Experiment ON YOUR OWN

BUILD A WATER-DRIVEN DEVICE

Before You Start ...

One of the earliest methods of providing energy to a mill or factory was to use the force of falling water. Water was channelled to pass over the top of a large wheel. The water would catch on paddles or buckets on the wheel, which forced the wheel to turn. The axle for the wheel extended into the mill. Belts attached to this axle would transfer the wheel's force to turn saws or grind flour.

In this activity, your challenge is to build a device that can use energy from flowing water to lift the largest mass possible a vertical distance of 10 cm.

The Question

How can you construct a mechanical device driven by water that can lift a mass a vertical distance of 10 cm?

Design and Conduct Your Experiment

1 Your teacher will show you the lift mechanism that you will use for this activity. Notice that your device must connect to this spool or tube, which has a string attached to it. The other end of the string will be attached to the mass. The device must turn the spool or tube so the string winds around it enough to lift the mass 10 cm.

2 Working in a small group, determine what combinations of simple machines would be useful in building this device. You may find it helpful to review the information on simple machines on pages 261 to 265 and page 268 earlier in this unit.

3 Create a plan of how you will build your device. Include a diagram showing how you plan to connect the simple machines together. Also include a list of materials that you will need to create your device. **Note:** Your source of water will be a thin hose connected to a tap. The tap will only be turned on low—it will provide a source of gently flowing water, not water under pressure.

Figure 2.21 Flowing water causes this huge wheel to move. Linkages connect the moving wheel to mechanical systems that operate the mill.

4 Build your device and test it. Remember: changes and modifications are part of the development process.

5 What was the largest mass your device could lift?

6 Be prepared to demonstrate your device to the class. Compare your device with others. How successful were the other devices?

7 After observing the other devices, describe one modification you would make to your device to improve how it functions.

8 How could you estimate the mechanical advantage of your device?

Careers and Profiles

PRACTICAL DESIGNERS

Mechanical engineers design engines and machines that extend our physical capabilities. These machines include automobiles, aircraft, ships, trains, spacecraft, robots, earth-moving equipment, harvesting machines, nuclear power plants—basically any object or device that moves. Colette E. Taylor is a mechanical engineer. Since 1988, she has worked at Chalk River Laboratories in Chalk River, Ontario. Here, she does research, along with other scientists and engineers, that supports and advances the development of CANDU nuclear reactor technology.

Q: Why did you choose to become a mechanical engineer?

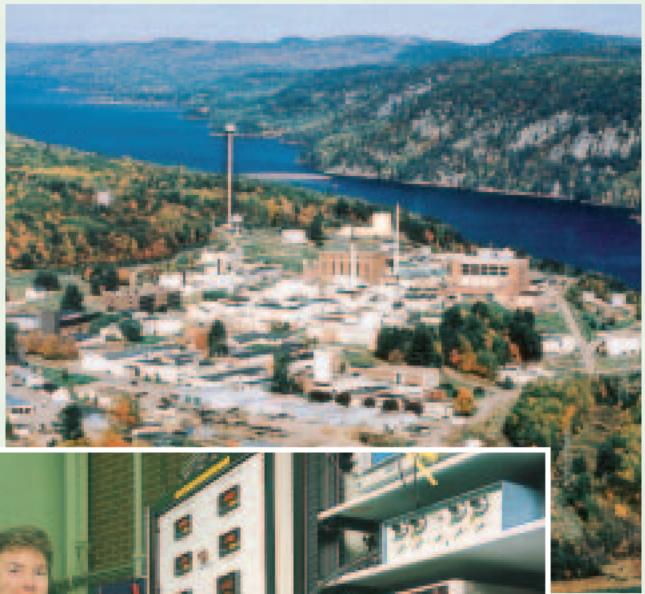
A: When I was in high school, I had no idea what a mechanical engineer was, but I really enjoyed taking a wide range of science courses. I didn't want to specialize in any one thing. I wanted to use all of my science background. When I looked at the options for university, I discovered that mechanical engineering was one of the few career choices that required you to use a wide range of sciences. It was perfect!

Q: Are there many women mechanical engineers?

A: There were nine women in my graduating class of 135 students. And that was considered high! I think women have a distorted idea about what engineers really do. They think that you have to work with big, dirty, noisy equipment. Well, that's just not part of the job. I spend most of my day in meetings and working on new designs in my office.

Q: What does it take to be a good mechanical engineer?

A: Strong technical ability, communication skills, and high motivation are important characteristics for a successful engineer in today's competitive and demanding workplace.



Colette Taylor conducts research at the CANDU nuclear generating station in Chalk River, Ontario.

Colette says, "If you want a job that challenges you each and every day, and provides you with a wide variety of career opportunities, mechanical engineering is an excellent choice."

1. Why do you think a career in mechanical engineering would give you "a job that challenges you each and every day"?
2. If you were a mechanical engineer, what kind of machines or systems would you like to work on?

Section Review

Assess Your Learning

1. Describe how to calculate the following aspects of a mechanical system:
   a) mechanical advantage
   b) efficiency
   c) speed ratio
2. Is it possible for a machine to be 100% efficient? Explain your answer.
3. Calculate the work done by a student doing 10 chin-ups. Assume that the student exerts a force of 400 N with arms that are 0.5 m long.
4. Describe how you could measure the efficiency of a bicycle.
5. A pulley system allows a load of 625 N to be lifted by a 90-N input force. What is the mechanical advantage of the pulley system?
6. Imagine that you work in a company that builds robots. You are asked to design a robot with hydraulic arms that can help out in the home.
   a) List some of the activities that this robot could use its hydraulic arms for.
   b) Why would hydraulic arms be better for these activities than mechanical arms without hydraulics?

Focus On Science and Technology

Scientists and engineers always encounter new questions and problems in scientific research and technology development. Think about the information you learned and the activities you did in this section.

1. Describe one problem you encountered in this section and how you solved it.
2. Do you think there could be more than one way to solve the problem you described in question 1? Why or why not?
3. After learning about mechanical advantage, what two new questions do you have about it?

