ACTIVITIES

CROSS-CURRICULAR EXTENSIONS

1. **SCIENCE** Contact the company that recycles aluminum in your community. Ask them to describe what happens to the aluminum cans that you recycle.

2. **MATHEMATICS** Design a method for keeping track of the number of aluminum cans recycled at your school.

3. **COMMUNICATION** Make safety posters or ads for the machines you use in class. *Optional:* Use a video camera, computers, or darkroom processes for special effects.

EXPLORING CAREERS

To produce high-tech products requires the input and skills of people in a variety of jobs. These people are on the leading edge of technology and are constantly striving to create new products or improve existing ones. Here are two of the careers involved in making things.

Computer Engineer Computer engineers work as part of a team to develop new hardware and software. Most specialize in the design and testing of computer hardware or the research and design of software programs. They must have strong communication skills and be willing to keep up with advances in technology.

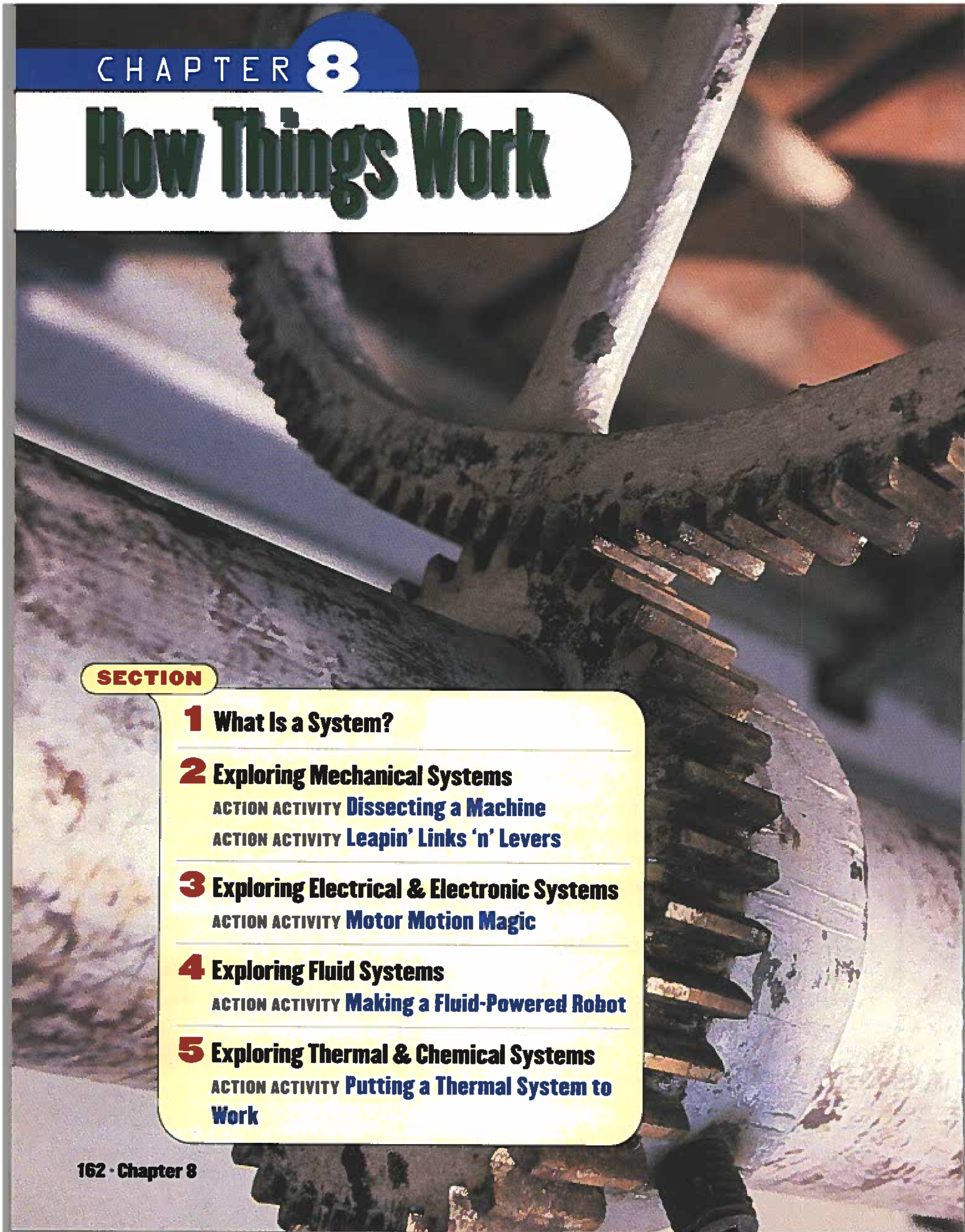
Computer Chip Technician
Manufacturing a computer chip involves several hundred steps that are controlled by computer chip manufacturing technicians. They make sure that the expensive equipment used in manufacturing chips continues to run. Most technicians have training in electronics, with a solid background in mathematics and science.

ACTIVITY

List the things you took to school today, including clothing, backpacks, and purses. What materials (cotton, plastic, wood, etc.) were used to make each product?

CHAPTER 8

How Things Work



SECTION

What Is a System?

SECTION 1

THINGS TO EXPLORE

- Tell what a system and a subsystem are and give examples.
- List and describe the four parts of a general systems model.
- Identify five systems used in technology.
- Explain how to troubleshoot problems.

TechnoTerms

- feedback
- input
- output
- process
- subsystem
- system

Most of us don't know how the machines we commonly use work. If a stereo, television, or bicycle breaks down, we often have no idea about what could be wrong or what to do about it. Fig. 8-1. The fact is, you don't have to be a rocket scientist to understand the basic operation of most machines and other devices. Even the most complex machine can be learned about as a system.

The Systems Model

A **system** is a combination of parts that work together as a whole. To understand systems, a general model can be used. It has four parts: input, process, output, and feedback. Fig. 8-2.

INFOLINK

See Chapter 4 for more information about computers.

Inputs are things that are *put into* a system. For example, in a fast-food restaurant, first you place your order. This is the input. The next step is the **process**—what is done with inputs. In a restaurant, the workers prepare the food you ordered. The final result is called the **output**—what comes *out of* the process. In our restaurant example, the output is your meal. If the system is working right, the output will be what you ordered. **Feedback** is information about the output. If the meal you received was not what you ordered, you might send it back. That's feedback.

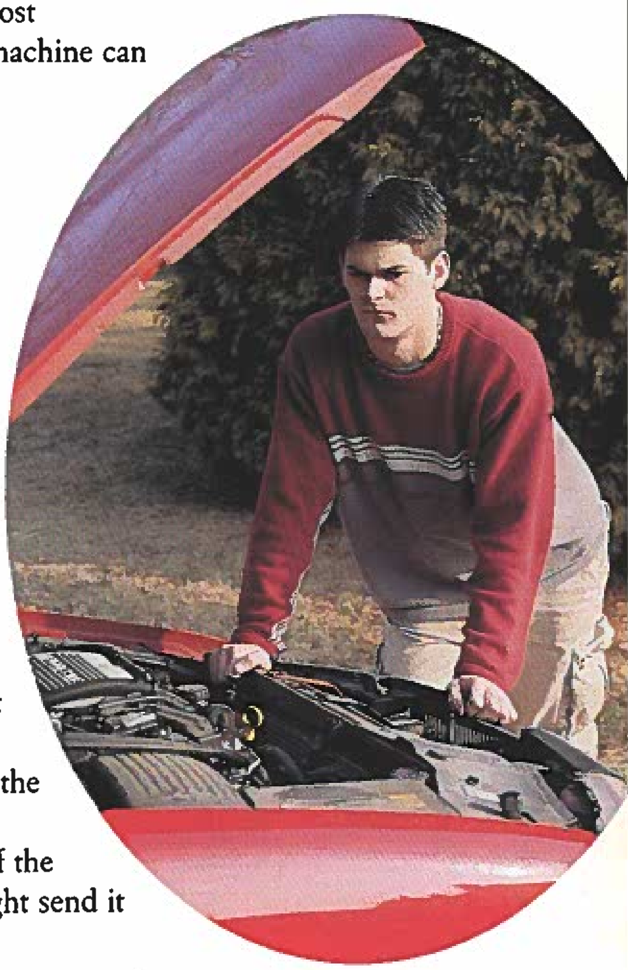


Fig. 8-1. Technology can be frustrating when it doesn't work. Has a technological device ever given you trouble? Describe your experience.

OPPOSITE Interlocking gears help transfer power in many machines.

