LESSON 7

The Force Exerted by a Motor

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The word "motor" comes from a Latin word that means "to move." Motors are used to lift and move heavy loads, like this huge metal drum.

INTRODUCTION

Motors are all around you. These devices generate motion by turning other forms of energy into mechanical energy. Motors do work and make difficult tasks easier. They range in size from tiny to huge. Later in the lesson, you will read about some of these motors. You will also use batteries to run a small electric motor, and you will investigate the motor's ability to lift a load of washers.

OBJECTIVES FOR THIS LESSON

Design and execute an experiment to determine the operating conditions that produce the maximum force from a motor.

Analyze experimental data.

Write a conclusion based on experimental evidence.

Measure the force that a motor exerts under the best operating conditions.

Getting Started

1. With the class, discuss the elements of a well-designed experiment. Review the meaning of independent and dependent variables.

2. Your teacher has displayed a model of an apparatus used in this inquiry. Identify each part and what each part does.

3. Discuss with your partner and then with the class the following questions:

   A. How many washers can the motor lift?

   B. Can you think of anything that would affect the motor's ability to lift the load of washers? If so, what is it?

4. Record a summary of the class ideas in your science notebook.

MATERIALS FOR LESSON 7

For you and your lab partner

1 electric motor with wire leads and alligator clips
1 motor pulley with nail
1 motor clamp
1 knife switch
1 pegboard assembly
3 machine screws with wing nuts
3 D-cell batteries
3 D-cell battery holders
5 insulated connector wires with alligator clips
1 large paper clip
1 piece of string
1 piece of masking tape
8 large washers
1 0- to 10-N spring scale

Inquiry 7.1
Measuring the Force Exerted by a Motor

PROCEDURE FOR PERIOD 1

1. Examine the equipment at your lab station. Predict what arrangement of motor, batteries, and string will enable the motor to lift the largest number of washers. Record your prediction in your science notebook.

2. Your goals for this period are to set up and test your equipment and to plan a procedure to test your prediction. Set up the motor, knife switch, and pegboard assembly as shown in Figure 7.1. If your teacher has not already done so, remove the black caps from the screw terminals on the knife switch and return the caps to your teacher. Use two screws and wing nuts to attach the motor clamp to the pegboard; fasten the knife switch to the pegboard using one screw and wing nut.

3. Compare your setup with the model setup to make sure everything is correctly connected.

4. Attach one battery to the motor and make sure the motor works. If it doesn't, check the connections. If the setup still won't work, ask your teacher for help.

5. Think about the following questions:

   A. Do you think the number of batteries you connect to the motor will have an effect on the motor performance?

   B. If you use more than one battery, do you think the way the batteries are connected will matter? (Figure 7.2 shows different battery arrangements.)

