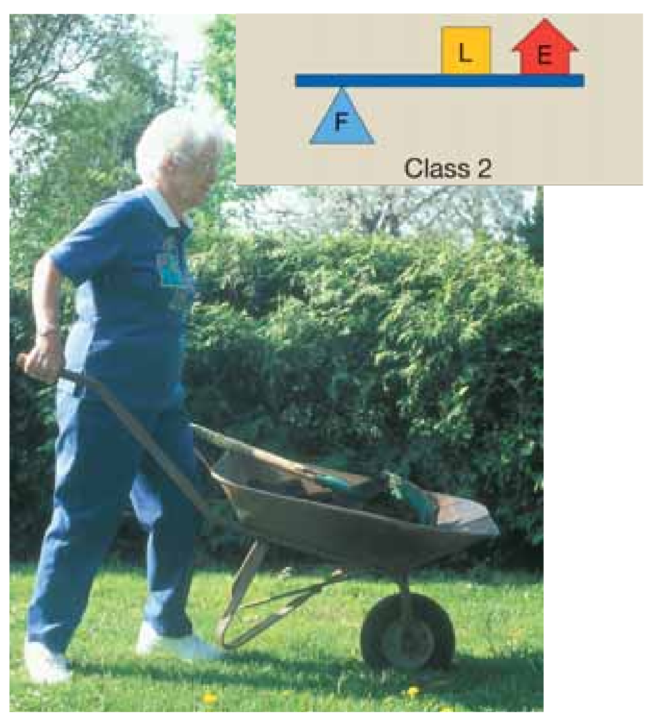


Figure 7.15 A wheelbarrow is a second class lever. Note the location of the fulcrum, effort, and load.

READING Check

How is a second class lever different from a first class lever?

Third Class Levers

A fishing pole is an example of a **third class lever**. As with the second class lever, the fulcrum is at one end. Unlike the second class lever, the effort in a third class lever is between the load and the fulcrum.

Third class levers are often used when the job calls for speed. Axes, rackets of all kinds (for example, tennis, squash, and badminton), and hockey sticks are examples of third class levers that use this speed advantage.

Tongs, brooms, and tweezers are also third class levers.

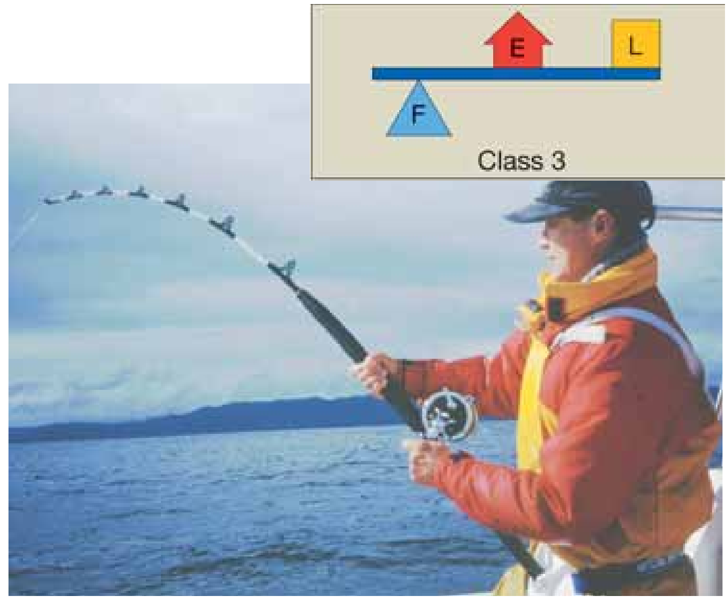


Figure 7.16 A third class lever applies effort between the fulcrum and load.

READING Check

Draw a picture showing a broom used as a third class lever. Label the location of the fulcrum, effort, and load. How does placement of effort slow the load?

DidYouKnow?

A batter will often "choke-up" a baseball bat. This is done by moving the hands closer to the hitting end, thus decreasing the load distance. Holding the bat like this allows the batter to hit with greater control and less effort. The ball is not hit as hard.

Find Out ACTIVITY

SKILL CHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Rackets, Bats, and Sticks

Do this activity to find out what advantage you gain with third class levers.

What You Need

hockey stick
metre stick
tape

What to Do

1. Work in groups of three. One person holds the hockey stick close to the floor as though about to make a wrist shot. One person is ready to mark the distance the stick moves. The third person measures how far the effort hand moves.
2. The student with the hockey stick holds the fulcrum hand unnaturally still and takes a shot in slow motion. The other two group members note the distances described in Step 1.

What Did You Find Out?

1. What difference is there between the distance the stick moved and the distance the hand moved?
2. **(a)** What effect would the moving stick have on a small ball placed at the blade?

   (b) Compare the movement of the effort hand and the blade of the stick. What is the effect on the ball if you speed up the effort hand?
3. What two advantages does a third class lever have?