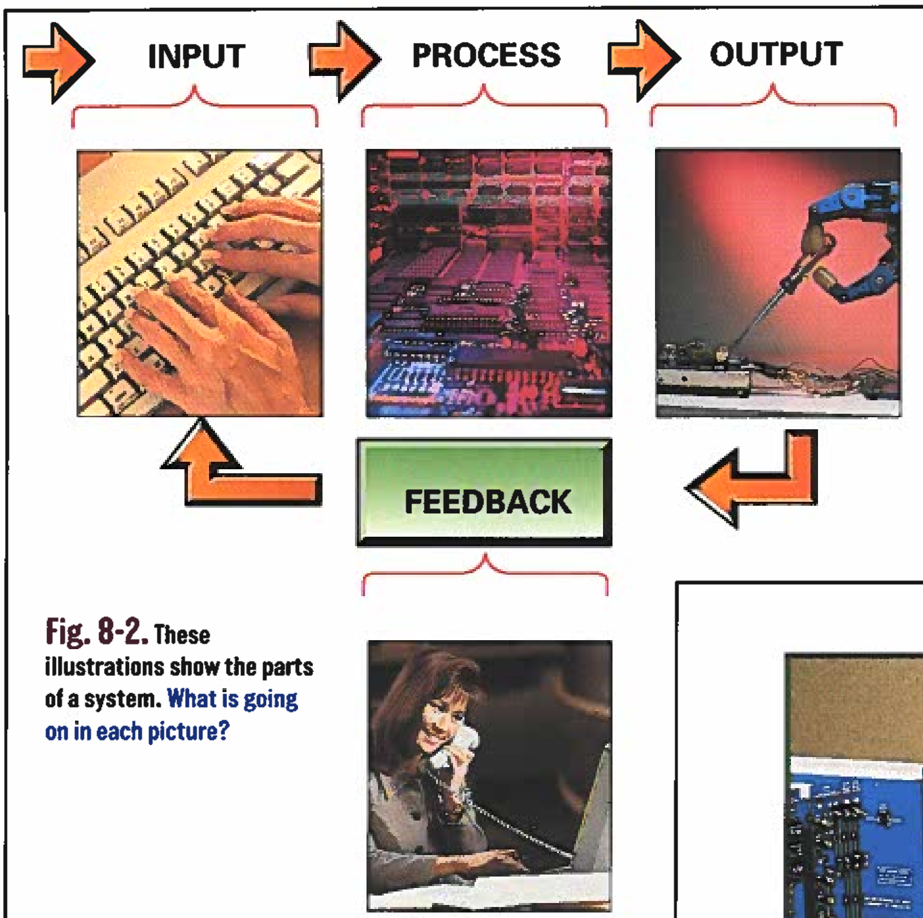


Fig. 8-2. These illustrations show the parts of a system. **What is going on in each picture?**

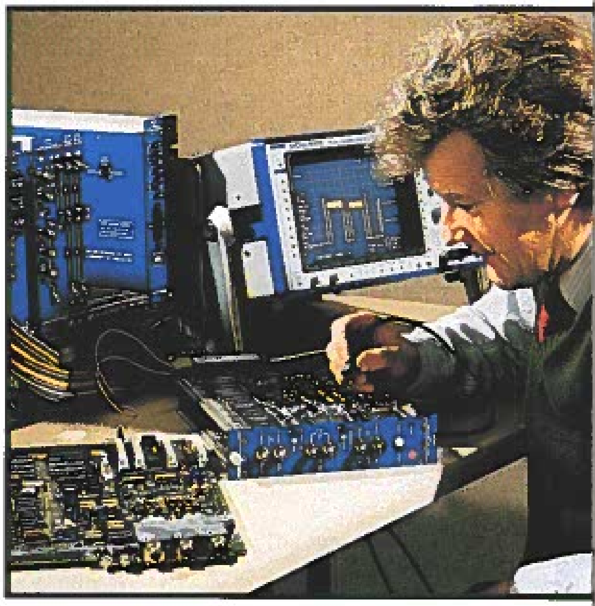


Fig. 8-3. This technician is using an oscilloscope to find problems in computer components.

Complex systems can be broken down even further into smaller **subsystems**. A bicycle, for example, is made of subsystems such as brakes and steering. Knowing about subsystems makes it even easier to understand how things work.

INFOLINK

Technology in every group can be looked at as a system. See page 474 for examples.

Troubleshooting System Problems

Do you know what *troubleshooting* is? It is trying to find the problem in a system. Fig. 8-3. Did you know that doctors troubleshoot? When you are sick, doctors investigate your different body systems to locate the problem. They look for *symptoms*, or signs, that might give them a clue to what's wrong.

Fig. 8-4. Autotechnicians often use electronic tools to diagnose problems. What kinds of symptoms do you think they look for?

When a car isn't working right, the problem is found by carefully checking each system related to the problem. Fig. 8-4.

Part of your job in troubleshooting technology system problems will be to look for symptoms. Instructions that come with some products often include troubleshooting charts to help you find and fix problems.

TechnoFact

SMILE! YOU'RE ON CT CAMERA Did you know doctors now use computers to help diagnose problems in the human body? PET (positron emission tomography) makes images of the brain showing where tasks such as looking, listening, or thinking occur. CT (computer tomography) scans the human body in seconds and turns the information into an image in less than a minute. A CT scan of your hand, for example, can show your fingers and muscles in motion!

Systems That Make Things Work

Technology usually depends upon five basic systems. They are mechanical, electrical, fluid, thermal (heat), and chemical systems. These five basic systems can be used independently or in combination to make something work. A car, for example, is a complex machine made up of all five types of systems.

- **Mechanical:** Door latches, fan belts, pulleys, gears
- **Fluid:** Water pump, shock absorbers, hydraulic brakes
- **Electrical:** Battery, lights, radio, ignition
- **Thermal:** Radiator, air conditioner, heater
- **Chemical:** Fuel, battery fluid, antifreeze

SECTION 1 TechCHECK

1. Define *system* and *subsystem.*
2. List the five basic systems used in technology.
3. What is *troubleshooting*?
4. What are the four parts of the general systems model?
5. **Apply Your Knowledge.** Dissect a ballpoint pen and identify the systems used to make it work. Identify the inputs and outputs.

SECTION 2

Exploring Mechanical Systems

TechnoTerms
- force
- resistance
- standard size

THINGS TO EXPLORE
- Identify mechanical parts used in everyday machines.
- Give examples of mechanical subsystems.
- Use levers and links to build a mechanical device for a robot.

Most machines and products contain at least a few mechanical parts. Can you identify some of the mechanical parts in the bicycle in Fig. 8-5?

Standard Sizes

Many mechanical parts, such as screws and other fasteners, are made in **standard sizes**. That means they are interchangeable and easy to replace. You can look in a parts catalog and find the right combination of parts needed to do a certain job.

Fig. 8-5. A bicycle has several mechanical parts. Identify as many as you can.

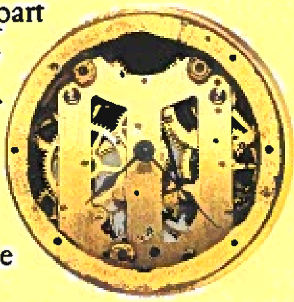
Mechanical Subsystems

Levers, springs, nuts and bolts, screws, belts and pulleys are just a few of the many mechanical parts that are used in everyday machines. In designing mechanical systems, you will need to know about mechanical subsystems such as levers and linkages, gears, and chain and belt drives. Fig. 8-6.

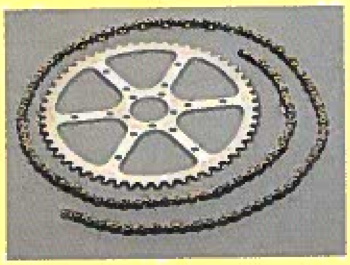
Fig. 8-6. MECHANICAL SUBSYSTEMS

- **Levers and linkages.** Levers help people to multiply their muscle strength and move heavy loads. How do levers work? When you use a lever to push or pull something, you are applying a **force**. The pivot point of a lever is called the *fulcrum*. The load you are trying to move is called the **resistance.** Machines sometimes use levers called *linkages* or *cranks*.

- **Gears.** Gears transmit forces from one part to another. They can be used to change the speed or direction of spinning parts. The speed at which a gear turns is measured in *RPMs*, or *revolutions per minute*. Gears are made in different shapes depending on how they are to be used. One type used in a car's steering mechanism is called a *rack and pinion gear*.



- **Chain and belt drives.** When forces have to be transmitted over a longer distance than gears can handle easily, a chain or belt is often used. Look at a bicycle chain. It rides on a toothed wheel called a *sprocket*. The chain transmits the force applied to the pedals to the back wheel through this chain and sprocket. Belts can do the same thing. You may have seen a belt drive on a washing machine or on a cooling fan in a car. Pulleys grip the sides of the belt just as a chain's holes mesh with the teeth in a sprocket. Belts are lighter and run more quietly than chains, but they can slip more easily.



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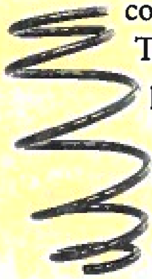
TechnoFact

MACHINE EVOLUTION Older machines, like early typewriters, had many mechanical links and springs. Old typewriters often jammed when two or more keys were struck at the same time. The next generation of typewriters used a combination of mechanical and electrical parts to make typing easier and faster. Machines that contain both electrical and mechanical parts are called *electromechanical* machines. Today's typewriters are almost entirely electronic. The keys you press on the keyboard are actually electric switches!

