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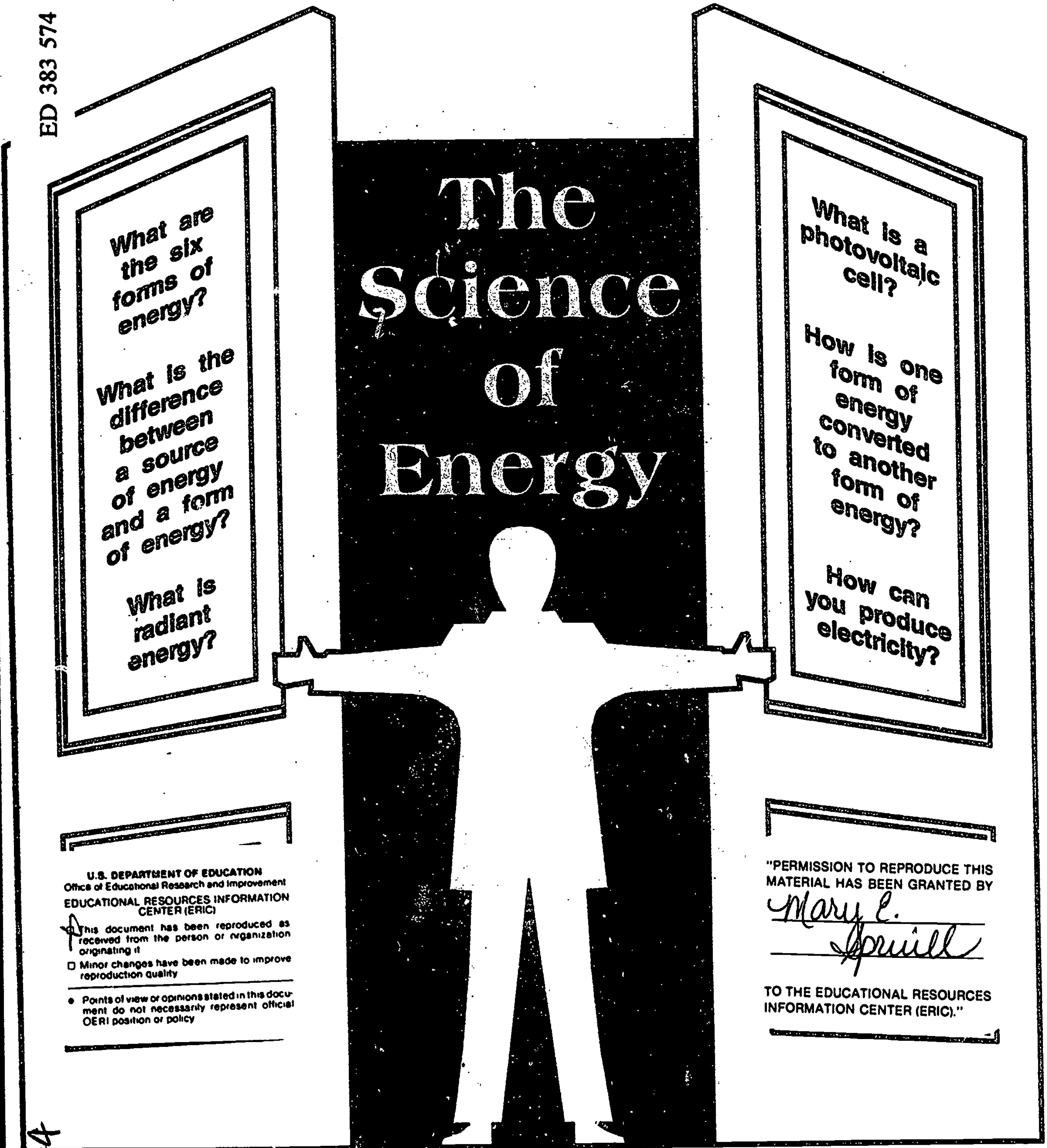
ABSTRACT

This unit of study for secondary students focuses on energy uses, energy sources, energy forms, and energy conversion. The unit is designed to take five 45-minute class sessions. In the first class session, the teacher conducts several energy conversion experiments. In subsequent sessions, students are divided into seven groups and each is assigned an energy conversion experiment and a station. Students learn how their experiment converts one type of energy into one or more other types of energy. Students at each station present their experiment to other groups of students rotating through the stations. The final session involves students working together to answer questions related to the unit. Teaching materials are provided for each class session and include vocabulary words, teacher demonstration instructions, worksheets, study sheets, an energy test, and instructions for station experiments. (LZ)

The Science of Energy



A publication of the National Energy Education Development Project

The Science of Energy

Contents

The Science of Energy

Teacher's Guide

How to Use the Science of Energy Kit

The Science of Energy Kit has been designed to take five class sessions of 45 minutes. In the first class session, the teacher divides the students into seven groups and conducts several energy conversion experiments. In the subsequent sessions, students teach themselves and others about energy conversions.

During the first 15 minutes of the second class session, the teacher reviews concepts from the previous day and explains the format of instruction for the next three days. The student groups are given their energy conversion experiments and accompanying materials for their stations. Students learn how their experiment(s) converts one type of energy into one or more other types of energy. Next, they prepare and rehearse a presentation they will give when students tour their station.