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

Key Concepts

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

- design and function
- social and environmental impacts

Learning Outcomes

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

- evaluate the design and function of a mechanical device in relation to efficiency and effectiveness
- identify the impacts of a mechanical device on humans and the environment
- develop and apply criteria for evaluating a mechanical device
- describe how the following factors affect technological development: advances in science, trial and error, and changes in society and the environment

Mechanical devices have evolved over time because of new developments in science and technology. The first lawn mowers, for example, were made of steel. They were powered by the person pushing the mower. Since then the lawn mower has been adapted to use first gasoline and later electricity as a source of energy. Most of the steel parts have been replaced by aluminum or plastic. The change in materials makes the mower lighter and easier to use. It also reduces its cost. Each change to the lawn mower was designed to make the machine more efficient, less expensive, and easier to use.

In this section, you will explore how the design and function of a mechanical device are related to its efficiency and effectiveness. You will also consider the effects that a device can have on the environment. Finally, you will look at how science and technology advance—through knowledge, trial and error, and changes in society and the environment.

3.1 Evaluating Mechanical Devices

Mechanical devices are constantly being evaluated. Manufacturers evaluate the devices they make to find ways to improve them. They want more people to buy their products so they want the devices to be better than, or different from, other brands. Inventors evaluate mechanical devices to find ways to make them easier to use or to find other ways of doing the same task. And you evaluate mechanical devices every time you use one or consider buying one.

Using Criteria to Evaluate a Device

Your bicycle has broken down. You need to buy a new one, but there are many bike designs available. How do you decide which one to buy?

Working with a partner, list the features that you would like to have in a bicycle. Begin by thinking about what you use your bike for. Is it for riding on city streets? Is it for riding on trails out in the country? Is it for BMX riding? Will you ride it to school? If so, you need some method of carrying things. Will you be riding after dark? If so, you need to make sure you have good lights and plenty of reflectors.

The list of features you want are your criteria for evaluating a bike's design. That is, they are the features you will consider when you look at different bike designs to see if they meet your needs. Look at the bicycles shown in Figure 3.1. Do any of them fit your criteria?

Of course, the features in the list you made are not the only criteria you have to consider when you buy a mechanical device. A very important one is cost. You may find a bike that fits all your criteria exactly, but if it's out of your price range, you can't buy it. When you evaluate a mechanical device or anything else, it's important to be clear about all the criteria that you have to consider.

*info***BIT**

Bikes without Brakes

Would you buy a bike without brakes? You would if you wanted it for track racing in a velodrome. You may have seen these bikes on television at the Olympics. They have no brakes and only one gear. The gear is sized according to the type of competition and the cyclist using the bike.

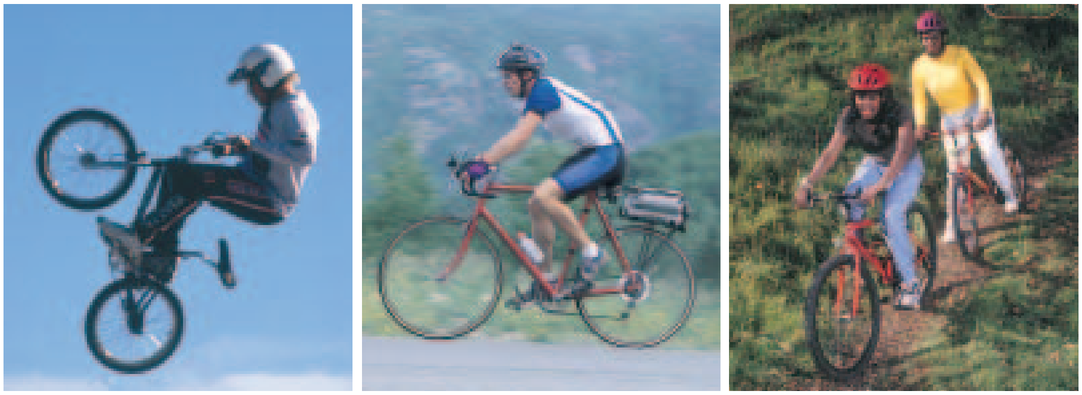


Figure 3.1 Do any of these bicycle designs meet your criteria?

Efficiency and Effectiveness

When you use a mechanical device, you want it to work efficiently. Earlier in this unit, you learned that efficiency could be calculated as a percentage by dividing the mechanical advantage by the speed ratio. That's a quantitative measure of efficiency because it gives you a number for a quantity or measurement. But efficiency can also be described qualitatively, just in words. For example, you can describe the efficiency of a mechanical device by saying how quickly and easily it helps you do a task. You also want a mechanical device to work effectively. It works effectively if it does its job well.

You can see the difference between efficiency and effectiveness by comparing different designs of bicycles. For example, a one-speed bicycle is effective in carrying you from one place to another. And it's more efficient than walking—you get there faster and use less energy to cover the same distance. A 21-speed bicycle is just as effective as a one-speed, but it's more efficient. By changing gears, you can increase your speed and climb hills more easily. You can cover the same distance more quickly and use less energy. That makes the 21-speed bike more efficient. So both designs are effective, but one is more efficient than the other. Usually, in evaluating a mechanical device, you are looking for the best combination of effectiveness and efficiency at a cost that you can afford.

Figure 3.2 The people in this photo use their bicycles as their main means of transportation for going to work, for visiting, and for shopping. Many of these are one-speed bicycles.

Function and Design

Scientists, engineers, and other inventors want to develop mechanical devices that work efficiently and effectively. To do that, they consider both the function and design of the device. The **function** is what the device is supposed to do. The **design** is the physical form of the device that makes it usable.

Figure 3.3 How do the designs of the mountain bike and the road racing bike show the different functions of the two kinds of bikes?

Think again about the bicycle. The basic function of a bicycle is to carry a person. But different types of bicycles have very specific functions, and their designs reflect these functions. Look at Figure 3.3. The two bicycles shown are both used for racing. However, the type of racing they do is so different that the designs are very different. They both have two wheels, handlebars, brakes, and seats, but even these look different. An important aspect of evaluating mechanical devices is ensuring that the design suits the function.

Evaluation for Development

If you are buying a mechanical device, you need to think about how to evaluate it. A thorough evaluation helps you make a better choice that suits your needs. Another reason for evaluating a device is to determine how it can be improved.

Earlier in this unit, you saw photos of how bicycles have changed from the early penny farthing to today's high-tech bikes. The design of bicycles is constantly being changed to improve how they function and to make them more comfortable and easier to use. The efficiency and effectiveness of bicycles as a means of transportation has greatly increased over the years.