Fig. 8-6. MECHANICAL SUBSYSTEMS (Cont'd.)

- **Cams.** A mechanical part that changes rotational (turning) motion into reciprocating (up-and-down) motion is called a *cam*. Cams are used in automobile engines.

- **Flywheels.** A flywheel is a metal wheel that is heavy enough to keep spinning once it is set into motion. A flywheel is used to keep engines running in such devices as lawn mowers.



- **Springs.** Mechanical energy can be stored in springs. Springs come in many sizes, strengths, and shapes. Take a look at the spring inside a ballpoint pen. Compare it with the spring in a car's suspension system. What do they have in common?

TechnoFact

DUST DEVILS Some of the first mechanical devices didn't work quite as planned. The first vacuum cleaners blew air out instead of sucking it in. They made huge clouds of dust but didn't clean anything! Inventors improved the vacuum so it had suction (pulled air in), but two people were needed to operate it. One person held the hose, while the other operated a crank or pedal to create the suction. Finally in 1901, Hubert Booth built a vacuum that had a motor. It worked well except for one thing. It weighed several hundred pounds! Portable models like those you see today didn't show up until several years later. Now researchers are working on home robots that will do the vacuuming for you!

SECTION 2 TechCHECK

1. Name some mechanical parts that you can buy in standard sizes.
2. Why do machines use springs?
3. Give three examples of mechanical subsystems.
4. **Apply Your Knowledge.** Check out the mechanical parts in an old computer keyboard or typewriter. Describe the parts in the system.

ACTION ACTIVITY

SECTION 2
ACTIVITY 1

Dissecting a Machine

Real World Connection

Most machines are a combination of many parts from mechanical, electrical, fluid, thermal, and chemical energy systems. The parts are designed to work together to make a complete system. Even the most complex machines can be divided into subsystems. In this activity you will dissect a mechanical system. Fig. A.

Be sure to fill out your TechNotes and place them in your portfolio.

Design Brief

Dissect a "junk" machine and group the parts into the five energy systems. Ask your teacher to approve your junk item before you begin. You will need to use hand tools to disassemble (take apart) your machine. Identify and save all of the parts for possible future use.

Materials/Equipment

- "junk" machine, such as a toaster, alarm clock, TV, video game player, toy, lawn mower, mixer, drill, blender, VCR, lamp, heater, stereo, record player, exercise machine, or bicycle
- small bags or paper cups
- various hand tools such as screwdrivers, nut drivers, Allen wrenches, adjustable wrenches, socket sets

SAFETY FIRST

Follow the safety rules listed on pages 42-43 and the specific rules provided by your teacher for tools and machines.

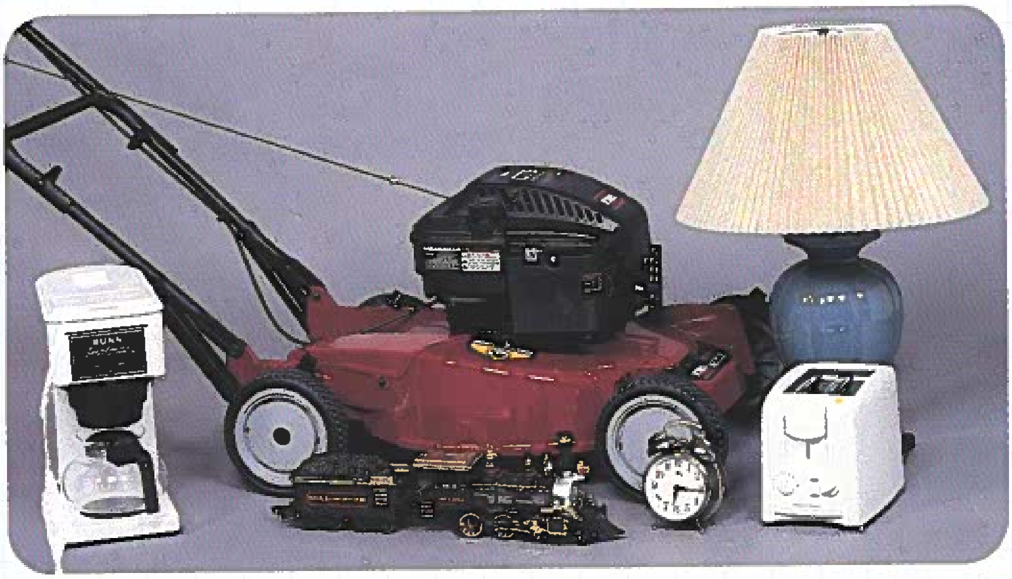


Fig. A

Procedure

1. In this activity, you will be working individually. Ask your parents, friends, or relatives if they have a "junk" machine that you could have. Please make it clear that you will not be repairing the item, and it will not be returned to them. Ask your teacher about storing any large junk items before you bring them to school.
2. Plan how you will dissect your machine so subsystems can be saved for future use. You should look for some of the following parts that can be reused: speakers, motors, batteries, pulleys, belts, gears, and fasteners such as nuts and bolts.
3. Take apart your machine using the right tools for each part. Ask your teacher for help if you can't loosen or remove a part.
4. Put the pieces into separate bags or cups according to their system. Identify as many of the parts as you can by name. Ask your teacher for help with parts that you can't identify.
5. Save all of your parts for future use. Explain to the class how you took the machine apart. Name all of the parts for them.

Evaluation

1. Into which of the five systems did the most parts of your junk item fall?
2. Make a list of all of the parts you found in your junk item.
3. **Going Beyond.** Make a display showing several parts from a dissected machine. Fig. B.

SAFETY FIRST

Ask your instructor to inspect your junk item and warn you of any dangerous parts you should avoid. Specifically, you should be careful with old TVs or computer monitors. They might have an electronic capacitor that can hold a charge even if the machine has been unplugged for many hours. Be careful! Ask your teacher for help.

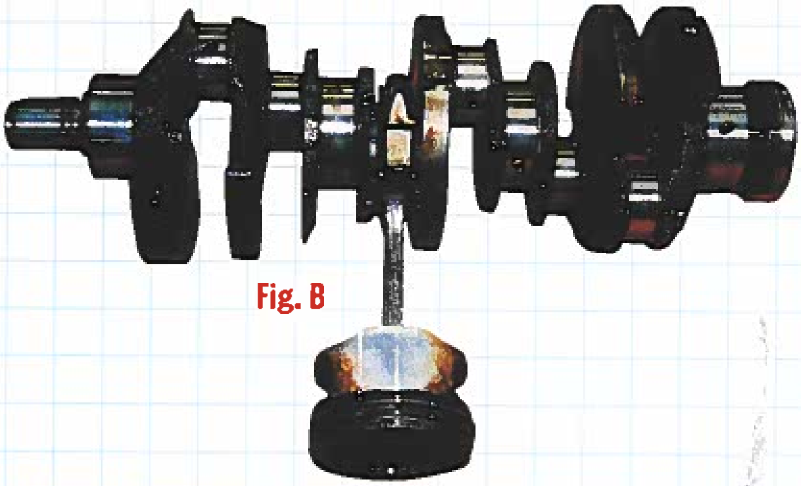


Fig. B

ACTION ACTIVITY

SECTION 2
ACTIVITY 2

Leapin' Links 'n' Levers

Be sure to fill out your TechNotes and place them in your portfolio.

Real World Connection

Levers have been used throughout history to help move heavy objects. When you pull out a nail with a hammer, crack open a nut with a nutcracker, or tighten a bolt with a pair of pliers, you're using levers.

In this activity, you will make a lever-and-linkage device that will work like a mechanical hand on the end of a robot arm. Fig. A.

Design Brief

Build a robot gripper that can be used to pick up a pencil from a desktop. The gripper will be used in the last activity for Section 4 of this chapter. To make it you can use any type of lever or linkage you can think of.

Materials/Equipment

- acrylic plastic
- wood
- wood screws
- drill press or power drill and drill bits
- scroll saw or band saw
- screwdriver
- ruler

SAFETY FIRST

Follow the safety rules listed on pages 42-43. Follow safety rules for using saws and drills as directed by your teacher.