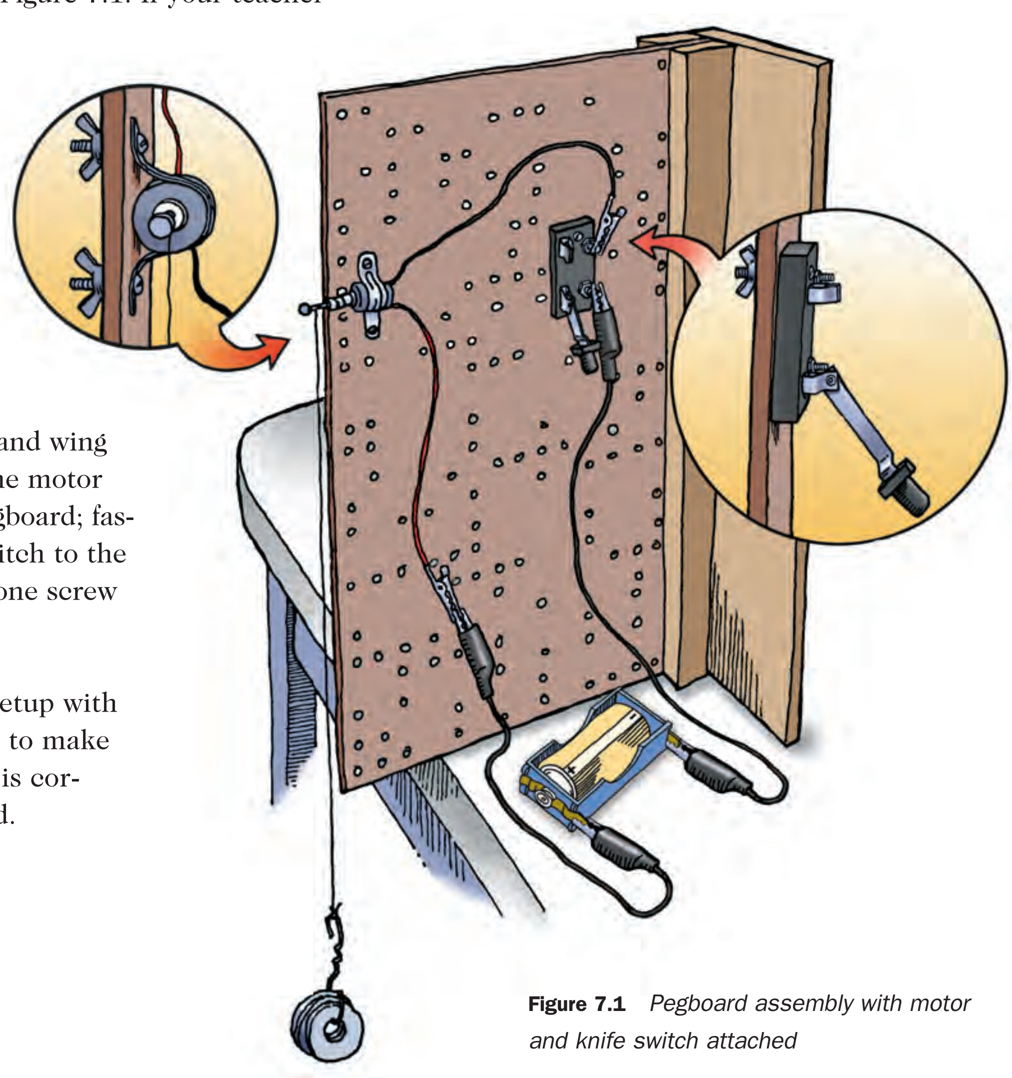


Figure 7.1 *Pegboard assembly with motor and knife switch attached*

Figure 7.2 *Some possible ways to connect the batteries*

6. There are two ways to connect the string to the motor. Figure 7.3 shows both arrangements. Do you think it matters if you wind the string around the plastic pulley instead of around the nail?

7. Record the independent variables for this experiment in your science notebook.

8. List the dependent variable in your science notebook.

9. Design an experiment that shows the effect of each independent variable on the total number of washers the motor can lift. Remember, when you conduct a scientific investigation, change one variable at a time while keeping all the others constant.

10. In your notebook, write a procedure that describes which variable you will change and how you will change it. Do this for each independent variable.

11. Design a table (or tables) in your science notebook to record your data. You will use this table to share results with the class.