Another factor that can be considered in evaluating mechanical devices is the environment. Sometimes the environment influences the design and function of a device. For example, mountain bikes are designed specifically for rough terrain. They have sturdier frames and larger tires than road-racing bikes do. Both these features help mountain bikes function more efficiently and effectively.

Considering the Environment

The effect of a device on the environment should also be considered in evaluating it. For example, spikes in the tires on a mountain bike might make the bike more effective in climbing slopes. However, tires with spikes would tear up the soil and plants even more than ordinary bike tires do. To protect the local environment, tires with spikes should not be used. Other devices, such as cars, affect the environment by contributing to air pollution. This can affect you directly and can contribute to global warming.

Figure 3.4 Leaf blowers help people clean leaves off roadways and paths. Some people feel that these devices pollute the environment with their noise. What criteria would you use in trying to decide whether to buy a leaf blower?

Evaluating a Mechanical Device—A Case Study

A good example of how evaluation leads to the development of better mechanical devices is a product that you use almost every day—the pop can opener. Its changes over the years show how evaluating a mechanical device can lead to improvements. These improvements made the product more convenient. They also affected the well-being of both people and the environment. The history of the pop can opener shows how trial and error can play a role in the development of even simple technology.

The development of an opening mechanism for the aluminum can went through four distinct designs:

- the church key
- the removable pull tab
- the buttons
- the non-removable tab

Each new design was the result of the previous device having some problem. Before you start reading about pop can openers, make a chart like the one below in your notebook. As you read, fill in the advantages and disadvantages of each design.

Opener Design	Advantages	Disadvantages
church key		

EVOLUTION OF A MECHANICAL DEVICE—THE POP CAN OPENER

To pour a liquid out of any container, you need two holes or one large hole. With two holes, the first hole allows the air into the can. The second hole lets the liquid out. The air flowing into the can replaces the liquid that is leaving the can. In fact, the air helps to create a smooth flow of liquid out of the second hole. One hole will work if it is large enough to let air flow into the can at the same time that liquid flows out of it. So one of the criteria for the design of an opener was that it could make either two small holes or one large one. Let's look at how pop can openers evolved.

Figure 3.5 The earliest cans were made of iron. They could be opened only by using a hammer and chisel!

Figure 3.6 The church key was the first practical design for a can opener.

Church Key

The first cans were completely sealed. They did not have an opener built into the lid. An opening device was needed to make two holes in the top of the can. This device was called a church key. A common church key is a piece of metal with a triangle end designed to punch into the can and open it. Figure 3.6 shows a church key being used to make two holes in the top of a can.

A church key is a simple machine—a lever. If you pressed on the top of the pop can with just your fingers, you would not have enough force to open it. The church key multiplies the force that you use. It also focusses it to a tiny point at the end of the triangle. Recall that pressure is the amount of force applied to a given area. So by using the church key lever to press on a tiny point on the top's surface, you can puncture the metal. The church key worked well, but it did have some drawbacks. Can you think of at least one problem with using a church key? Add the advantages and the disadvantages of the church key to your chart.

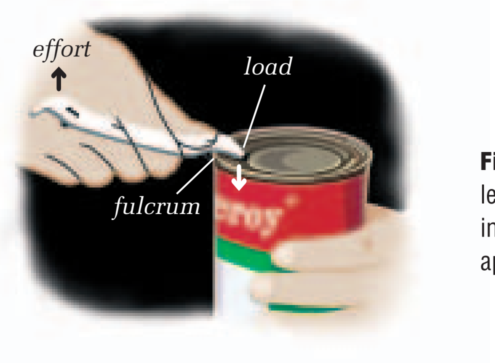


Figure 3.7 The church key is a lever that enables you to increase the pressure you can apply to the top of a can.

Removable Tab Top

One sunny summer day in the early 1960s, Ermal Fraze of Ohio was picnicking at the local lake. Unfortunately he forgot the church key to open his cans of soda pop. It was clear that this was a failure of the church-key can. If you didn't have a church key with you, you couldn't open the can. Fraze was determined to find a better solution. Making sketches, the metal engineer designed his solution on paper.

Fraze solved the problem by having a ringed tab that could be pulled off the top of the can. After much trial and error, he found the right design. When you wanted a drink, you would put a finger in the ring part of the mechanism and pull back the ring like a lever. The tab would "fail" and rip from the lid. Now you could have your drink. Not needing a church key was a big improvement, but an environmental problem arose from the new pull tab design. What do you think that was?

Figure 3.8 The removable tab top made opening the cans much easier. It was a simple machine built right into the top of the can. But it too had problems.

Buttons

With billions of cans being used every year, an environmental problem arose with the removable pull tab. What do you do with the tab after you take it off the can? Many people just threw their tabs onto the ground. The result was a litter problem and a safety hazard. A new solution was needed.

One solution was to have two holes with buttons pre-formed in the can's lid. One hole was smaller than the other. The directions on the can told the user to open the small hole first.

Recall from earlier lessons that pressure is force divided by area. By pushing on the small button, you exerted the same force as you would on the large one, but over a smaller area. You created more pressure at that point, so the smaller button was easier to open.

Opening the small button released the pressure in the can. This pressure came from the can's contents, usually carbonated pop. The bubbles in pop are carbon dioxide. In order to keep the bubbles in the pop, the can has to be sealed to contain this pressure. Once this pressure was released by opening the small hole, the large button was much easier to open.

While this solution solved the litter problem, many people didn't like having to push two buttons. Some found the small button difficult to press. A better solution was once again needed.

Figure 3.9 The buttons eliminated the litter problem, but consumers didn't like using them.

Non-Removable Tab Top

In 1976, the easy-to-open top with an attached tab was invented. It eliminated the environmental problems of the earlier pull tabs, so it is called the "ecology top."

The tab top opener is another example of a simple machine. Like the church key, the tab top is a lever. This mechanical device and its specially designed metal top provide an easy-to-open product. Figure 3.10 shows how the tab top exerts pressure on the top of the can to open it. However, the lever action alone of the tab would not be enough to open a hole in the can. The metal has weaker lines in it that outline the shape of the hole. When you exert pressure using the tab lever, you strain the metal along the weaker lines, and the hole pops open.