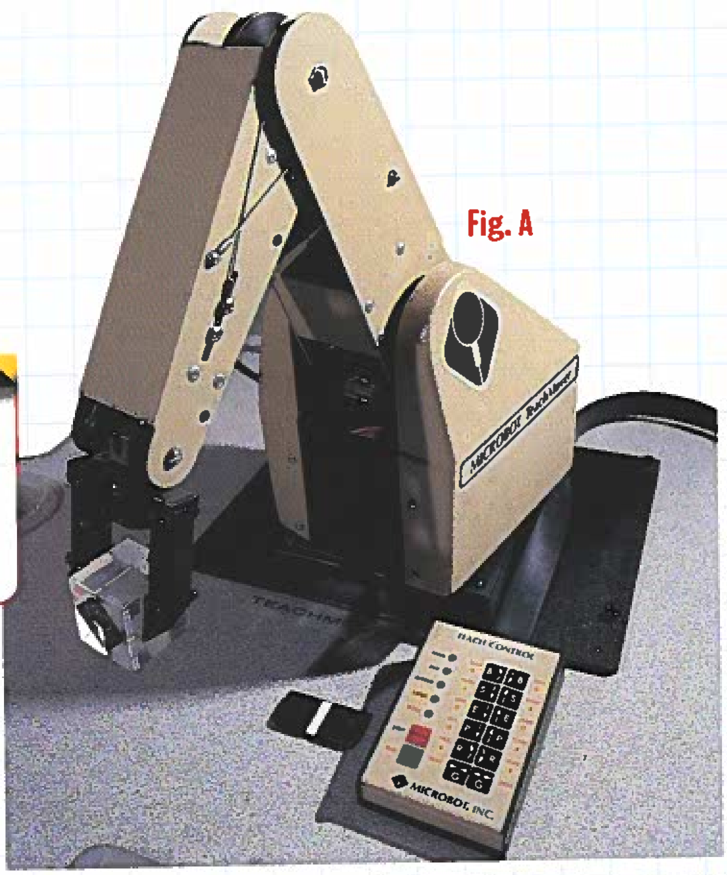


Fig. A

(Continued on next page)

Procedure

1. Work in groups of four. Each group will work together to make one robot gripper. Each member of the group should brainstorm at least four different design ideas. Each member should make four sketches on paper or use graphics or CAD software on a computer.
2. As a group, choose one design. Refine the design and have it approved by your teacher. If your idea is original and workable, your teacher will issue a patent to your group. Then no one else in the class will be able to use your idea without your permission.
3. Safely and carefully cut the materials you will need to make your gripper. Have each person in the group make a different part to save time.
4. Assemble and test your gripper. Later you will attach your gripper to the end of a robot arm.

INFOLINK
See Chapter 6 for more information about patents.

Evaluation

1. Name a lever that is a part of most cars.
2. What mechanical parts (or simple machines) are of help in making a robot gripper?
3. How could you design a robot to pick up small delicate parts such as a watch crystal?
4. **Going Beyond.** As you use tools and machines to make your gripper, make a list of all the levers and linkages you notice.
5. **Going Beyond.** Find out about the Space Shuttle's Remote Manipulator System (RMS). How do astronauts use this "arm"? Fig. B.

INFOLINK
See Chapter 18 for more information about the RMS.

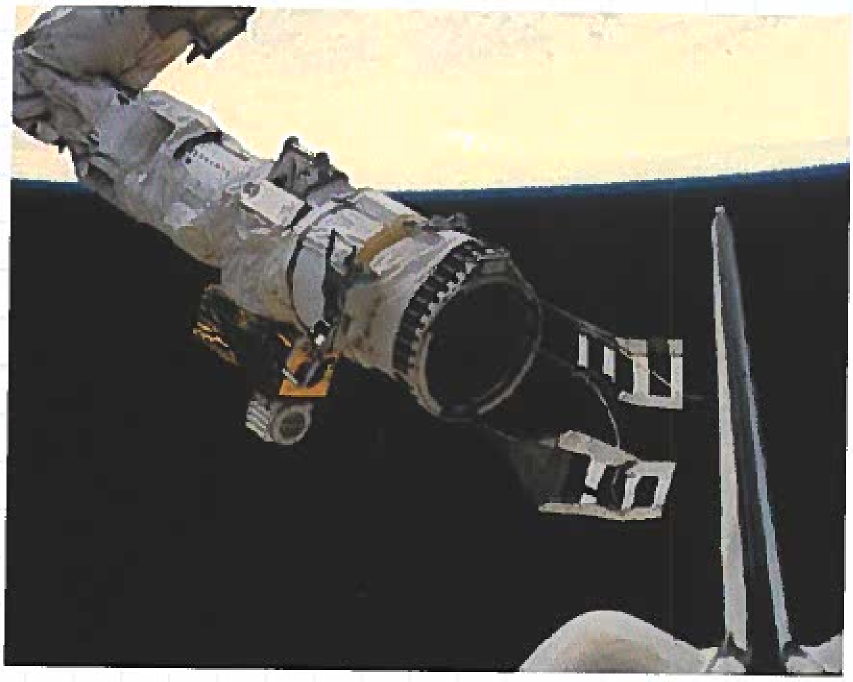


Fig. B

Exploring Electrical & Electronic Systems

SECTION 3

THINGS TO EXPLORE

- Define electricity and electronics.
- Identify conductors, insulators, semiconductors, and superconductors and give examples.
- Explain how to properly set up series, parallel, and series-parallel circuits using electronic components.
- Make an electrical circuit.

TechnoTerms

- circuit
- component
- electricity
- electronics

Electricity is the flow of electrons (small, negatively charged parts of an atom) through a material. **Electronics** is a part of technology concerned with the movement of these electrons through conductors, insulators, semiconductors, and superconductors. Fig. 8-7.

- **Conductors.** A conductor is a material that lets electrons pass easily from one atom to another. Most metals are good conductors. Can you think of other materials that are good conductors?
- **Insulators.** Materials that do not allow electrons to flow easily are called insulators. Examples of insulators include plastic, rubber, and glass. Can you think of other materials that are good insulators?
- **Semiconductors.** Semiconductors are important to electronics because they conduct electricity only under certain conditions. Silicon is a commonly used semiconductor. It is used to make integrated circuits (ICs).
- **Superconductors.** Superconductors can conduct electricity perfectly. Even some of the best ordinary conductors, such as copper, *resist* (hold back) the flow of electrons a little. Superconductors have no resistance at all.

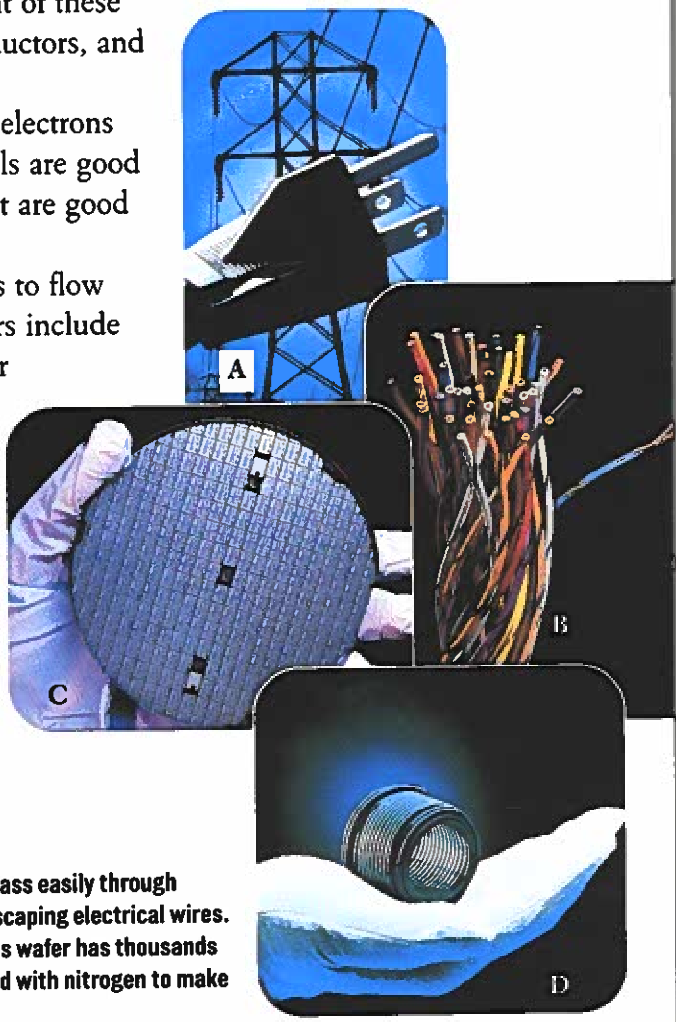


Fig. 8-7. **(A) Conductors allow electricity to pass easily through them. (B) Insulators prevent electricity from escaping electrical wires. (C) Semiconductors are used in electronics. This wafer has thousands of semiconductors on it. (D) A wire can be cooled with nitrogen to make it a superconductor.**

TechnoFact

FLOATING TRAINS

Experiments are being conducted to build trains that float on a magnetic field instead of rolling on a track. These *magnetic levitation*, or *maglev*, systems would allow trains to travel over 300 miles per hour! What makes maglevs possible? Superconductors.

INFOLINK

See Chapter 20 for more information about maglev trains.

Electrical Circuits

To be useful, conductors, insulators, semiconductors, and even superconductors must be connected in some way into a circuit. A **circuit** is the complete path along which electrons flow. Electronic parts, or **components**, are commonly connected in three basic types of circuits: series, parallel, and series-parallel. Fig. 8-8.

When components are connected in line, one after the other, they are in series. *Series* circuits are very common. One disadvantage to them is that if one part in the series fails, the entire circuit fails. Some holiday lights are wired in series, so if one light burns out the whole string goes out.