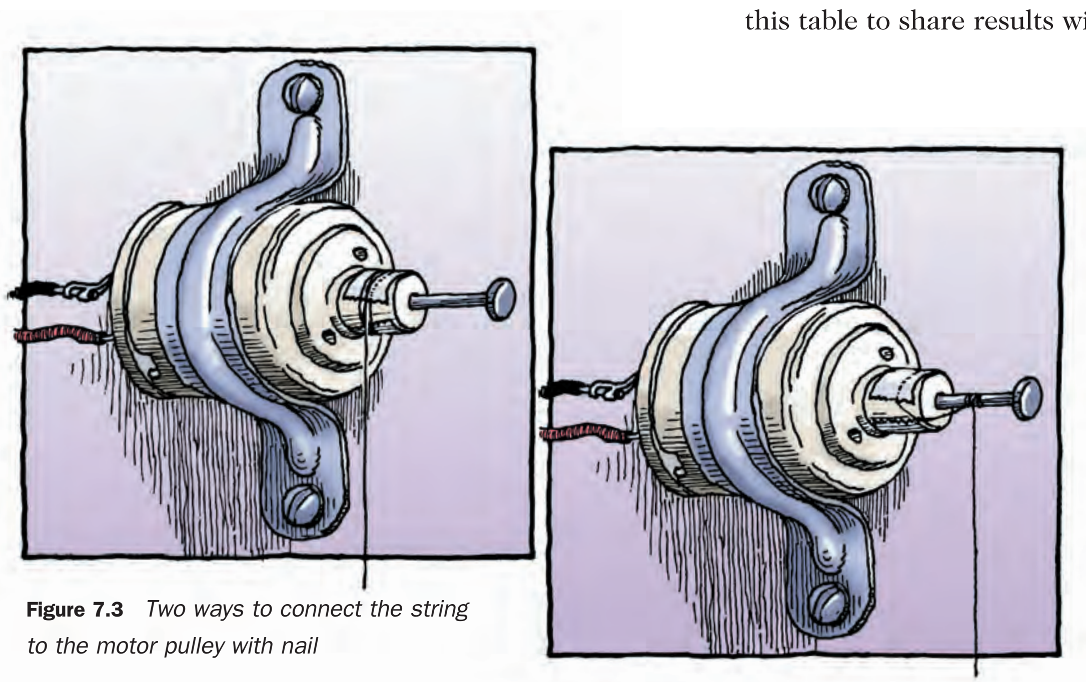


Figure 7.3 *Two ways to connect the string to the motor pulley with nail*

PROCEDURE FOR PERIOD 2

1. Conduct the experiment following the procedure you designed. Record your observations and data in your science notebook.

2. Use the results of your experiment to describe the arrangement of motor, batteries, and string that allows the motor to lift the greatest number of washers. Describe the arrangement in your science notebook or draw a picture showing the arrangement.

3. Using a spring scale, measure the force of the motor for this arrangement. To measure the pull of the motor, follow these directions:

   A. Set up your pegboard as shown in Figure 7.4.

   B. Make a loop in the loose end of the string and attach it to the spring-scale hook.

   C. Secure the other end of the spring scale with a machine screw and wing nut so it is positioned as shown in Figure 7.4.

   D. Fasten the string to the motor, using the arrangement that allows the motor to lift the greatest number of washers.

   E. Close the knife switch and observe the force reading on the spring scale. Record the reading in your table, and then open the knife switch.

   F. If you have time, repeat the experiment several times and record the measurements to show that your data are reproducible (that is, you get the same or similar results each time you do the experiment). If you collect several sets of data, average the data and record this average value in your notebook.