Extension

4. How do tennis rackets and baseball bats provide the advantages of a third class lever?

Your Body Has Levers Too

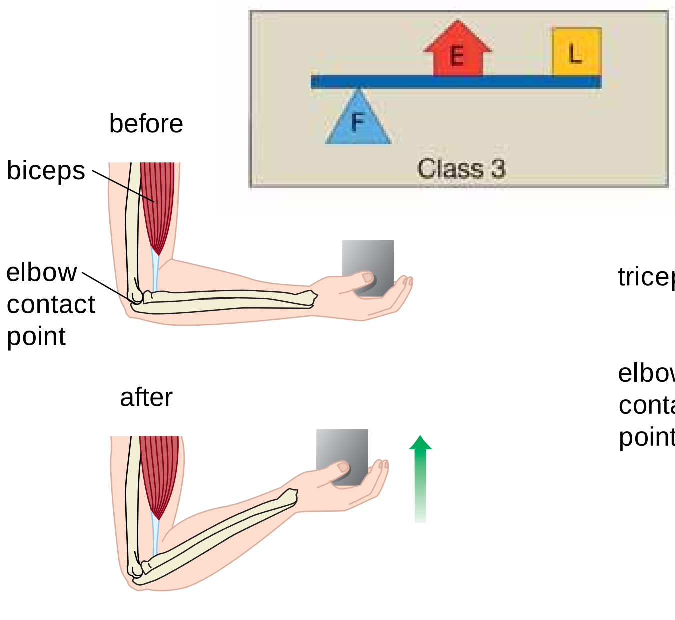


Figure 7.17A Many of the muscles and bones in your body work as levers. In the third class lever shown here, the biceps muscle *provides* the effort force. The effort itself occurs where the tendon meets the bone. The hand is lifting.

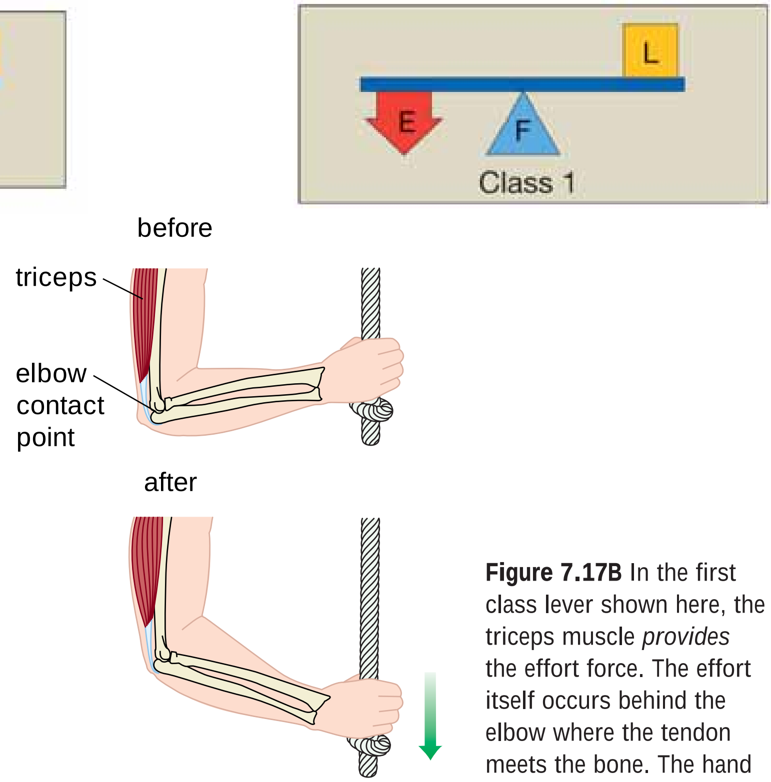


Figure 7.17B In the first class lever shown here, the triceps muscle *provides* the effort force. The effort itself occurs behind the elbow where the tendon meets the bone. The hand is pulling down.

READING Check

Which of your arm muscles should provide the most speed when you are throwing a ball?

Examine Figure 7.17 to see how your forearm has an example of a first and a third class lever. In both cases, the hand holds the load and the elbow is the fulcrum. Check it out.

First class lever — Triceps reach from the back of your upper arm and around your elbow. (Check to see where the ligament for this muscle is attached.) This muscle pulls your arm down. Notice the location of the effort, fulcrum, and load.

Third class lever — The biceps, the large muscle at the front of your upper arm, provides effort. (Check to see where the ligament for this muscle is attached.) This muscle moves your arm up. Notice the location of the effort, fulcrum, and load.

Off the Wall

Archimedes said that if he had a lever long enough and a fulcrum strong enough, he could move the world. Do you think he meant a third class lever? Explain.

Distance Multipliers

Fishing rods and hockey sticks are simple machines that work as **distance multipliers**. When you make a cast, the end of the fishing rod moves more than a metre as your wrist flicks and hardly moves at all.

A distance multiplier moves a load through a large distance but requires a short effort distance. Third class levers are common distance multipliers. When distance is multiplied, it provides a speed advantage. During a good cast, the tip of the fishing rod moves far and fast. During a good smash, the head of a tennis racket also moves fast.

Besides sports equipment, axes and mallets are common distance multipliers.

Force Multipliers

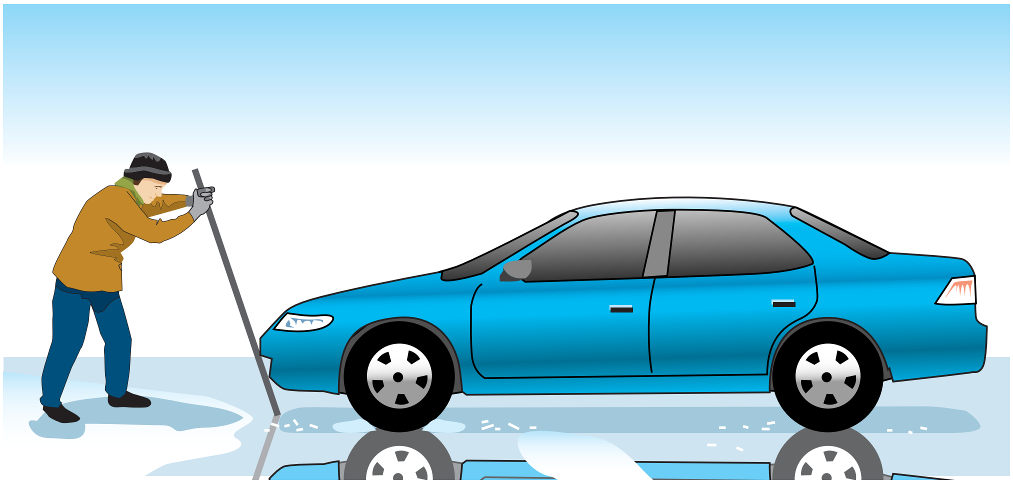


Figure 7.18 When the load distance is small, a large load can be moved with little effort. But don't try this if you have a plastic bumper!