Parallel circuits are arranged so that other parts continue to work even if one part fails. Parallel circuits are common in all electronic products such as televisions, radios, and stereos.

The third type of circuit consists of a combination of series and parallel circuits. This type is called a *series-parallel* circuit.

In a *short circuit*, electrons bypass the proper path. For example, two uninsulated wires may touch in a way that causes the electrons to pass through the wires rather than the components. This causes too much current to flow in the circuit, which can be dangerous. If the excess current is high enough, it can cause a fire or even death.

SCIENCE CONNECTION

Superconductivity

What is superconductivity? You might think it is something brand new, but scientists have known about superconductivity since 1911.

Superconductivity was discovered by Dutch physicist Heike Kamerlingh Onnes. He was researching the effects of extremely cold temperatures on different metals. He discovered that mercury lost all resistance to the flow of electricity when cooled to about 4 Kelvin (K) (about -452° F or -269° C).

To understand how important his discovery is you need to think about how electricity works. Even the best conductors are not perfect because some electrical energy is lost to resistance. Before Onnes' discovery, there was no way to eliminate resistance. Superconductors were the answer. They let electricity flow with no resistance at all.

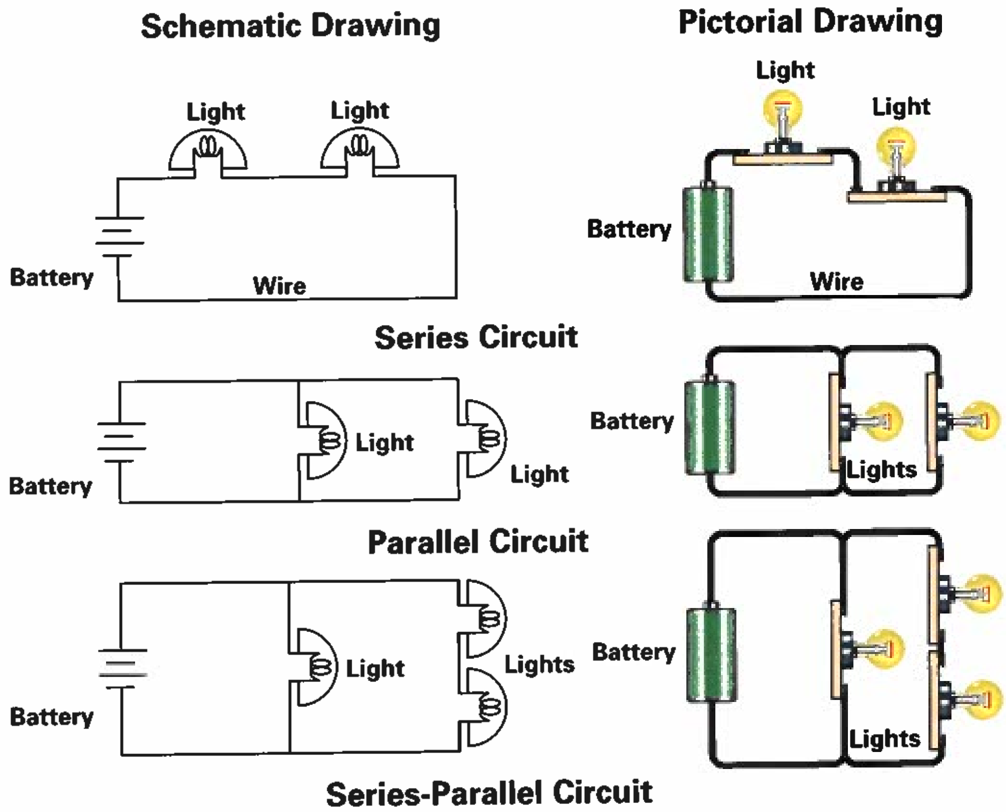


Fig. 8-8. Components are connected in a circuit in one of three basic methods. What would happen to the second light in the series circuit if the first light went out?

Imagine all the uses for such a discovery! Superconductors can be used to save energy and money in power systems. Generators wound with superconductor wire instead of copper wire can generate the same amount of electricity with smaller equipment and less work.

The magnet to the left is floating above a superconductor that was cooled with liquid nitrogen. The magnetic field of the magnet produces an opposing magnetic field in the superconductor. The result is magnetic levitation.

Scientists see superconductivity as a very promising, exciting application of technology that will help us save energy and provide better ways to make things work.

ACTIVITY

Design a futuristic device based on superconductivity or write a story about how superconductivity could benefit your life.

Electronic Components

The components that are put into circuits are designed to control the flow of electrons. Some you might use to make electrical circuits include resistors, capacitors, diodes, and transistors. Fig. 8-9.

- **Resistors.** Resistors resist the flow of electricity. They come in many sizes and shapes. The most common types are coded with colored stripes to show their resistance level.
- **Capacitors.** Components that temporarily hold an electrical charge are called capacitors. Televisions and computer monitors, for example, have high-voltage capacitors that can hold a charge for many hours after the power is turned off. However, they can be dangerous because, even though the power is off, the capacitor holds enough charge to cause injury.
- **Diodes.** In a diode, electrons flow in only one direction. Diodes are marked in some way to show the direction of flow. They come in a variety of sizes, depending on the amount of current that will flow through the circuit.
- **Transistors.** Transistors are made with a semiconducting material. They have three wires called *leads*. A very small current or voltage applied to one lead can control a large amount of electric current at the other two leads. Transistors are commonly used as switches or to *amplify* (make larger) electrical circuits. Transistors started a revolution in technology because they made it possible for electronic products to be smaller, lighter, more reliable, and less expensive.

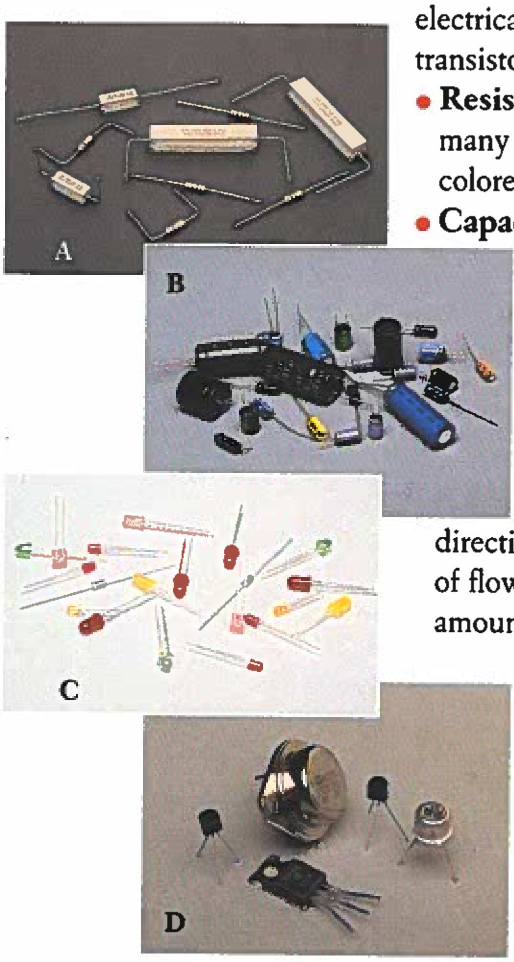


Fig. 8-9. Electronic components include (A) resistors, (B) capacitors, (C) diodes, and (D) transistors.

SECTION 3 TechCHECK

1. Define *electricity* and *electronics.*
2. What is the difference between a semiconductor and a superconductor?
3. How is a parallel circuit different from a series circuit?
4. **Apply Your Knowledge.** Make a display of electronic components found when you dissect an electronic device such as a radio.

ACTION ACTIVITY

Motor Motion Magic

Be sure to fill out your TechNotes and place them in your portfolio.

Real World Connection

A simple battery-operated motor can be used in many ways. Small motors that run on 1 1/2 to 12 DC volts can be found in many products. Fig. A. Portable tape players, toys, and even full-size cars use battery-operated motors. You can probably think of many more examples.

In this activity you will learn to reverse a small motor using a type of switch called a double-pole, double-throw (DPDT) switch. This is one of many different types of switches used to control the flow of electrons.

Design Brief

Make an electric circuit using a DPDT switch that will reverse the direction of a motor.