4. When you finish your experiment, clean up and store the materials as your teacher directs.

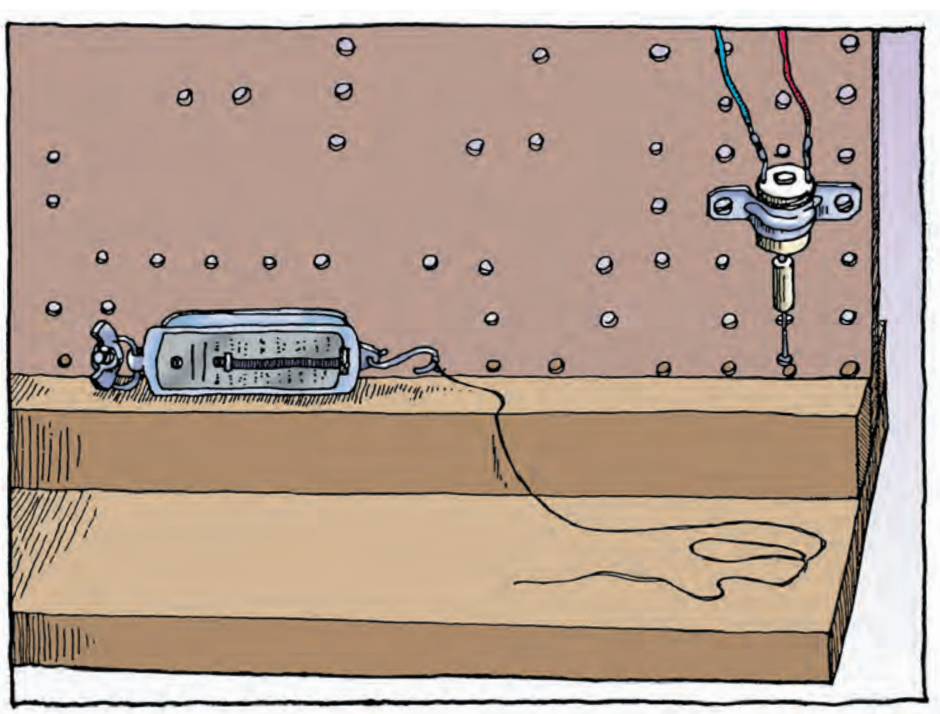


Figure 7.4 *Setup for measuring the motor's force*

PROCEDURE FOR PERIOD 3

1. Review your data and observations and discuss the results of your experiment with your lab partner.

2. Discuss the following questions with the class:

A. What are the effects of changing the following variables:

i. number of batteries
ii. series versus parallel connections of the batteries
iii. winding the string around the plastic pulley instead of around the nail

B. What might account for the variations in the number of washers lifted by a given motor?

REFLECTING ON WHAT YOU'VE DONE

1. Write a conclusion summarizing what you learned. Record your final observations and conclusions, including the following:

A. Your observations of the effect on the motor of changing the number of batteries connected to the motor

B. The effect you observed when connecting the batteries to the motor in series and in parallel

C. Any differences you observed in the motor's performance between when the string was wound around the nail and when it was wound around the plastic pulley

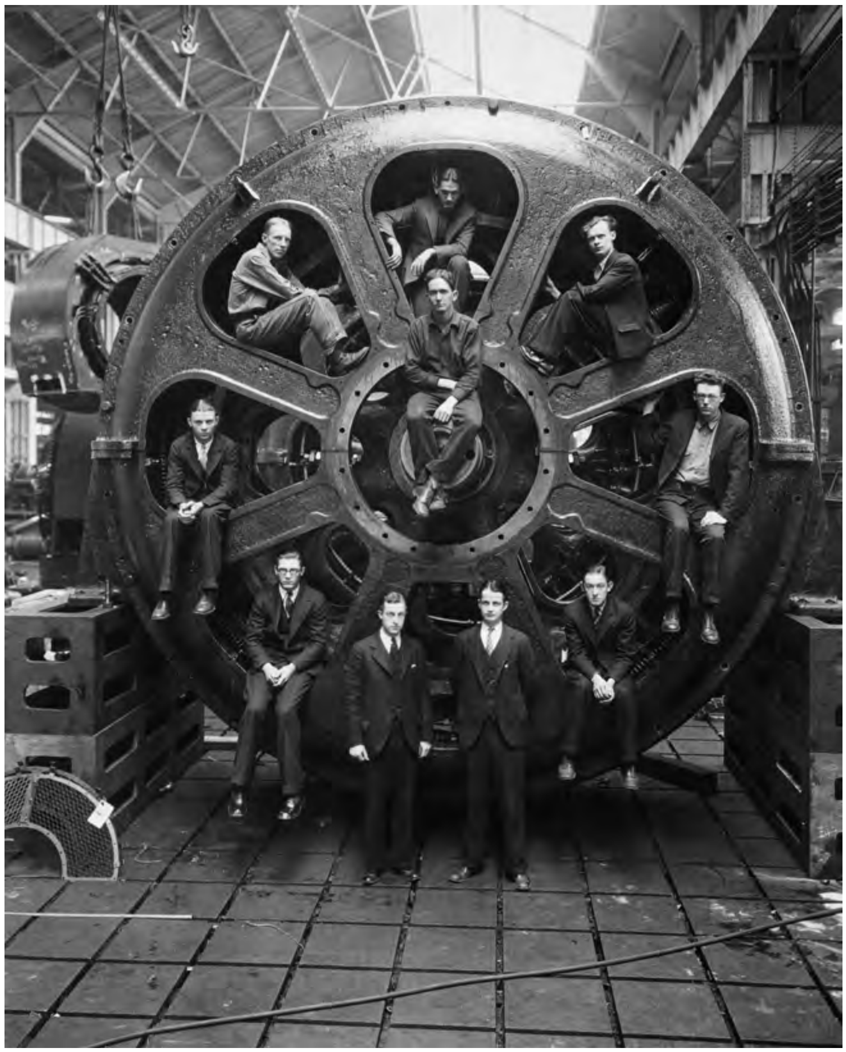
D. A detailed description of the setup that allowed the motor to lift the greatest number of washers, along with any drawings you wish to include