A **force multiplier** is a simple machine that easily moves a large load. A small force on the effort end of the lever puts a large force on the load. Force is multiplied.

What happens with the distance that the force and load move? Think back to the Find Out activity on page 137. When the effort end moves a great distance, the load moves a small distance. If the load distance is small, the lever is a force multiplier.

First and second class levers tend to be force multipliers.

Try This!

How many levers are within reach as you sit in a car? Are they first or second class?

READING Check

Explain the difference between a distance multiplier and a force multiplier.

Check Your Understanding

1. How can a simple machine make work easier?
2. Draw and label a diagram to show the three parts of a second class lever.
3. Use sentences or sketches to explain the difference between a first and third class lever.
4. Use your knowledge of levers to explain why an axe with a long handle chops more easily than one with a short handle.
5. List three examples for each of the three classes of lever. Identify each example as a force or a distance multiplier. Use part of your body as at least one example.
6. What happens to the effort distance and load distance when the fulcrum is moved?

Key Terms

fulcrum
load
effort
load distance
effort distance
first class lever
second class lever
third class lever
distance multiplier
force multiplier

7.3 Wheels, Pulleys, and Blocks

Anyone who enjoys cycling, inline skating, or riding a ski lift will agree that the wheel is a most important human discovery. A **pulley** is a grooved wheel. When there is a rope threaded around the pulley, it is a simple machine. The load is attached to one end of the rope. Effort is applied at the other end. When the *effort* can just support the *load*, the system is in equilibrium. Do the Investigation that follows to learn more about pulleys.

CONDUCT AN INVESTIGATION 7–B

SKILLCHECK
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Pulleys Make Work Easier — Sometimes

Problem

How can we use a pulley to make it easier to lift a load?

Apparatus

ruler

board 1 m long with two hooks, one on either side of the centre

3 pulleys

block of wood (30 cm piece of 2x4) with a hook screwed into one end

Newton spring scale

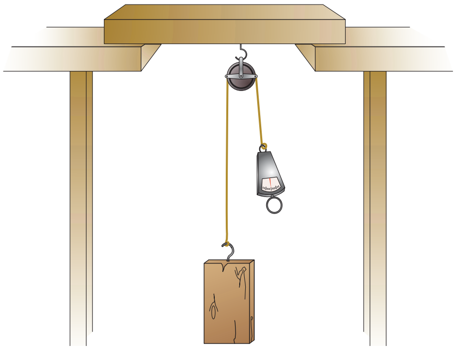
Materials

2 pieces of heavy string or butcher cord (1.5 and 3 m)

Procedure

Part 1

1. Hang the block of wood from the scale. Record the force required to suspend the wood.
2. Support the board between two desks as in the illustration. Hang a pulley from one of the hooks on the board. Put the block of wood on the floor under the pulley. String the cord through the pulley and tie it to the block of wood.



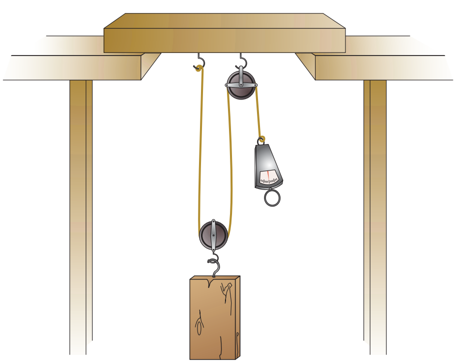
3. Mark the cord at the point where it exits the pulley.
4. Tie a loop in the loose end of the cord. Hook the scale to the loop. Gently pull down on the scale until the block of wood rises slowly.
5. Record the reading on the scale.
6. Keep pulling until the block is 10 cm off the floor. Mark the string at the point where it now exits the pulley. Record how far the string was pulled.

Part 2

1. Attach a pulley to the hook just to the right of the centre of the board.

2. Attach the block of wood onto a second pulley using the hook on the end of the block.

3. Tie the cord to the hook just to the left of the centre of the board. String the cord down through the pulley attached to the block of wood, then up and through the fixed pulley on the board, and then back toward the floor. See the illustration below.



Mark the cord at the point where it exits the pulley system.

5. Hook the scale to the loop on the free end of the string. Gently pull down on the scale until the block of wood rises.

As the block rises, record the reading on the scale.

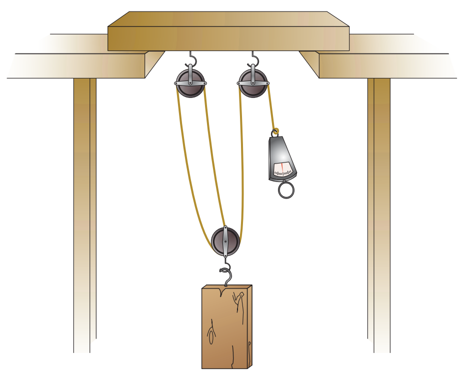
7. Measure and record how far the cord is pulled down to raise the block 10 cm.