Materials/Equipment

- small DC motor (1 1/2-12 volts), such as from the machine dissection activity for Section 2
- hookup wire
- power supply (0-12 volts DC)
- wire strippers

SAFETY FIRST

- **Follow the safety rules listed on pages 42-43 and the specific rules provided by your teacher for tools and machines.**
- **When you are experimenting with electricity, use low-voltage batteries to avoid the possibility of a painful or life-threatening electrical shock.**

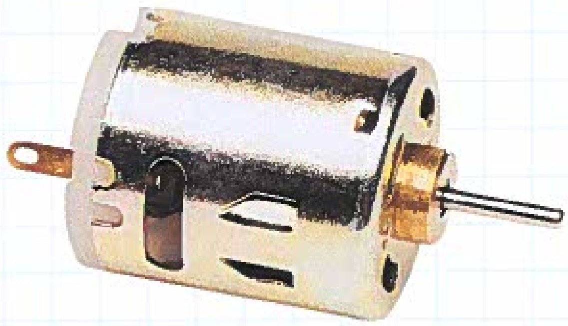


Fig. A

Procedure

1. Work in pairs. Use a small electric motor from the junk machine dissection activity, or get one from your teacher. You will be connecting your motor in a series circuit with a switch to control its direction.
2. Electronic circuits are drawn using a set of symbols to represent real parts. These drawings are called *schematic diagrams*, or simply *schematics*. Connect the circuit according to the schematic in Fig. B.
3. Be sure to set the power supply to zero before you connect the motor. Have your teacher check your circuit.
4. Turn on the power supply. Check your circuit to see if it will reverse the direction of the motor when you flip the switch.

Evaluation

1. Did your circuit work the first time you tried it? If not, what was wrong?
2. How could you use a circuit with a DPDT switch and motor in a crane or winch?
3. **Going Beyond.** Design an electrical maze using wires, batteries, and a buzzer.

Schematic Drawing

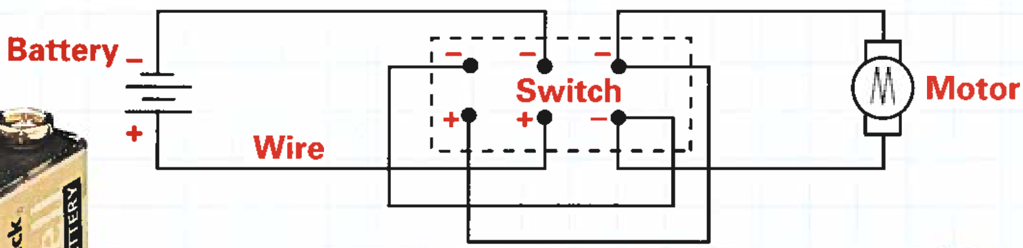
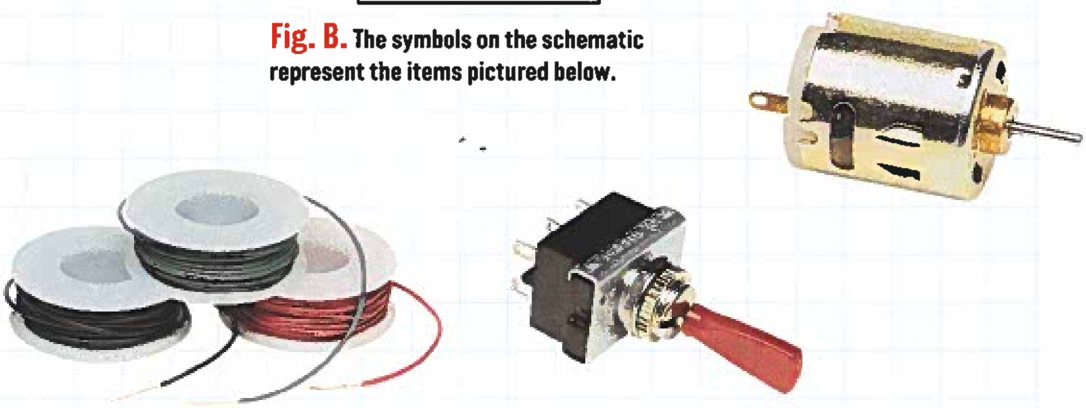


Fig. B. The symbols on the schematic represent the items pictured below.



Exploring Fluid Systems

SECTION 4

THINGS TO EXPLORE

- Tell what a fluid is and give examples.
- Explain how hydraulic and pneumatic systems operate.
- Design and build a robotic arm powered by hydraulics.

TechnoTerms

- air compressor
- hydraulic pump
- hydraulic system
- piston
- pneumatic system

When someone says "fluid," what do you think of first? Most people think of water or some other liquid. The fact is that fluids can be either liquids or gases. Both air and water are examples of fluids.

Fluid Systems

Fluid systems are one of two types: hydraulic or pneumatic. **Hydraulic systems** operate using a liquid, usually oil. **Pneumatic systems** operate with a gas, usually compressed air. Fig. 8-10. These fluid systems apply pressure on the fluid to do work. Since it is harder to compress a liquid than a gas, hydraulic systems apply more pressure and can lift heavier loads or stop heavier objects.

Fluid systems need a source of power. In hydraulic systems, a **hydraulic pump** is used. Pneumatic systems use an **air compressor** (a machine that squeezes, or compresses, air) as a power source.

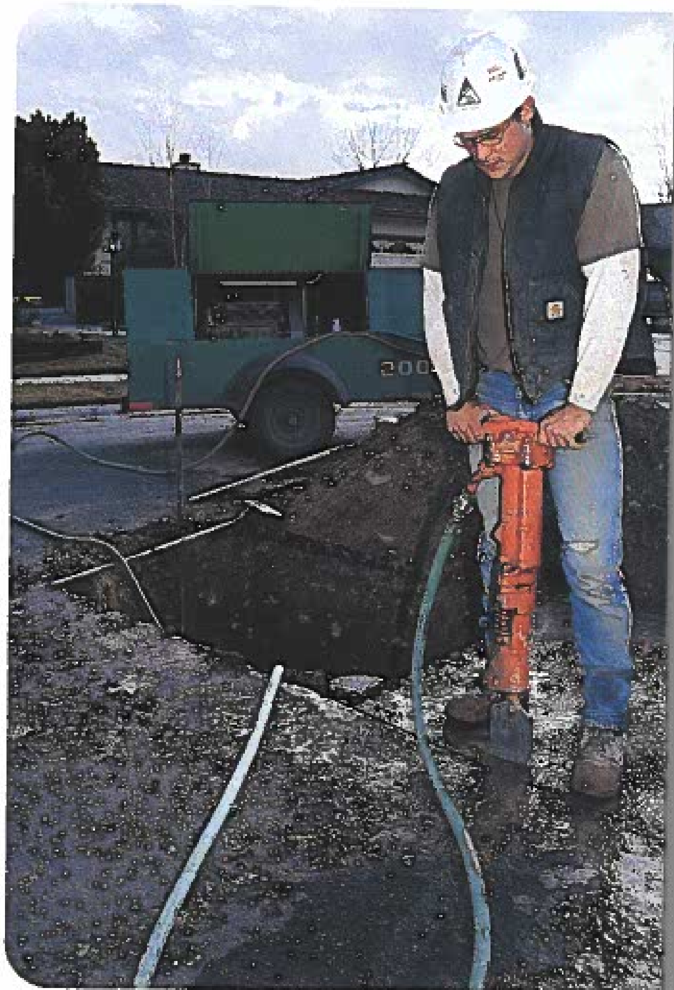


Fig. 8-10. The compressed air that powers this pneumatic hammer is created in the generator in the background. How does the air travel to the hammer?

Fig. 8-11. Hydraulic pistons are used in locomotives. Why do you think they are so large?

Cylinders and Pistons

A common component in both hydraulic and pneumatic systems is a cylinder containing a **piston**. As air or oil is pumped under pressure into the cylinder, it makes the piston move. Fig. 8-11.

Cylinders commonly come in two types, single-acting and double-acting. In single-acting cylinders, pressure is applied to the piston in one direction only. Automobile shock absorbers and hydraulic door closers contain single-acting cylinders. In double-acting cylinders, pressure is applied in either direction. This type of cylinder can push as well as pull. You may have seen hydraulic cylinders working on a backhoe or a dumptruck. Which kind of cylinder do you think is at work in the backhoe? Which is used in the dumptruck?

SECTION 4 TechCHECK

1. What is a fluid?
2. Explain how pneumatic and hydraulic systems operate.
3. Which fluid system would you use to lift heavy loads? Why?
4. Apply Your Knowledge. Research fluid systems used in airplanes. Make a chart to show your findings.

ACTION ACTIVITY

Making a Fluid-Powered Robot

Be sure to fill out your TechNotes and place them in your portfolio.

Real World Connection

Real robots can do many different jobs. Many are operated using hydraulic or pneumatic power. In this activity, you will have a chance to put fluid systems together to make a hydraulic robot. Real robots use computers to control their actions. In this activity, you will act as the computer-controller for your robot.

Design Brief

Design, build, test, and refine a robot arm that can pick up a pencil from the surface of a table by means of fluid power. The robot must be able to move the pencil to another part of the table and release it. During testing, you may touch only the controls of your robot, not the gripper or the arm. The controls must be at least 12 inches from the gripper.