Both the removable tab top and the non-removable tab top are mechanical devices that act as levers. The only difference is that the non-removable tab top stays attached and so does not create a litter problem.

Figure 3.10 Like the church key, the tab top is a mechanical device that is a lever.

Criteria for Evaluation

The changes to the pop can openers didn't happen accidentally. Can manufacturers evaluated each device and tried to improve it. To evaluate their can openers they probably asked questions such as:

- Is it efficient: does it open the can quickly and easily?
- Is it effective: does it allow air in so the liquid can flow out?
- Is it safe: does it create an opening that allows people to drink directly out of the can?
- Is it convenient: is it there when you need it?

These are just some of the questions they might have asked. After the problems with the removable pull tabs, they added questions about the environment. These included:

- Will the opener contribute to litter?
- Is the opener recyclable, along with the can?

As you were reading about pop can openers, you filled out a chart about their advantages and disadvantages. This is the type of information that is used in evaluating mechanical devices. However, in a real evaluation, you would begin with a list of things you want or are looking for in the device. The questions above are examples of how to start. This helps to ensure that you collect enough of the right kind of information to help you make your decision.

When you are buying, planning to use, or building a mechanical device, think of criteria that can help you evaluate your choices. These include: efficiency, effectiveness, design, function, and impacts on the environment and other people.

Figure 3.11 Today's aluminum cans are easy to open. Because the pull tabs stay attached to the cans, they don't contribute to litter.

reSEARCH

Making Sure That Consumer Products Are Safe

Next time you use a mechanical device like a hair dryer or toaster, look on the outside casing for a symbol that looks like a large C with a smaller S and A inside it. This symbol stands for the Canadian Standards Association (CSA). The CSA is a non-government association that tests and approves a wide range of products to make sure they are safe for consumer use. Other consumer product-testing organizations test for safety and value. Using the Internet or your library, find out how these organizations evaluate consumer products. Find out how they set the criteria they will use, and what kind of tests they do.

Decision Making Activity

Evaluating a Mechanical Device

The Issue

Every day you use a large variety of mechanical devices. Some are more efficient and effective than others. Some are better designed than others. You might notice how easy a device is to use, or how well it works in getting the job done. But do you notice whether it affects the environment? Or how it affects other people when you use it? What criteria should you use to evaluate a given mechanical device in a responsible way?

Background Information

1. When we think about buying a mechanical device, we usually have criteria to help us make a decision. Criteria are guidelines or standards that we use to gather information that we need for decision making. Usually these include only criteria directly related to our own use. But we should consider a wider range of criteria. That way, we can make sure that we buy and use mechanical devices and other technology more responsibly.
2. In any type of evaluation, you need to develop criteria. Depending on the situation, they may cover many aspects of a device, or only a few. Cost, energy efficiency, environmental impact, appearance, ease of use, comfort—these are just some of the criteria you might consider when you evaluate a mechanical device.
3. Imagine that the snowmobile was a new device about to be introduced onto the market. You are a member of an organization that tests consumer products. Your organization will be evaluating this new product to see if you should recommend its use. You are concerned not only about how the device meets the needs of individual consumers. You are also concerned about social and environmental factors.
   a) Working with your group, develop a set of criteria that will help you evaluate the snowmobile. Remember to keep in mind the reason for your evaluation.
   b) Evaluate the snowmobile. You will have to do some research to determine how well it fits your criteria.

Figure 3.12 What criteria would you use to evaluate this mechanical device?

Support Your Opinion

4. When your evaluation is complete, design a presentation to summarize your group's findings so you can share them with the rest of the class.
5. Be prepared to defend how well your evaluation criteria address social and environmental needs.

Check and Reflect

1. What personal and societal factors influenced the changes in devices used to open aluminum cans?
2. Do you think the design of the non-removable pull tab will change again or is this the final design? Explain your answer.
3. Your school wants to install a new bell. Which of the following are appropriate criteria for evaluating the bells available? Explain your answers.
   a) How well does the device do its job?
   b) How efficient is the device?
   c) Is the device waterproof?
   d) Are there any negative side effects to using the device?
   e) How reliable is the device?
   f) Is the device disposable?
   g) Does the device come in a wide variety of colours?
4. What other criteria would you add to help your school choose a suitable bell? (Hint: Think about what the bell will be used for, and its possible effect on people who live near the school.)

Try This at Home — Activity

Choosing a New Set of Wheels

You may have seen push scooters like this one—you may even have one of your own. Why do you think someone would choose to use one of these devices instead of a skateboard or roller blades?

- List the criteria someone might use to help her decide which device to buy.
- If you had to choose a new skateboard, a pair of roller blades, or a scooter, which one would you choose? Why? If you already have a scooter, explain your reasons for buying one.
- Why do you think these scooters are available now and weren't available 10 years ago? List as many factors as you can think of. Do some research by visiting stores that sell these devices and by searching the Internet to find out what these devices are made of. Which items on your list do you think are good reasons for the scooters' availability?
- Interview some of your friends to find out how they would make a choice among skateboards, roller blades, and scooters. Do any of them have a set of criteria that they use to evaluate purchases?

Figure 3.13 A push scooter

3.2 Technology Develops through Change

In subsection 3.1, you saw how a simple mechanical device like a pop can opener can develop over time. The changes in the pop can opener resulted from both human and environmental needs. New materials and technology also contributed to its development. The original steel cans changed to more flexible and lighter-weight aluminum. As well, new methods of making the cans helped.

Another part of the development process for pop can openers was failure—not all changes succeeded. The button-top pop can did not succeed because people found it difficult to use. Trial and error are also part of technology development.

Look at Figure 3.14, which shows how the sewing machine has developed for home use since it was invented in the 1800s. What factors do you think contributed to the changes in sewing machines over the years? (Think about the factors that affected the development of the pop can opener.)

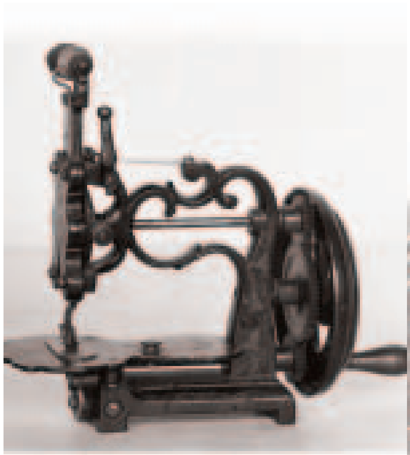


Figure 3.14a) Early sewing machines were operated by a hand crank. They could sew only simple stitches.