Part 3

1. Attach a pulley to each of the hooks on the board.

2. Attach a pulley to the top of the block of wood.

3. Run the string from the top of the pulley attached to the block of wood, up through the pulley on the left, back down and through the lower pulley, and then up and through the second pulley on the right. Run the loose end down toward the floor. See the illustration, left.



Repeat Steps 4–7 in Part 2.

Analyze

1. Which pulley set-up required the most effort to lift the block of wood? Explain why.
2. Which pulley set-up required the least effort to lift the block of wood? Explain why.
3. What difference was there in the distance the cord was pulled in Parts 1, 2, and 3?

Clotheslines have pulleys like the one you used in Part 1. This is called a fixed pulley because the pulley does not move with the load.

Some oil rigs move loads with pulleys like the one you used in Part 3. This is called a moveable pulley because the pulley moves with the load.

Fixed and Moveable Pulleys

Single pulleys like the one in Figure 7.19 are used to change the direction of effort. This is what raises a flag or adjusts a curtain. The rope that you pull is threaded through a pulley fixed at the top. In a **fixed pulley**, effort force is equal to load force. You used this type of pulley in Part 1 of Investigation 7–B.

Moveable pulleys are like the ones you tied to the block of wood. **Moveable pulleys** move with a load.

Review the results of Investigation 7–B. In Part 1, the block of wood was supported at one point. In Part 2, the block of wood was supported at two points — at the hook and at the pulley. Twice as many supports meant half the effort to lift the weight. What happened when the load was supported at three points?

READING Check

What is the difference between a fixed and a moveable pulley?

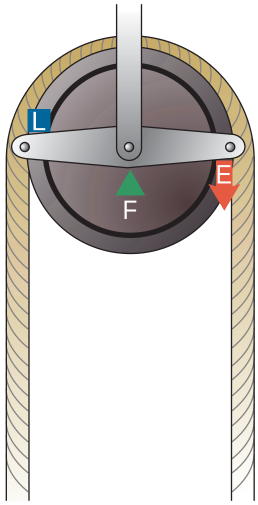


Figure 7.19 This pulley works much like an equal-armed teeter-totter. What downward force would you need to lift 50 kg off the ground with this pulley?

Career CONNECT

Figure 7.20 Machines such as these use many kinds of levers. Heavy machinery clears forests, levels earth for a new highway, and demolishes buildings. The biggest machines use a complex variety of simple machines. Where is the input force and the output force for the machine pictured here?

To become a qualified heavy equipment operator, you need a high school diploma and two years of vocational training in diesel mechanics. An apprenticeship program gives you practical experience under the supervision of an experienced worker.

To enter the apprenticeship program, you need to pass an entrance exam that tests knowledge of simple machines.

Turning and Turning: The Wheel and Axle

Every time you turn a doorknob, you rotate a simple machine known as a **wheel and axle**. The doorknob, a large wheel, turns the axle. Have you ever tried to turn the shaft and open the door when the knob is missing? If you have, then you know the large doorknob is easier to turn than the small axle. Would it take more or less effort to open the door if the knob were very small?

A screwdriver operates on the wheel and axle principle. The handle of a screwdriver is large compared to the diameter of a screw. The fat handle acts like the wheel; the screw is the axle. As you rotate the handle, the screw moves a small distance. The circumference of the handle moves a greater distance.

READING Check

How is the wheel and axle similar to the lever?

Figure 7.21 Both the wrench and the nut will turn through 360°. By the time the wrench has gone completely around, it has acted like a large wheel. This large wheel is easy to turn compared to the smaller wheel, the nut. A little effort on the wrench moves a heavy load on the rusty nut.

DidYouKnow?

A winch is a lever that keeps on lifting. The centre of the axle is the fulcrum. The effort distance is the distance from this fulcrum to the winch handle. Where is the load distance?