Materials/Equipment

- acrylic plastic or foam core poster board
- wood, wood screws
- syringes
- plastic tubing
- water
- food coloring
- drill press or power drill, drill bits
- scroll saw or band saw
- screwdriver
- ruler
- usable parts from the machine dissection activity in Section 2 (optional)
- gripper from the links and levers activity in Section 2

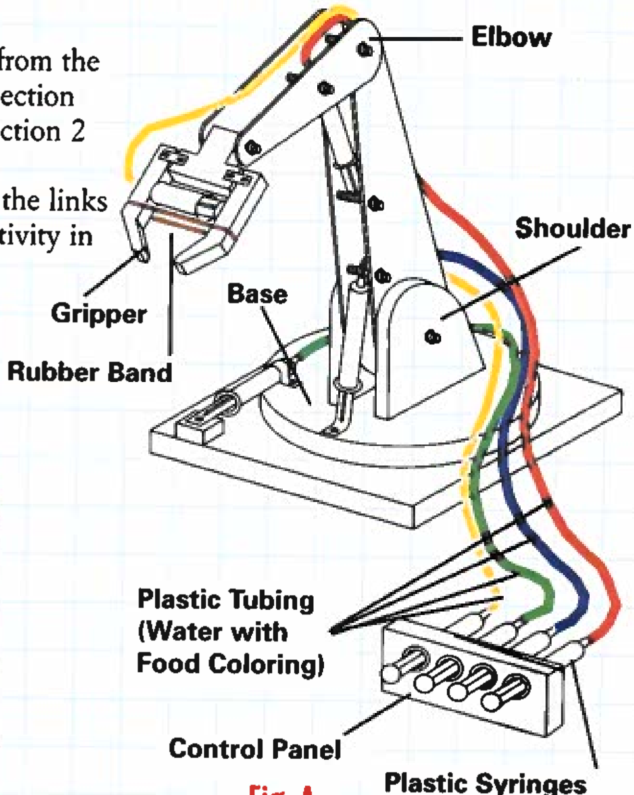


Fig. A

SAFETY FIRST

Follow the safety rules listed on pages 42-43 and the specific rules provided by your teacher for tools and machines. Do not use too much force to push the plunger in the syringes. If you do, the tube might come loose and the colored water might leak out.

(Continued on next page)

Procedure

1. In this activity you need to remember how to solve a problem systematically. Do you remember the problem-solving steps?
   - Identify or define the problem.
   - Gather ideas or solutions.
   - Use your best judgment to pick the best solution.
   - Test your idea.
   - Evaluate your idea, and refine it until it is the best solution to the problem.
2. Work in groups of four or five. Design your hydraulic robot to work with plastic syringes and tubing containing colored water. Fig. A.
3. Brainstorm different ideas. Make sketches or use graphics or CAD software on a computer.
4. As a group, discuss how the robot will operate and what materials will be best to use.
5. Make a list of the materials needed, their size, and quantity. This list is called a *bill of materials*. Fig. B.
6. Following your teacher's instructions, carefully cut the materials for each part of your robot. Have everyone in the group work on a different part to save time.
7. Assemble and test your robot arm. Remember that very few new ideas work perfectly the first time. The last step in solving a problem is to evaluate and refine the solution as needed.

Evaluation

1. List the steps in problem solving. Next to each step, write a description of what you did to solve the robot problem.
2. What is a bill of materials?
3. How are real robots controlled?
4. **Going Beyond.** Try using your robot arm with just air in the syringes and tubing. Now you have a pneumatic or air-powered robot. How does it work? Which system works better? Why?
5. **Going Beyond.** Try to animate your robot using animation software on a computer.
6. **Going Beyond.** Measure the maximum range of your robot's movements. This is called a robot's *work envelope*. Make a sketch with dimensions showing the work envelope.

Quantity	Item Name	Description
3	Syringe	50 cc
2	Wood Screw	1 1/2" #8 Flat Head
3 ft.	Tubing, plastic	1/8" I.D. (Inside diameter)

Fig. B

Exploring Chemical and Thermal Systems

SECTION 5

THINGS TO EXPLORE

- Identify various chemical systems.
- Explain the difference between dry-cell and wet-cell batteries.
- Tell what a thermal system is and how it works.
- Design and build a hot wire cutter.

TechnoTerms

electrolyte
petrochemical
petroleum
refining
thermocouple

Chemical systems are those based on—you guessed it!—chemicals. Thermal systems have to do with heat. Both are important to technology.

Chemical Systems

Have you ever heard of sodium tallowate, stearic acid, ammonium chloride, or methylchloroisothiazolinone? Read the label on everyday products such as toothpaste, soap, or shampoo and you might find these names as well as some that sound even stranger. Chemicals play an important part in technology.

Batteries Did you know that a chemical system enables you to use a portable stereo? Chemical reactions produce electricity in batteries, providing a portable electrical source. The chemicals used to produce voltage are called **electrolytes**. Small batteries such as those used in a flashlight require a paste of chemicals *(dry cell)*. Fig. 8-12. Larger batteries, such as those used to start a car, use a liquid *(wet cell)*.

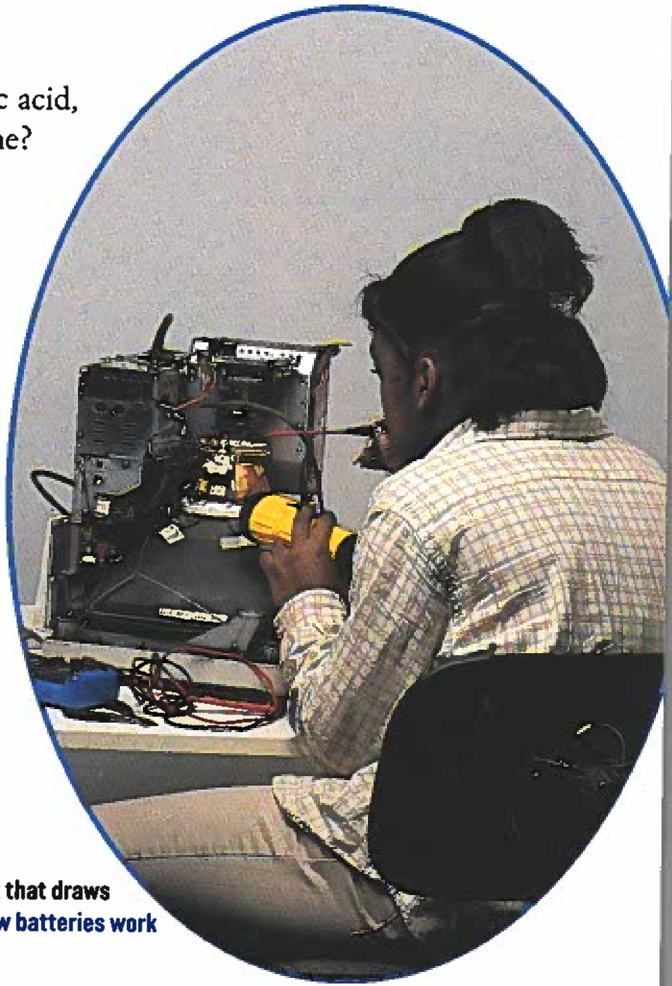


Fig. 8-12. This teen is using a flashlight that draws power from dry-cell batteries. Find out how batteries work and report your findings to the class.

Fig. 8-13. **Petroleum comes from wells like this one off the coast of California. Why do you suppose a small boat is used to travel between the rig and any visiting large ships?**

TechnoFact

CHEMICAL FACTORIES Oil refineries are chemical factories that change crude oil into such products as heating oil, gasoline, and kerosene. Special chemicals called *catalysts* are added during the refining process to make the chemical reaction go faster or to change the desired result.

Batteries are only one example of a chemical system used for energy.

Chemical systems produce most of the electrical energy we use at home, in school, and in factories. For example, the chemical energy stored in coal is changed into heat (thermal) energy and then into electrical energy.

Petroleum Products The gasoline we use in cars or trucks is a product of very specialized chemical systems based on **petroleum**, or oil. Fig. 8-13. The oil found in the ground is called *crude oil*. Crude oil is not usable in its natural form and must be changed into other products by **refining**.

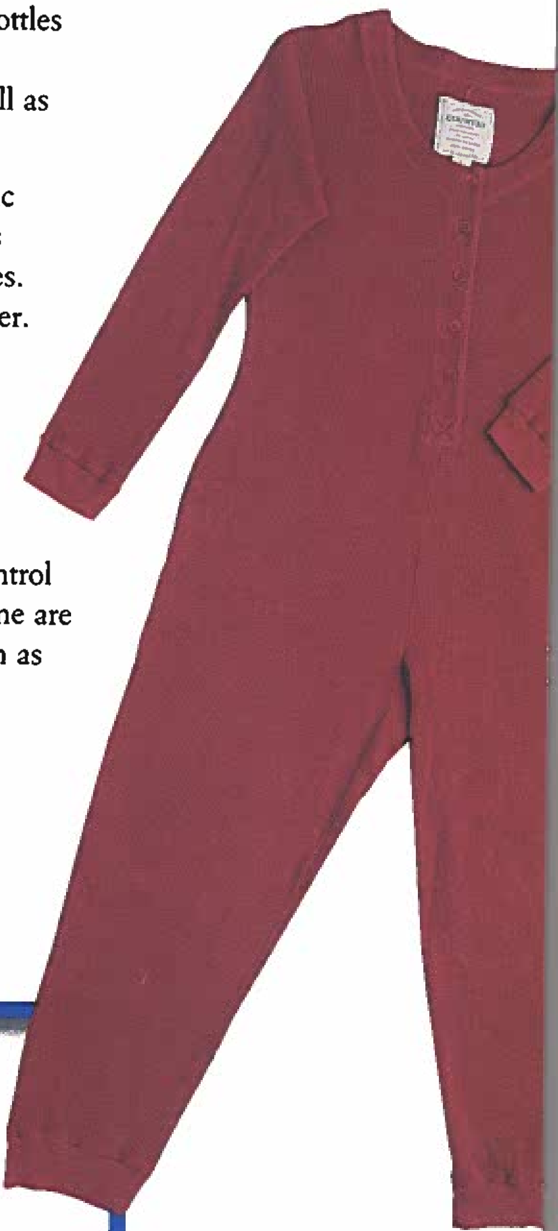
Did you know that some plastics and medicines come from oil? Products produced from oil are called **petrochemicals**.