2. Answer this question in your science notebook:

What is the maximum force exerted by the motor?

MOTORS—
Getting Smaller Every Day

CORBIS/BETTMANN



Motors come in many sizes. What do you think this big electric motor was used for?

You get up in the morning and shower, then blow-dry your hair and brush your teeth. You take some orange juice out of the refrigerator and get a piece of toast. You've been up for only about half an hour, and you've already used at least three appliances with motors.

Of course, if you'd been born 200 years ago, your life would have been quite different. Before electric motors were invented, humans had to rely on their own muscle power, or on the muscle power of animals, to do most of their work. They captured the power of the wind or of falling water to grind grain.

But in the early 1800s, scientists discovered the relationship between electricity and magnetism. This led to the invention of electric motors. The electric motor changed the course of everyday life, and that change continues.

Magnets and Motors

In 1820, Hans Oersted, a professor in Copenhagen, Denmark, discovered the link between electricity and magnetism. Oersted connected a copper wire to a large copper–zinc battery. An electrical current flowed through the wire. Oersted then noticed that when he brought a magnetic compass near the current-carrying wire, the needle of the compass moved. He concluded that the electrical current created a magnetic field.

Oersted's discovery was the basis of additional research by the French scientist André Ampère, who developed a theory to explain the connection between electricity and magnetism. Then, in 1821, Michael Faraday repeated Oersted's experiment and built the first electric motor. To do this, Faraday used the magnetic force that caused the compass needle to move and put it to work.

Faraday's motor was small and simple. It consisted of a battery, a spool of wire, and a bar magnet. When Faraday ran an electric current through the wire, the magnet rotated. Inventors who followed would apply this principle to move the shaft of larger and larger electric motors.