Figure 3.14b) A major development in sewing machine design was the development of the foot-operated treadle. This left the operator's hands free to guide the fabric better.

Figure 3.14c) Today's sewing machines run on electricity, and can produce a wide range of stitches.

*info***BIT**

New Technology through Invention

In the winter of 1903, Mary Anderson was riding a streetcar in New York City. She noticed that the shivering driver had to keep getting out to wipe the snow and ice off the windshield. Mary had an idea, and made a quick sketch. Her device allowed the driver to operate a lever from the inside that moved a swinging arm on the outside that mechanically swept ice and snow off the windshield. By 1913, the windshield wiper was standard equipment on cars, trucks, and buses.

Advances in Science Result in New Technology

Many of the devices we use today—from computers to hair dryers—are possible only because of electricity. Charles Coulomb first identified electric charges in the 1700s. However, it wasn't until the late 1800s that electricity was distributed widely in cities. And it wasn't until the 1940s that it became widely available outside Canadian cities and towns.

As scientists, engineers, and other inventors learned more about electricity, they saw how it could be used in new technologies, such as light bulbs. They also found that electricity helped them make new scientific discoveries. For example, we would not have electron microscopes without electricity. These microscopes opened up a whole world that had been invisible to human eyes.

From Particles to Trains

Sometimes new technology develops from scientific research that may not even seem to be related. One example is the MAGLEV trains in Japan, shown in Figure 3.15. These trains are powered by electricity and float on magnets so that they never touch the tracks. They can travel at speeds over 350 km/h! The technology for the MAGLEV train resulted from physics experiments using particle accelerators.

Figure 3.15 Because they float on magnets, MAGLEV trains experience very little friction. This enables them to use more of their energy for increasing speed rather than opposing friction.

Particle accelerators are huge machines that break up atoms and other particles. To do this, they use large amounts of energy to create powerful magnetic and electric fields. Only a few particle accelerators exist in the world. It might seem that the specialized field of particle physics has very little to do with transportation. But scientists working in this field developed the technology that makes the MAGLEV train possible.

Changes in Society Result in New Technology

New technology can also result from changes to human society. An interesting example is the use of robots. Robots are widely used today, mainly in industry. But they don't look anything like the robots that were first popularized in movies and comic books in the mid-20th century. Those robots all looked like humans—with a head, torso, arms, and legs. The word "robot" comes from the Czech word *robotnik*, meaning "workers" or "slaves." It was first used in 1920 in a play in Czechoslovakia. In the play, human-like creatures were manufactured by the millions to work as slaves in factories.

While movie makers were busy creating fictional robots, scientists and engineers were trying to build real ones. The first practical examples were developed in the 1960s. Today, robots perform tasks far more efficiently and quickly than humans are able to do. Robots weld car bodies together, diffuse bombs, perform surgery, help the handicapped, and even explore other planets.

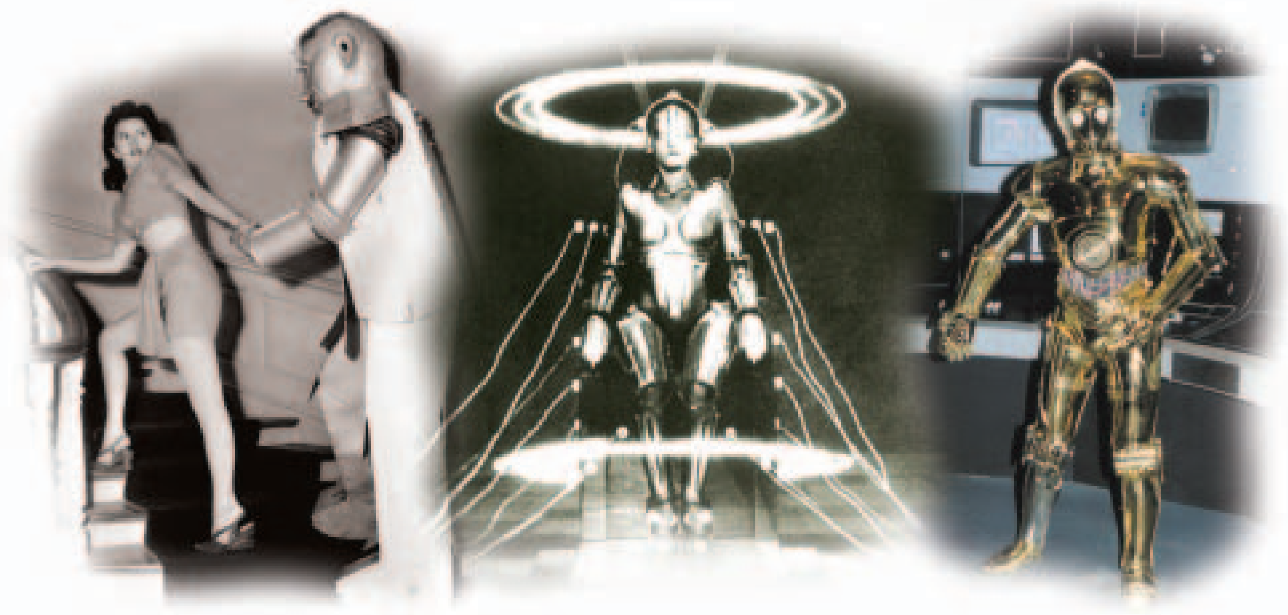


Figure 3.16 Some movie robots

Figure 3.17 Assembly-line robots weld car bodies together in an automobile factory.

Changing Society—Changing Technology

The drive to develop more effective and efficient robots came from the need to replace humans in different tasks. In the past, people had been willing to work for low pay and carry out boring or dangerous tasks. However, by the middle of the 20th century, people were demanding better wages and better working conditions. As wages went up, industry looked for ways to replace humans in manufacturing and other applications. Robots were the answer.

An industrial robot that welds car parts together, for example, works faster and more efficiently than any human. But it doesn't look anything like a human. It doesn't need a head, torso, or legs to do its job. All it needs is an arm. In fact, most industrial robots today are nothing more than "smart" arms.