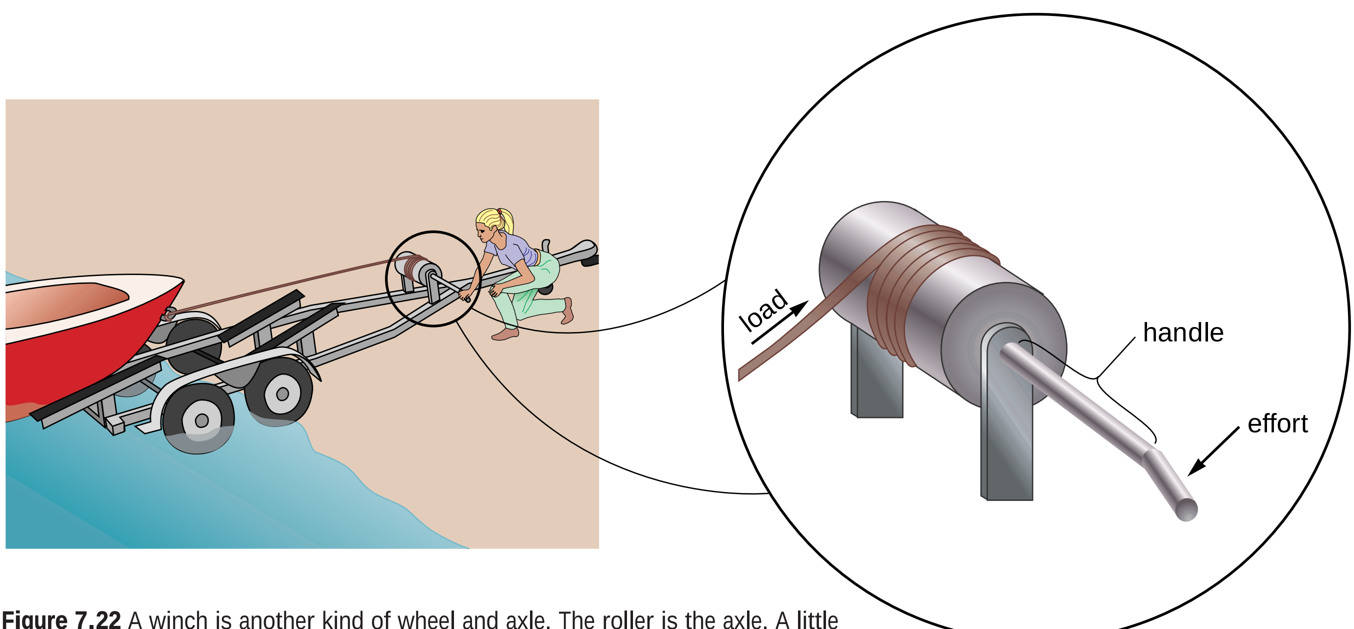


Figure 7.22 A winch is another kind of wheel and axle. The roller is the axle. A little effort on a winch handle turns the axle and pulls a heavy load toward the winch. What if the load were too heavy to move? What would be two effects of having a longer handle?

Find Out **ACTIVITY**

The Great Pyramids of Egypt

The pyramids of Egypt are among the most spectacular structures on Earth. How did workers make these gigantic pyramids using only simple machines?

What to Do

1. Review the simple machines outlined in this chapter. Predict which machines the Egyptians might have used.
2. Make drawings of what these tools might have looked like. Explain how each probably worked.
3. Using reference books, research the tools used to build the great pyramids of Egypt.
4. Prepare a report to present to the class.

SKILL CHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

What Did You Find Out?

1. Make a summary of all the simple machines that were suggested by members of your class.
2. Which of these simple machines could easily move giant blocks like those used on the pyramids?

Internet CONNECT

www.mcgrawhill.ca/links/science.connect1

In this Internet Connect, you will investigate the building techniques that the Egyptians might have used to build the pyramids. You will also consider the simple machines that might have been used to do some of the work. To learn more, go to the above web site. Go to Internet Connects, Unit B, Chapter 7, and then to The Great Pyramids.

Key Terms

pulley
fixed pulley
moveable pulley
wheel and axle

Check Your Understanding

1. What is the difference between a fixed pulley and a moveable pulley?
2. Explain how each type of pulley can make work easier.
3. What type of simple machine is each of the following?
   (a) water faucet
   (b) clothesline
   (c) winch
   (d) gearshift on a car
   (e) wrench
4. You find it difficult to put screws into a piece of wood. You cannot turn the screwdriver. Would you be better to change to a fat-handled or thin-handled screwdriver?
5. Give three examples of everyday items that use the wheel and axle as a force multiplier. Explain how each works to multiply force.

7.4 Spinning Our Wheels: Energy and Efficiency

When your car is stuck in a drift, usually it does not help to spin your tires. It wastes energy, and often gets you stuck even worse. Despite this fact, all machines spin their wheels to some extent.

When you worked with the inclined plane, you found that it took more work to move the block up the plane than to lift the block to the same height. Using the machine was easier but it took more work.

This is true of all machines. Remember that Work = $F \bullet d$. When a load of 100 N is lifted 5.0 m, it requires 500 J of work. The 500 J of work must be done whether a machine is used or you lift the mass yourself.

Figure 7.23 What can you do instead of spinning your tires?

When a machine is used, the machine itself will lose energy through:

- friction between any two moving parts that touch each other, such as between a piston and the cylinder wall of an engine, or between a tire and the road;
- heat that is given off by the cooling system or through the exhaust and is therefore not used to do the work; and
- poor combustion (if it uses fuel) — when an engine is poorly tuned, some of the fuel is not burned but given off as smoke or carbon particles.

The amount of work input is always greater than the amount of useful work output.

READING Check

Name two factors that make machines either efficient or inefficient.

Efficiency

You get compliments on your **efficiency** if you complete a task well and quickly.

A machine's efficiency is a comparison of the work the machine does with the energy it uses to do that work. No machine is 100 percent efficient. The work output does not equal the work input. For example, when you push a car, all of the work you do does not help to move the car forward. Your feet may slide backward — that is work. Similarly, you pant and sweat, which are ways of using energy.

When you use a burner to cook food, the food being cooked does not receive all of the energy put out by the burner. Some of the heat moves from the burner into the air by way of convection. Convection currents also move some of the heat from the pot to the air. Only a fraction of the heat supplied by the burner actually reaches the food.

Did You Know?

One kilowatt hour is equal to a little more than 3.5 million joules. We use kilowatt hours as the unit for large amounts of energy.

Efficiency Around the House

Does anyone around your house complain when someone leaves the doors open in winter, the lights on, or the stereo volume on high? The cost of energy has risen — and continues to rise. Efficiency is a way to conserve energy and money. Conserving energy also helps the environment. The table below will begin to give you an idea about where you can start conserving.

Table 7.1 Efficiency of Some Common Technologies

Type of Technology	% Efficiency
battery	90
furnace	70–90
electrical appliances	80–95
gasoline engine	25–40
incandescent light bulb	5–20

Household appliances and machines vary in efficiency. Electric appliances are quite efficient; gasoline engines are not. Where could you replace inefficient non-electric engines with efficient electric ones?