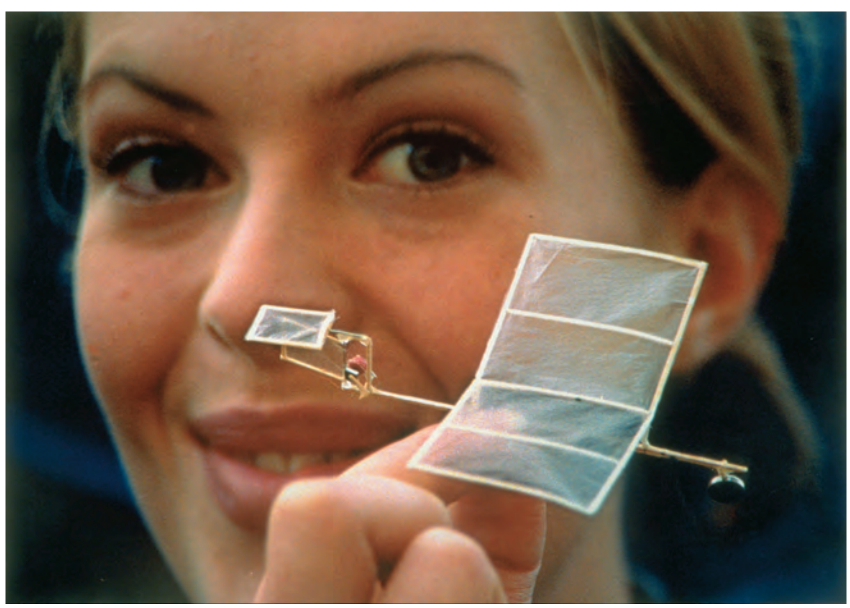
Smaller Is Better

Although "Bigger Is Better" might have been the motto of inventors and designers who followed Faraday, many of today's most interesting motors can't even be seen by the unaided eye. They are called micromotors, or micromachines. You might say they come in two sizes: small and supersmall.

The small motors are the product of microtechnology, which measures things in microns. (A micron is one-millionth of a meter.) Just how small are they? Hundreds of thousands of microdevices could sit on the surface of a piece of toast.

Supersmall motors are the product of a new science called nanotechnology ("nano" means "one-billionth"). Scientists in this exciting field are trying to build devices on the atomic or molecular scale. Micromotors of this size could be used to work on individual cells in the human body.

About 600 research labs around the world are doing work on micromotors, and many U.S. companies have begun to develop commercial applications for them. Interest in these motors is high, because once the designs are perfected, the machines will not be expensive or hard to make. Making them will involve the same procedures that engineers already use to manufacture microchips for computers.



AP/WIDE WORLD PHOTOS

Sometimes a tiny motor is just what you need. This is a picture of the world's smallest remote-controlled model gliding plane. It is 109 millimeters long and has a wing span of 75 millimeters. The mass of the plane, with its motor and microbattery, is only 0.97 gram.