Anatomy of a Robot

Robots are extremely complex devices and vary widely in appearance, depending on the job they're designed to do. However, a very simple robot contains some or all of the following basic parts:

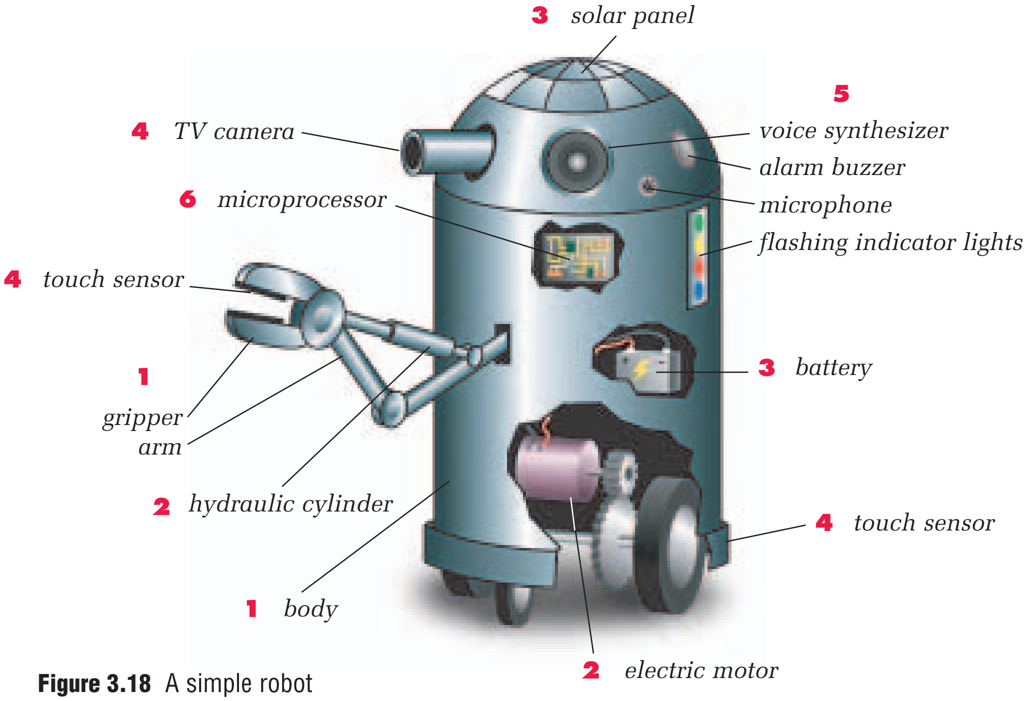


Figure 3.18 A simple robot

1 Body: steel, aluminum, or plastic. Metal rods are used for arms. Simple grippers that open and close are used for hands. Wheels are used for movement.

2 Motor Devices: electric motors and hydraulic or pneumatic cylinders. They move the robot's arms and wheels.

3 Power Source: battery or solar cells.
4 Sensors: detect light, sound, pressure, and heat. They tell the robot about the outside world.
5 Output Devices: buzzers, flashing lights, or synthesized speech. They enable the robot to communicate.
6 Microprocessor: minicomputer that acts as the robot's brain. It receives signals from the robot's sensors and decides what actions to take. It sends instructions to the robot's output devices or motor devices.

CHANGES IN THE ENVIRONMENT RESULT IN NEW TECHNOLOGY

Space exploration is a fascinating area of technology, but it does not affect very many people directly. The environment here on planet Earth does. Since the early 1960s, people have become more aware of their impact on the environment. The increasing human population and the use of certain technologies have damaged the environment. Chemicals have polluted water in lakes, rivers, and streams. Exhaust from cars and other vehicles has polluted the air.

People observed the changes in the environment and realized that new technologies were needed to prevent more damage. One example is the development of recycling technologies. These include new mechanical devices for processing materials so they can be used again or in a different form. Another example is the development of new materials, such as biodegradable plastic that breaks down much faster than ordinary plastic.

New technologies can help protect the environment from damage. Figure 3.19 shows a skimmer device used to clean up oil spills in water.

Figure 3.19 Oil floats on water, so clean-up crews can use skimmers such as this one to skim oil off the water's surface.

reSEARCH

Flying High

The first scheduled aircraft passenger service began in 1909. Passengers were carried by large, lighter-than-air craft called *zeppelins*. These lighter-than-air vehicles flew slowly but could travel long distances. So why are we not flying in zeppelins today? Use the Internet or your library to find out how passenger airplanes have developed through the years.

- How have new materials and other technologies affected the development of passenger airplanes?
- What role has the process of trial and error played in the development of passenger airplanes?

Check and Reflect

1. Look back at Figure 3.14 on page 315, which shows some of the stages in the development of the sewing machine. How do you think each of the following affected sewing machine development?
   a) advances in science
   b) advances in other technologies
   c) changes in society
2. Give an example of the role that trial and error can play in technology development. You can use an example from your reading in this section or any other example you know about.
3. Do you think cars will use the same kind of engine in the future as they do now? Why or why not?
4. Describe two ways that the environment could affect the development of new technology.

Careers and Profiles

Inventor

Canadian Peter L. Robertson (1879–1951) invented the Robertson square-headed screw in Milton, Ontario. The new square design prevented screwdrivers from slipping off the screw head as easily as they did with other screws. In 1908, he set up the Recess Screws Limited factory to manufacture the new screw. Now known as Robertson Inc., the plant is still busy turning out Robertson screws.

Figure 3.20 Peter Robertson

Most successful inventors will tell you that they started developing their natural curiosity at an early age. They took things apart to see what made them work. They constructed gadgets using toy building sets. They participated in science fairs. And in school, they took a variety of science, math, and engineering courses.

1. Have you ever thought of inventing something? If so, what was it and did it work?
2. What do you think would be the most difficult part of being an inventor?
3. Why do you think both ordinary screws and Robertson screws are used—why not just one kind?

Assess Your Learning

1. Define in your own words the terms *design* and *function* as they are used to describe mechanical devices.
2. If you were buying a blow dryer, you might use criteria such as the following to choose one:
   - It has to cost less than $20.
   - It has to have at least two speed settings (high and low) and two temperature settings (hot and warm).
   - It has to have adjustable electrical settings so it can be used on other continents.
   - It has to be foldable for easy packing.