Also consider your use of light bulbs. Light bulbs are very inefficient because they waste a lot of energy making heat.

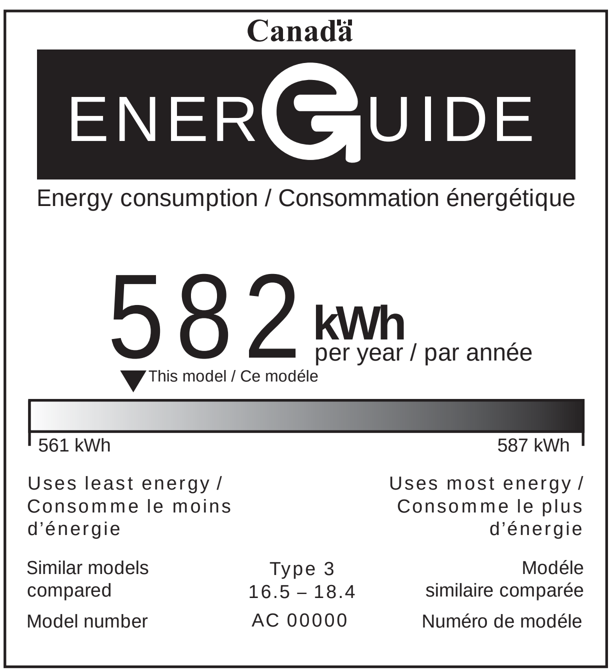


Figure 7.24 The Energuide Number indicates how much electrical energy a machine will use during one year of average use. Smart shoppers check the Energuide Numbers on any appliances they are thinking of buying.

New appliances have a label with an "energy use" rating called an Energuide Number. The number tells how much electrical energy that machine will use during one year of average use.

The Energuide Number shows energy in **kilowatt hours** (kW•h). A kilowatt hour is the amount of electricity used when 1000 watts is used for one hour. A 100 watt bulb burning for 10 hours uses one kilowatt hour of energy.

Reading Check

Explain one good way to use the Energuide Number.

INVESTIGATION 7–C

SKILLCHECK
- Initiating and Planning
- Performing and Recording
- **Analyzing and Interpreting**
- Communication and Teamwork

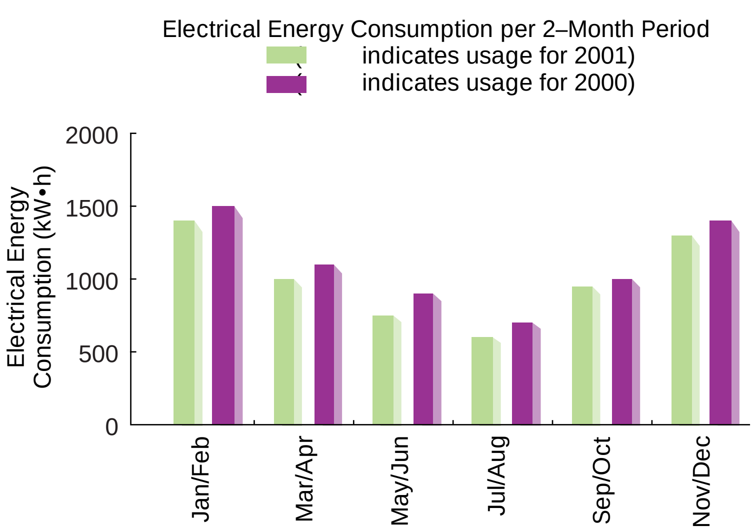
Energy Efficiency in the Home

Think About It

In Canada, the average household uses 39 200 kilowatt hours (kW•h) of energy per year. With rates rising, you can save some of that money for other things by being energy efficient.

What to Do

1. One way to judge the energy efficiency of your home is to look at the consumption of electricity. In Alberta, power companies send users a graph like the one below. The graph shows how much electricity the household used that year and the previous year.



Analyze

1. Consumption graphs can be used to compare energy use from year to year.

(a) In which pairs of months was more energy used in 2000 than in 2001?

(b) Suggest reasons to explain this.

(c) Suggest several reasons why more electrical energy might be used during winter months.

2. In a small group, discuss ways of reducing use of electrical energy around the home. Make a list of ideas. Prioritize the list according to the amount of energy that could be conserved.

3. Record energy use in your home by doing a meter reading or by examining bills sent in the mail.

Try This!

If electricity costs 11¢ per kW•h, calculate how much 39 200 kW•h would cost.

The Bigger Problem

One obvious benefit to using less energy is lower monthly energy bills. Another reason to use less energy is that it benefits the environment.

Most of the energy used in Canada comes from burning fossil fuels. There are two environmental concerns related to the use of fossil fuels:

- burning fossil fuels contributes to global climate change and air pollution, and
- fossil fuels are non-renewable.

How can we deal with these problems? Fortunately, there are two ways.

1. Reduce the amount of energy you use, either by using machines less or by changing to more efficient machinery.
2. Use energy from renewable sources.

The photos on these pages provide several ideas for conserving energy. Which ideas might you try?

Figure 7.25 For years, windmills have powered water pumps and ground flour. Recently, new styles of windmills have been put together on wind farms. These batteries of windmills produce electricity. The Cowley Ridge Wind Plant, for example, produces more than 55 million kW•h of electricity per year. That is enough to power 6800 efficient homes.