Thermal Systems

What do thermostats, thermal underwear, and thermos bottles have in common? If you said "heat," you're right! Thermal systems control heat—the temperature of your toaster as well as the temperature of your automobile engine.

Devices that control temperature often contain a bimetallic strip. *Bimetallic* means it is made of two different metals. As metals heat up, they expand (get larger), but at different rates. One metal in the bimetallic strip expands more than the other. This difference causes the bimetallic strip to bend to one side. As it bends, it triggers an electric circuit to start or stop heating or cooling equipment.

Another interesting device in thermal systems is a **thermocouple**. A thermocouple is like an electric thermometer. Thermocouples are connected to gauges in control rooms away from areas affected by extreme heat or cold. Some are used to read very high temperatures in dangerous areas, such as the core of a nuclear reactor.



SECTION 5 TechCheck

1. Name two chemical systems that affect your life.
2. What is the difference between a wet-cell and a dry-cell battery?
3. What is a thermal system?
4. Apply Your Knowledge. Write down the contents of several household products, such as toothpaste and shampoo.

ACTION ACTIVITY

Putting a Thermal System to Work

Be sure to fill out your TechNotes and place them in your portfolio.

Real World Connection

In long-distance power lines, resistance to electron flow is not something we want. However, resistance is not always bad. Sometimes it is used to create thermal energy. In this activity, you will use resistance to create thermal energy to cut plastic foam.

The hot wire cutter you will make is an example of a simple series circuit. Electrons flowing through *Nichrome wire* make it hot. Electric heaters and toasters use this same type of wire to heat your home or to make toast.

Design Brief

Design and build an electric hot wire cutter that you can use safely and accurately to cut shapes out of plastic foam. Fig. A.

Materials/Equipment

- Nichrome wire (28 gauge x 12" long)
- prefinished particleboard, 3/4" x 12" x 24"
- steel rod, 1/4" diameter x 18"
- DC power supply, adjustable 0-12 volts
- hookup wire
- wood glue
- Styrofoam plastic foam
- wood block, 1 1/2" x 3 1/2" x 3 1/2"
- stick-on plastic "feet"
- drill press or power drill with 1/4" drill bit
- wire cutter or stripper
- hacksaw
- band saw
- scroll saw
- 6" C-clamp

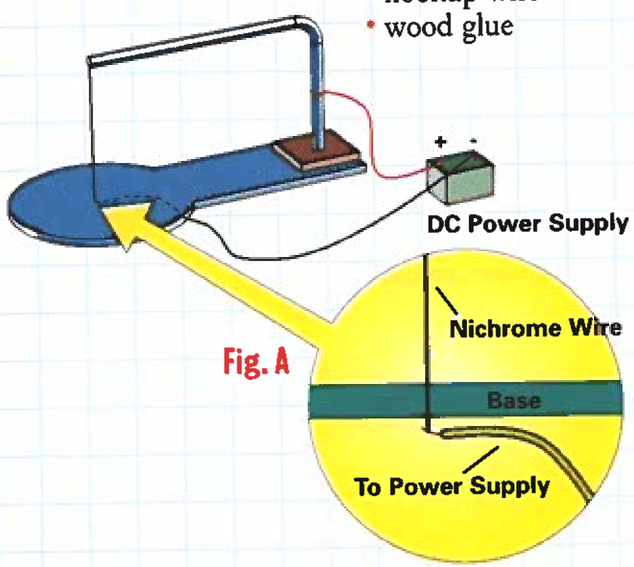


Fig. A

SAFETY FIRST

Follow the safety rules listed on pages 42-43 and the specific rules provided by your teacher for tools and machines.

Procedure

Part 1 • Designing the Foam Cutter

1. Work in groups of five or six. Design a base for your hot wire cutter. Your base should be sturdy and have a wide area for holding the plastic foam flat. You might design your base using graphics or CAD software on a computer.
2. Lay out your design on particleboard. With your teacher's help, carefully cut the particleboard using a scroll saw for sharp curves and a band saw for straight lines or wide curves.
3. Cut a 2" x 4" to the 3 1/2" length needed, using a hand saw or a band saw.
4. Glue and clamp the wood block to the back of the base to help support the steel rod. Let the glue set.
5. With your teacher's help, use a drill press to drill a 1/4"-diameter hole in the center of the block and press through the base. If you are using a portable power drill, be sure to hold the drill in a vertical position.
6. Place an 18"-long piece of 1/4" steel rod in a vise. Carefully bend the rod to almost a 90° angle. You may have trouble bending the rod. Try to think of a safe way to make it easier for you. Ask your teacher for help with your idea. (When you finish, the Nichrome wire will pull the rod into a 90° angle. The steel rod works like a spring to keep the Nichrome wire tight.)
7. Locate a point in the center of your cutter base for the Nichrome wire to pass through. Drill a 1/4"-diameter hole.
8. Cut and strip the ends of the hookup wire needed to attach your cutter to the power supply.
9. Assemble the cutter so the Nichrome wire is pulled tight enough to bend the steel rod to 90°.
10. Finish your cutter by putting on the plastic "feet" to help steady it and to protect countertops.

Part 2 • Testing the Hot Wire Cutter

1. Ask your teacher to inspect your work. Be sure to start with the power supply turned off and adjusted to 0 volts. Connect the hookup wires to the positive (+) and negative (-) terminals. It doesn't matter which wire is positive or negative.

SAFETY FIRST

The Nichrome wire will become very hot. Do not touch it or let it touch anything other than the plastic foam you are cutting. Adequate ventilation must be provided to remove the fumes produced when plastic foam is cut. Do not use the hot wire cutter in closed spaces, without teacher supervision, or to cut anything but foam.

2. Test your hot wire cutter by holding a piece of Styrofoam plastic foam against the wire. Slowly turn up the voltage until the Nichrome wire can melt the foam. Try cutting various shapes.

Part 3 • Improving Your Hot Wire Cutter

1. Design and test a method to accurately cut the following shapes: long, thin rectangles; perfect circles; cones; other geometric shapes.
2. Sketch your methods on paper.

Evaluation

1. What happens if you start to cut into Styrofoam plastic foam and stop before the cut is finished?
2. Why is it important to watch what you are doing when using the hot wire cutter?
3. **Going Beyond.** List three electrical appliances you might have at home that have Nichrome wires in them that get hot.

CHAPTER 8

REVIEW &

CHAPTER SUMMARY

SECTION 1

- A system is a combination of parts that work together as a whole.
- The systems model includes input, process, output, and feedback.
- The five basic systems used in technology are mechanical, electrical, fluid, thermal, and chemical.
- Trying to find the problem in a system is called troubleshooting.

SECTION 2

- Mechanical systems often include levers, gears, chains, cams, flywheels, springs, and other parts.

SECTION 3

- Electronics involves the movement of electrons through conductors, insulators, semiconductors, and superconductors.
- Electronic components such as diodes, capacitors, transistors, and resistors are connected in three basic circuits: series, parallel, and series-parallel.

SECTION 4

- Fluid systems are either hydraulic or pneumatic.

SECTION 5

- Chemical systems include batteries and petroleum products.
- Thermal systems control the temperature of things.

REVIEW QUESTIONS

1. What systems can you find in a flashlight? Do they work together or independently?
2. What is the difference between a single-acting cylinder and a double-acting cylinder?
3. What is a superconductor?
4. List three materials that are insulators and three that are conductors.
5. Why is it important that mechanical parts be made in standard sizes?
6. What parts of a car would be considered thermal systems?

CRITICAL THINKING

1. Name a situation in which pneumatic systems would be better to use than hydraulic systems. Explain why.
2. Research ways to use a computer to control a part of your robot.
3. Make a chart identifying different kinds of mechanical fasteners by name.
4. Design a hand-held foam cutter. Sketch your design on paper, and discuss it with your teacher. Make and test your hand-held cutter with the help of your teacher.
5. Design a flywheel-powered car.