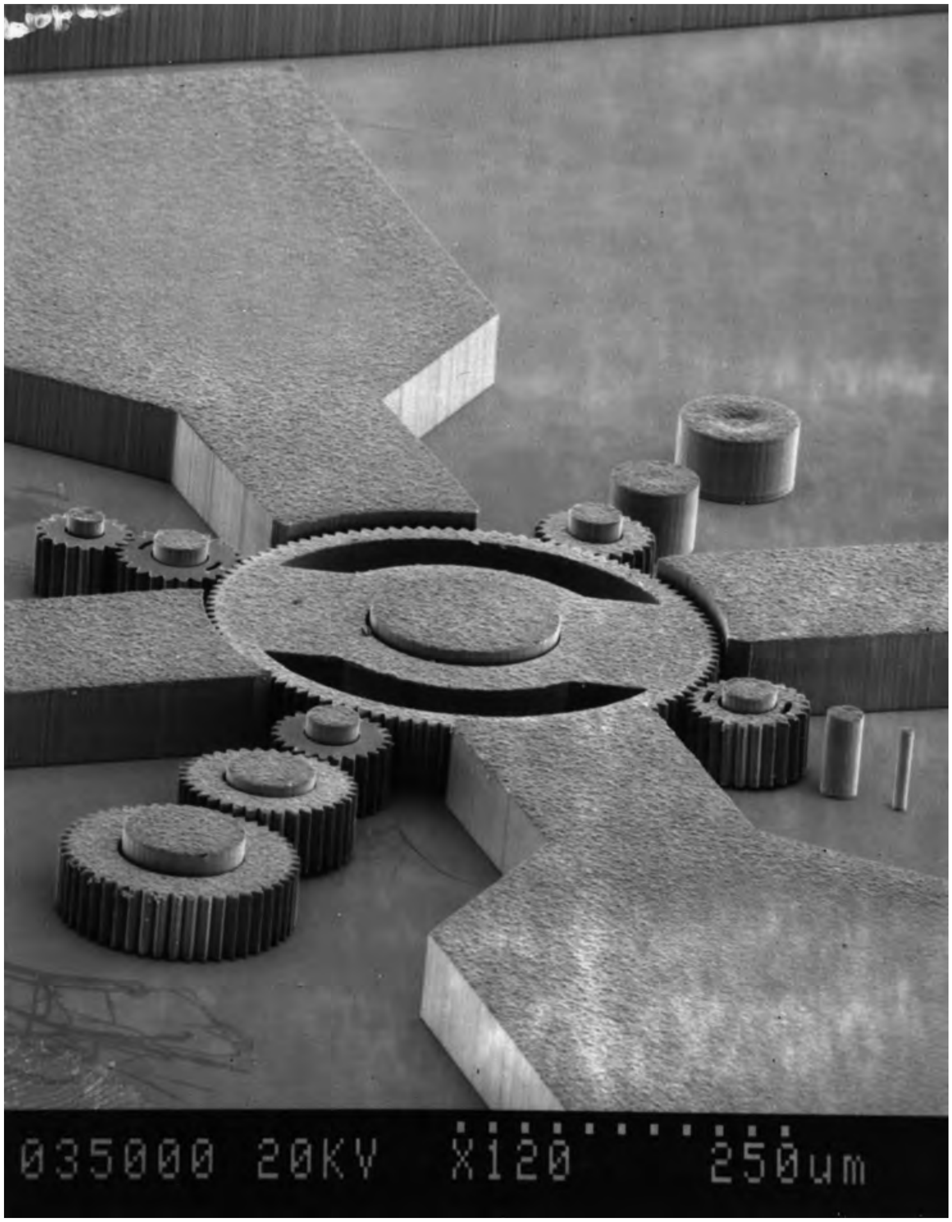
AP/WIDE WORLD PHOTOS

Microsensors and micromotors can be put inside small probes. The Personal Satellite Assistant shown here is only the size of a softball. It will carry sensors to monitor the amount of oxygen and carbon dioxide in a spacecraft, as well as monitor bacteria growth, air temperature, and air pressure. It also contains a video camera and its own propulsion system.

What will these small machines be used for? One company has designed a microsensor that can trigger an air bag in a car to deploy. Micromachines can shoot out the ink in ink-jet printers and regulate the mixture of gasoline and air in automobiles. Designers are talking about microgyroscopes that could keep cars from skidding or keep hikers from getting lost in the woods. Wristwatch-sized radios are in the planning stages.

Meteorologists can send microweather stations (about the size of a quarter) to other planets to measure temperature, density, and pressure in their atmospheres. Meanwhile, back on planet Earth, chemical engineers are designing a "microplane" that will fly through the ventilation systems to monitor the air quality in buildings.

Micromotors will have many uses in medicine. Today, microsensors are already being used to monitor blood pressure in people who have had



This may look big, but it is actually the first magnetic micromotor made with nickel. It was developed by Professor Henry Guckel at the Wisconsin Center for Applied Microelectronics and Micromotors.

heart attacks. Biomedical engineers foresee using miniature motors to remove plaque from inside the arteries of people who are at risk for heart disease. Tiny gears no wider than a human hair could be used to send microrobots into the bloodstream to perform surgical repairs. Also in development is the "thermometer pill." Less than 2 centimeters long, this capsule is filled with microcircuits. It moves through the digestive tract and sends information to a computer, which analyzes the data that doctors can use to make diagnoses.

What other uses do you see for micromotors? How might they work? What would they look like? What would you name them? □