Figure 7.26 Solar panels collect energy from the Sun and convert it to electrical or heat energy. Many Canadians use such panels to run electric fences, heat water, and power calculators and lights. Electricity can either be used right away or stored in batteries for later use.

Figure 7.27 Recently, solar-powered and hand-wound radios were developed for use in countries where electricity is scarce. Many Canadians now use these radios because they do not need batteries or an electricity source.

Figure 7.28 Car and truck exhaust is a major cause of pollution. For years, manufacturers and private citizens have worked to make cars less polluting. The Ballard fuel cell uses hydrogen and oxygen gas to power passenger vehicles. This innovation is being developed by Ballard Generation Systems (a British Columbia company). The company sells fuel cell engines to DaimlerChrysler and Honda, who are testing the engine on passenger cars and buses.

A researcher at the University of Toronto is working with Toyota to develop another efficient and cost-effective car. This car's power system consists of a fuel cell and a hydrogen storage system. Within the next two decades, we should be able to drive vehicles that do not produce harmful exhaust.

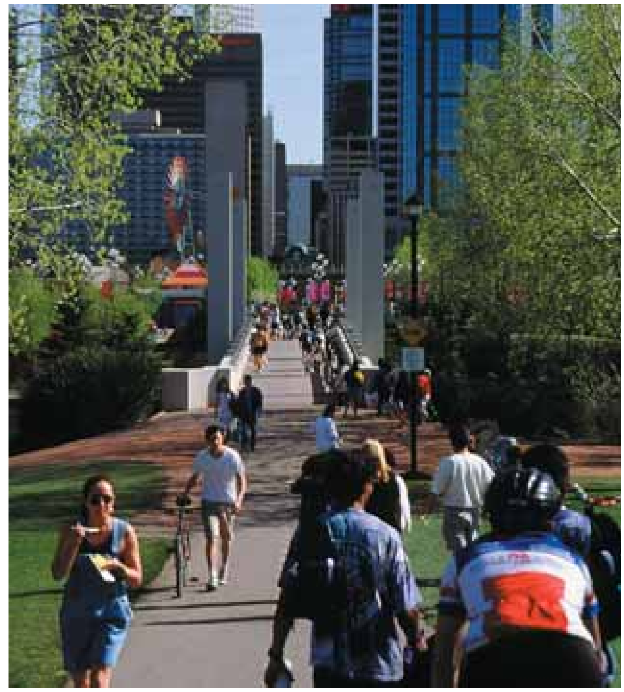


Figure 7.29 Many people commute to work using muscle power. Inline skates, bicycles, and walking are low-cost ways to save energy and money. That is why many messenger companies deliver important parcels using couriers who skate or cycle. On busy streets, skating and cycling can be faster than driving.

READING Check

List three ways to reduce your use of electricity.

Internet CONNECT

www.mcgrawhill.ca/links/science.connect1

To learn more about fuel cells, go to the above web site. Go to Internet Connects, Unit B, Chapter 7, and then to Fuel Cells. The promises seem too good to be true. What do you think?

Try This!

With a partner, watch the cars that pass on a busy street. Record the number of cars with one, two, three, or more people. Graph your results for a class comparison.

How is car pooling encouraged in your area?

Check Your Understanding

1. Name two factors that reduce the efficiency of machines.
2. List three benefits of becoming more energy efficient.
3. List three ways a home may become more energy efficient.
4. What is one disadvantage of becoming more energy efficient?

Key Terms

efficiency
kilowatt hour

CHAPTER

7 Review

Key Terms

equilibrium
energy
thermal energy
force
work
newton-metre
joule
simple machines
inclined plane
fulcrum
load
effort
load distance
effort distance
first class lever
second class lever
third class lever
distance multiplier
force multiplier
pulley
fixed pulley
moveable pulley
wheel and axle
efficiency
kilowatt hour

Reviewing Key Terms

If you need to review, the section numbers show you where these terms were introduced.

1. In your notebook, match each clue in Column A with a key term in Column B.

A	B
(a) a rod attached to a wheel	i. distance multiplier (7.2)
(b) when a force moves an object	ii. pulley (7.3)
(c) a push or a pull on an object	iii. energy (7.1)
(d) rope on a grooved wheel	iv. wheel and axle (7.3)
(e) load moves farther than effort	v. work (7.1)
(f) the ability to do work	vi. force (7.1)
(g) small effort moves heavy load	vii. simple machine (7.3)
(h) a wheelbarrow is one	viii. first class lever (7.2)
(i) fulcrum is in the middle	ix. second class lever (7.2)
(j) a comparison of work input to work output	x. moveable pulley (7.4)
(k) it has no moving parts	xi. third class lever (7.2)
(l) pulley attached to load	xii. force multiplier (7.2)
(m) it has only one movement	xiii. efficiency (7.4)
(n) a hockey stick, for example	xiv. inclined plane (7.1)

2. Draw a picture of a second class lever. Add the following labels in the correct place. (7.2)

load force, effort force, load distance, effort distance, fulcrum.

Understanding Key Ideas

Section numbers are provided if you need to review.