   Imagine that you are a professional hair stylist, buying a blow dryer to use at work. Would you use the same list of criteria? Explain your answer.
3. Describe three reasons why people invent new machines or products.
4. What impact could the following discoveries have on a machine? Use an example of a machine in your answer.
   a) the development of new types of materials
   b) the development of new sources of energy

Focus On — Science and Technology

The goal of technology is to provide solutions to practical problems. The development of good technology depends on solid scientific knowledge. It also depends on evaluating prototypes and designs to improve how they function. Think back to what you learned in this section.

1. What were some examples of the link between science and technology that you read about in this section?
2. What are some factors you would have to consider if you invented a new machine that you wanted people to use?
3. Why are machines and other products constantly being evaluated?

Living with a Machine

The Issue

Imagine that a large new machine has been developed. It will transport up to six people in all kinds of weather for short or long distances. It will provide jobs for millions of people in everything from mining to manufacturing to servicing. However, it will also have the following impacts:

- It will pollute the air wherever it is used.
- It will affect the entire Earth by contributing to the "greenhouse effect."
- It will kill thousands of people every year in accidents.
- Its operation will require that millions of square kilometres of the environment be paved over, destroying habitat for animals and plants.
- It will kill thousands of animals every year.
- Its manufacturing and operation will require large amounts of non-renewable resources—metals and petroleum products.

Of course, this information describes the cars and other vehicles that we rely on today.

Now, when brand new technologies are developed, people try to identify such effects. They can then prevent the effects from happening or reduce the possible harm they could cause. But what do we do with existing technology such as the car?

Efforts are being made to reduce the harmful effects of cars. Research continues on ways to make cars more energy efficient and less polluting. In some areas, cars carrying more than two people are given special lanes to promote car pooling. Cars are being made safer with the use of airbags and other features.

What do you think should be done to reduce the harmful effects of cars? Use the following suggestions to find out more about what can be done about cars.

Cities such as Calgary have large areas covered in highways. This allows easy movement of cars. But the pavement destroys the natural environment, increases temperatures locally, and causes increased runoff of water polluted by oil and other chemicals.

Go Further

Now it's your turn. Look into the following resources to help you form your opinion:

- Look on the Web: Check the Internet for information on new car technology and how cities are dealing with cars.
- Ask the Experts: Try to find an expert, such as a city planner, a traffic engineer, or an engineer who works on car engines or design.
- Look It Up in Newspapers and Magazines: Look for articles about engine technology, car body design, and the environmental impact of cars.

In Your Opinion

- Where should new technology development for cars focus?
- Should the use of cars be restricted?
- Should we be concerned about the impact of new technology on people and the environment? Explain your answer.

Key Concepts

1.0

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

1.0 Machines are tools that help humans do work.

- A machine is a device that helps us do work. Machines use energy from animals, people, electricity, and fossil fuels to produce motion.
- There are six types of simple machines: the lever, inclined plane, wedge, screw, pulley, and wheel and axle.
- Complex machines are made up of two or more simple machines. Gears, linkages, and transmissions connect subsystems and help to transmit force in complex machines.

2.0

- mechanical advantage, speed ratios, and force ratios
- mechanical advantage and hydraulics
- measurement of work in joules

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

- Mechanical advantage is a measure of how much a machine can increase an applied force. The speed ratio describes how the speed of an object is affected by a machine.
- Work is done when a force acts on an object to make the object move. Machines help us do work by transferring energy. Work input and work output are not equal in the real world because of friction.
- Efficiency is a measurement of how well a machine or device uses energy. It is usually given as a percentage. It can be calculated by dividing the mechanical advantage by the speed ratio and multiplying by 100. This is a quantitative description of efficiency. No machine can be 100% efficient.
- Hydraulic systems use a liquid to transmit force in a closed system of tubes. They work because of Pascal's law. These systems can have a large mechanical advantage because of the difference in the sizes of the pistons used.

3.0

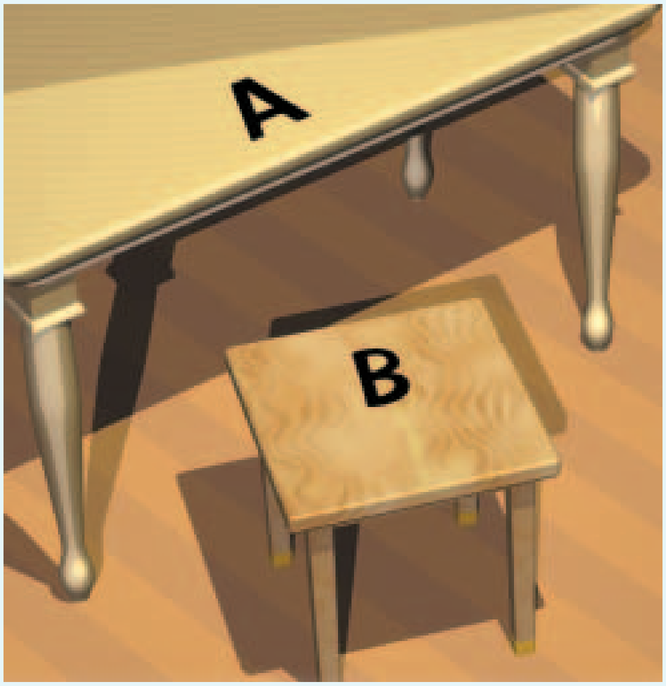
- design and function
- social and environmental impacts

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

- Function and design are two important aspects of mechanical devices. Function is what the device is supposed to do. Design is the physical form of the device that makes it usable.
- The main factors that should be included in an evaluation of a mechanical device are: efficiency, effectiveness, and impact on humans and the environment.
- Efficiency can also be described qualitatively. A machine or device is efficient when it helps you do a task quickly and easily.
- Technology development is influenced by scientific knowledge, trial and error, and changes in society and the environment.

PROJECT

BUILDING A MECHANICAL HAND



Place gripper device at A and load to be lifted at B.

Getting Started

At the beginning of this unit, you drew a design for a device to solve the problem of retrieving a robotic explorer that had become wedged in a drainage pit. After you designed the device, you studied simple machines, gears, and hydraulic systems. Now it's time to put all that information to use.

If you did not design a mechanical device to remove a robotic explorer from a drainage pit earlier in this unit, you should do that activity now. If you have completed this activity, collect your notes and designs and organize them in a manner that makes sense to you. Review your results with your partner or group.

Your Goal

Redesign the gripper device you designed earlier, and construct a working model of it.

What You Need to Know

Your teacher will show you the model of the drainage pit where the robotic explorer is located. It will look something like the picture on page 256. Note that in the earlier activity you assumed that the robotic explorer had a mass of 100 kg. For this activity, you can choose the mass of load that will work with your model.

Steps to Success

1 Review your original design drawings and make modifications to improve your design.

2 Create a plan that describes how you will build your gripper device. Include in your plan a list of the materials you will need.

3 Show your plan to your teacher for approval. Revise your plan based on your teacher's comments.

4 Build your device and test it.

5 Demonstrate your device to the class.

6 Observe how your classmates' devices work. Record any ideas you think you could incorporate into your device.

How Did It Go?

7 What worked well in your gripper device?

8 What would you modify so your device would work better next time?

9 What were some of the limitations you faced when you built your device? For example, did you have enough time?

10 Which device out of all of those made by your class do you think worked best? Explain your answer.

11 What are some possible applications of your gripper device?

Unit Review: Mechanical Systems

Unit Vocabulary

1. Create a concept map that illustrates the relationships between the following terms. Begin your concept map with the phrase *mechanical systems*.

simple machine	friction
complex machine	work
subsystem	efficiency
mechanical advantage	hydraulic
speed ratio	pressure

Check Your Knowledge

1.0

2. Why are machines useful?
3. What is the difference between a simple machine and a complex machine?
4. Identify four simple machines, and describe the advantages of each one.
5. a) What is a subsystem in a complex machine?
   b) Identify as many subsystems as you can in the robotic dog shown in the drawing below. For each one, explain why it is a subsystem.

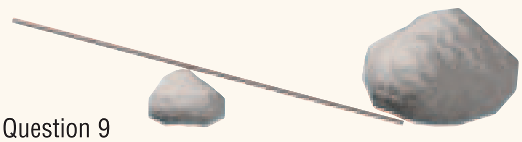
Question 5b) Sparko, the robot dog

6. What is the purpose of the transmission in a car?
7. What type of simple machine is in each item below?

bottle opener	hammer
your jaw	roller blades
shovel	screwdriver

2.0

8. Describe three effects of simple machines and give one example for each.
9. A lever is made out of a long pole and a rock, as shown in the diagram here. How would you change the location of the rock to increase the lever's mechanical advantage?



Question 9

10. A sailor uses a force of 600 N to pull on a pulley system to raise sails on a boat. The maximum weight of sails that the sailor can raise with this system is 2400 N. What is the mechanical advantage of the pulley system? (Hint: The weight of the sails is the same as the pulley's output force.)
11. Heavy equipment operators use a joystick to control the hydraulic arms on front-end loaders. When the joystick is moved forward 3 cm, the hydraulic arms move 4 m. What is the speed ratio of the front-end loader?
12. What is the difference between force and work?

13. Three students have built a prototype of a mechanical device to move gym equipment from the storeroom into the gym. They test their prototype and measure the forces and distances. They use their measurements to calculate the work done. They find that the work input and work output are equal. Is their calculation correct? Explain your answer.

14. Engineers are working to develop new car engines that are up to 60% efficient. What does "efficiency" mean in this example?

15. Why do hydraulic systems usually have large mechanical advantages?

3.0

16. *The development of new technology can be a process of trial and error.* Explain the meaning of this statement. Use an example to support your explanation.

17. Why is it important to know how to evaluate mechanical devices? Use the following words in your answer: efficiency, effectiveness, impacts on people and the environment.

18. We often see the words "science" and "technology" used together. Describe in your own words the relationship between the two terms.

19. A new type of one-person motorized vehicle has been developed. It is about the size of a motorcycle but you sit in it like a car. List some of the social and environmental issues that should be considered when this machine is evaluated.

Connect Your Understanding

20. The food at the grocery where your family shops arrived there by truck. But it may have arrived in your community—before it got to the store—by truck or train or air.
   a) Describe two ways in the past that people transported goods.
   b) Why do you think so many different ways of transporting goods have been developed?

21. What do you think would happen to a car's braking system if a hole developed in one of the brake lines? Use the words "force" and "pressure" in your answer.

22. List two examples of machines that use both hydraulic systems and levers. Why do you think hydraulic systems are used in each example?

23. You are delivering a large box of erasers to the back of a store. At the loading dock, you can lift the box a distance of 1 m onto the dock. This requires a force of 10 N. Or you could push the box up a ramp 4 m long. This requires a force of 2.5 N.
   a) Which method of raising the box requires more work? Include your work calculations in your answer.
   b) Which method do you think would be easier? Why?

24. The ride-on lawn mower like the one in the photo is a small tractor.

   a) Make a list of criteria that could be used by a family trying to decide whether to buy one of these mowers.
   b) What factors, other than cost, might affect a family's decision to choose this type of mower instead of another type of lawn mower? (Other types of lawn mowers include the push mower without any motor, the electric mower, and the gasoline mower.)

25. Imagine you were listening to an inventor in the 1800s describe his development of the internal combustion engine. (This is the type of engine used in cars and other vehicles today.) During the discussion, you realize he hasn't considered any of the social or environmental issues associated with the engine. Why do you think the inventor ignored those aspects of his invention?

Practise Your Skills

26. Draw a design for a catapult device that could launch a golf ball over a small tree. The catapult should include at least two simple machines and a hydraulic system.

27. Plan an experiment to measure the mechanical advantage and speed ratio for a stapler.
   a) What materials would you need?
   b) What procedure would you use?
   c) What variables would you need to control?

Self Assessment

28. Describe what you found most interesting about studying mechanical systems in this unit.

29. Describe one issue or idea in this unit that you would like to explore in more detail.

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

31. What major factors will you consider the next time you want to buy a mechanical device of some kind?

Focus On Science and Technology

In this unit, you have investigated science and technology related to mechanical systems. Consider the following questions.

32. Reread the four questions on page 257 about the science and technology of mechanical systems. Use a creative way to demonstrate your understanding of one of the questions.

33. Describe a situation where a machine was invented to meet a specific human need.

34. Describe an example of how advances in science contributed to the development of new technology.

35. Describe two ways that the environment can affect the development of mechanical devices.