3. What class of lever has the fulcrum at one end, the load in the middle, and the effort at the other end? Give one example of this class of lever. (7.2)

4. A fixed pulley does not decrease the amount of effort required to lift a load. How does using a fixed pulley make lifting a load easier? (7.2)

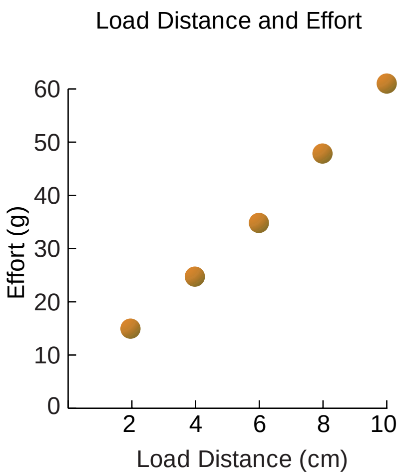
5. The steering wheel of a large truck is usually larger than the steering wheel of a small car. Explain why the large truck might have a larger steering wheel than a small car. (7.3)

Developing Skills

6. A student investigated to see if altering the load distance affected the force required to lift a mass. The graph on the next page shows the data collected.

(a) Write the student's conclusion.

(b) Study the graph. Write a general statement about the amount of effort required to lift a load when the load distance is increased. Make sure your statement is supported by the information in the graph. (7.2)



Problem Solving/Applying

7. (a) A dog picks up a bone that has a weight of 5.0 N and lifts the bone a vertical distance of 0.2 m. Calculate the work the dog did. (7.1)

(b) The dog then carries the bone horizontally a distance of 10.0 m. How much work has it done now? (7.1)

8. You must lift a heavy load to the top of a tall building. Describe or sketch a simple machine that could help you do the job. (7.3)

Critical Thinking

9. Does a simple machine really reduce the amount of work you do? Explain your answer. (7.4)

10. Why does it require less effort for a moveable pulley to lift an object than it does for a fixed pulley to lift the same object? (7.3)

11. (a) Explain why the efficiency of a machine is always less than 100 percent.

(b) Suggest three ways you can increase the efficiency of a machine. (7.4)

Pause& Reflect

1. Knives, spoons, and hand whisks are levers.
   (a) Sketch each in use. On each, label the fulcrum, effort, and load.
   (b) Identify each item as a first class, second class, or third class lever.
2. Check your original answers to the Getting Ready questions on page 128. How has your thinking changed? How would you answer those questions now?

unit B PROJECT

SKILLCHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Capture Sun Rays

In North America and Europe, electricity is used for cooking. Some of this electricity is generated using fossil fuels. This process is harmful to the environment.

Why use non-renewable resources when the Sun gives off vast amounts of heat energy every day? This heat can be harnessed and used to purify water, sterilize instruments, and cook food.

For example, heating water in a solar cooker to 65°C or more for 30 minutes will kill disease-causing micro-organisms. In bright sunlight, some solar cookers can reach temperatures of 90 to 135°C. This is hot enough to cook food.

Challenge

Using the knowledge you have gained in this unit, construct a solar cooker that works well enough to cook rice.

Safety Precautions

- Use protective mitts when handling material in a hot solar cooker.
- Handle glass with care.

Materials

laboratory thermometer

small cardboard box

plate of glass or clear plastic large enough to cover the top of the box

black, non-toxic paint or black markers

dark, lightweight, shallow cooking pot (such as an empty 500 mL soup can)

plastic bag large enough to hold the pot

aluminum foil

corrugated cardboard

utility knife

electrical tape

duct tape

Design Criteria

A. Work with a partner. Complete a detailed sketch of the solar cooker you plan to build.

Your design should address these points:

- Keep heat transfer by conduction, convection, and radiation to a minimum.
- Plan to reflect solar rays to increase heat transfer.
- Reduce air leaks to a minimum.

B. Using the techniques of heat transfer and insulation you have learned, design a container to collect and retain heat.

Your design should address these points:

- Show an understanding that dark or black surfaces absorb heat better than lighter-coloured surfaces.
- Illustrate proper use of a reflective surface.
- Demonstrate knowledge of how insulation is used.

Plan and Construct

1. Use a cardboard box as the base for your solar cooker.
2. If you use a piece of glass for the top, tape the edges of the glass to protect the edges. Use the glass plate to cover the top of your box and receive direct sunlight.
3. As you plan your cooker, consider:
   (a) How can you use the advantage of still air?
   (b) What kinds of insulation can you use?
   CAUTION: Some types of insulation should not be near food. Choose your materials with this in mind.
   (c) Where might a coat of aluminum foil be most helpful?

Construct your cooker after getting your teacher's approval.

5 Half fill the pot with water. Place the pot in the centre of the cooker and the thermometer in the water. Cover the top of the cooker with clear plastic or glass.

On a sunny day, place the cooker in direct sunlight in an area protected from wind.

7 Record the cooker temperature every 20 min. Wash your hands thoroughly.

Solar energy enters the oven through a sheet of glass. As in a greenhouse, heat enters but does not all reflect out through the glass. You can increase or decrease the amount of heat by changing the angle of the reflective top.

Solar energy is reflected to the pot from the surfaces of the mirrors. Would you expect this to be a better cooker than the oven shown above?

Evaluate

1. Complete a detailed sketch of your solar cooker design. Prepare to describe the features you built into your design, and why you used some materials over other materials.
2. If the inside of your cooker did not reach 90°C, discuss what you can do to improve your design.
3. With light cloud cover, solar panels continue to produce electricity. What effect will cloud cover have on how well your solar cooker works? Explain your answer.

Extension

4. If your solar cooker reached 90°C, try to cook rice. Since it might take an hour to fully cook rice, start before noon.

Internet CONNECT

www.mcgrawhill.ca/links/science.connect1

There are many different plans for cooking with sunlight. You can research solar cookers on the Internet. Go to the above web site, then to Internet Connects, Unit B, Closer, and then to Solar Cookers to get more information on how to build other solar devices. Follow the links from there.