In the third class session, the seven groups are divided into A and B teams. The A teams present their experiments to the B teams that are rotating through the other six stations.

During the fourth class session, the A teams tour the other stations while the B teams serve as the presenters for their stations.

In the fifth and final class session, the original seven groups of students work together to review questions related to the Science of Energy unit. During the last session, the seven groups work as individual teams to answer multiple choice and essay questions.

Objectives

Upon completion of the Science of Energy unit, students will be able to:

- List and explain five things that energy enables us to do.
- Differentiate between sources of energy and forms of energy.
- Identify what forms of energy the nation's top ten energy sources provide.
- Describe the six forms of energy and give an example of each.
- Explain how one form of energy is converted to other forms of energy.
- Trace the energy conversion flow of any system back to nuclear energy.
- Explain how 16 energy conversion experiments work.

The Science of Energy is sponsored in part by Mobil Oil Corporation and Omniglow Corporation.

Getting Ready

1. Unpack the Science of Energy Kit and assemble eight sets of experiments by looking at the labels attached to the experiments. One set of experiments will be marked TD for Teacher Demonstration, and the other seven sets will be marked Station 1-7. If a label falls off an experiment, check with the teacher demonstration instructions or student station instructions to identify where it belongs.

2. Duplicate one set of instructions for each of the seven stations, or, duplicate enough copies so that each student can have his/her own set of station instructions.

3. Duplicate the Forms of Energy sheet, the Science of Energy Study Sheet, and the Science of Energy Test to distribute to each student.

4. Divide the class into seven groups that you feel will work well together. Make sure you have at least one strong science student per group.

5. Divide each of the seven groups into two teams. One half of the group will be the A Team and the other half will be the B Team.

6. Determine how to organize students into seven stations in the classroom. Student groups requiring hot water (stations 1, 4, and 5) should be positioned close to a source of hot water. **Teacher should dispense hot water to students.**

7. Read the Teacher Demonstration materials and become familiar with experiments to be performed for the class.

8. Read the Energy Conversion Station instructions for each of the seven stations and be prepared to answer student questions.

Science of Energy Test Answers

1. b   2. b   3. d   4. a   5. a   6. c   7. c   8. a   9. d   10. d   11. c   12. d   13. b

Class Session One

- Divide students into their seven groups.
- Distribute the Forms of Energy sheet to each student.

Part I

Teacher demonstration—5 minutes

Explain to students that they will be starting a five-day unit called The Science of Energy. The students' grades will be based on how well their group performs rather than individual scores. Group grades will be determined by five factors. The first four factors are worth 50 percent of the grade, and the last factor is worth 50 percent.

- Their ability to work as a team to answer questions and solve problems during the teacher demonstration.
- Their ability to work as a team to learn the material and prepare their experiment.
- Their ability to teach students from other teams about their experiment.
- Their ability to handle equipment properly and safely.
- Their ability to correctly answer multiple choice and essay questions from the unit exam.

Presentation

"Before we start talking about the various types of energy and energy sources, I would like to begin a simple experiment. Here I have two containers of sand. One container is filled about one-third of the way, and the other is filled to the top. I would like someone to stick a thermometer into each container of sand and tell me the temperature in centigrade of each container. Let's record those temperature readings on the board. Now, please put the tops on the containers and shake the containers vigorously for 30 seconds. After 30 seconds, pass the container to the next person in your row. I would like everyone in the class to shake both containers. Make sure you shake the containers as briskly as you can. After the last two students in the class have shaken the containers, they should record the temperatures of the sand. **[Give the thermometers to the last two students in the class.]** We will use this data later."

Part II

What does energy enable us to do?—10 minutes

"Energy enables us to do many things. For example, energy has the ability to make things move. Can you give me some examples of moving objects and how energy produced that motion? (i.e., car is moved by the combustion of gasoline, sailboat by the energy in the wind, a baseball by the energy given to it by a person's arm and hand, exploding gun powder enables a bullet to move at great speed.)

"In addition to making things move, energy also enables us to do four other major things. As a group, I want you to determine the other four major things energy enables us to do. Once your group has come to a decision, each one of you should write those four things on a piece of paper."

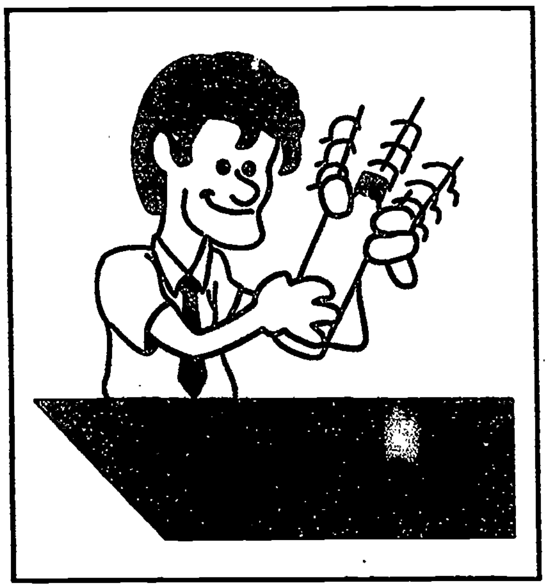
After one minute, ask student groups for their lists of four major things energy does for us. The list should be as follows:

1. **Motion**
2. **Heat**
3. **Light**
4. **Operate electrical equipment**
5. **Make plants grow**

"There are six types of energy that enable us to do these things. They are: mechanical, chemical, electrical, radiant, thermal, and nuclear." **[Distribute Forms of Energy sheet to each student and discuss the six forms of energy.]**

Part III

Teacher demonstration continued



"Now let us see what, if any, temperature change occurred in the sand as a result of all that shaking. **[Ask last student for a temperature reading of the container that is one-third full of sand—you should see about a five degree centigrade increase.]** What is the cause of the temperature change? **[Get answers.]**

"The shaking of the bottle is mechanical energy—the energy of motion. By shaking the container we gave the grains of sand kinetic energy, which caused friction between the particles, creating heat. Another example of how mechanical energy can be transformed into heat is when a moving hammer strikes a nail. Have you ever felt the head of a nail or head of a hammer after several strikes? They both feel warm. A portion of the mechanical energy in the moving hammer is transferred to thermal energy. Where do you think the rest of the mechanical energy has gone? **[Get answers.]** That's right, the energy goes into sound, the motion of the nail pushing into the wood, and the heating of the nail and the wood.

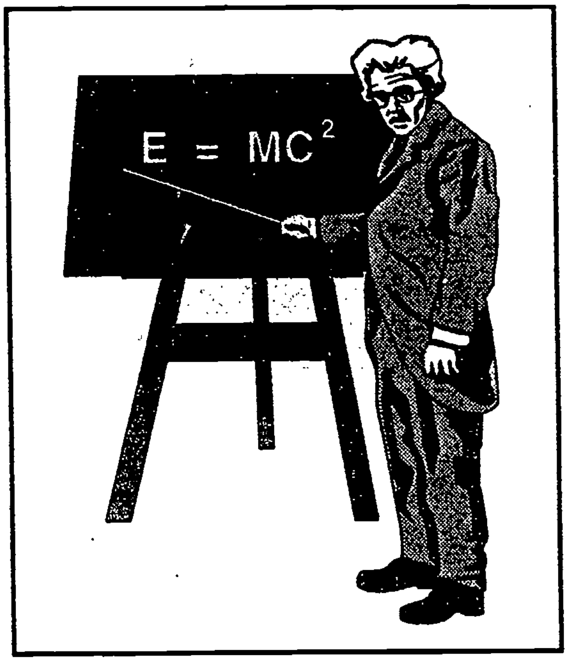
[Ask the student holding the container that is filled with sand what the temperature of the sand was after it had been shaken by the class. You should see about a two degree centigrade increase.] Why is the increase in temperature much greater for the container that is only one-third full? **[Get answers.]** Right, it is because the partially filled container has more space in it, and therefore the grains of sand collide with each other and the sides of the container with more velocity. More velocity means more kinetic energy. The equation to calculate kinetic energy is: $K_e = 1/2\ MV^2$. This means if you double the velocity of an object you quadruple its kinetic energy. Triple the object's velocity and you will increase its kinetic energy by a factor of nine. In the container filled with sand, the grains of sand have little space to move, therefore a lower velocity and less kinetic energy.

"Let's examine the energy flows from shaking this container of sand. Let's start with the thermal energy we produced as a result of the mechanical energy our bodies provided. Where did our bodies get the energy to shake the bottle? **[Get answers.]** That's right, from the food we ate. Of the six types of energy, what type of energy is stored in food? **[Get answers.]**

"Chemical energy is stored in food through the process of photosynthesis. Sunlight, or radiant energy, is needed to take simple compounds and build them into more complex compounds as you can see in the following equation:

$$\underset{\text{water}}{6H_2O} + \underset{\text{carbon dioxide}}{6CO_2} \xrightarrow[\text{solar energy}]{} \underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2}$$

"What type of energy was transformed to produce this radiant solar energy? **[Get answers.]** Right, the answer is nuclear energy. Inside the sun's core, atoms of hydrogen are fused together to form heavier atoms of helium. The fusion occurs because of the tremendous heat and gravitational forces inside the sun's core. The resulting atom of helium has less mass than the original four atoms of hydrogen. This missing mass is changed into energy and can be calculated using the equation $E=Mc^2$ made famous by Albert Einstein. The E is the amount of energy produced, the M is mass which is being lost or converted, and the c represents the speed of light.



"The increase in the temperature of the sand is the result of nuclear energy. In fact, all energy transformations can be traced back to nuclear energy, either fission or fusion. The energy stored in fossil fuels (coal, petroleum, natural gas) is a result of sunlight from millions of years ago. Wind, hydropower, and biomass energy are also results of the sun's radiant energy. Geothermal energy is a result of the radioactive decay of heavy elements in the earth's core. The electricity produced in a nuclear power plant is a result of the splitting or fission of heavy uranium atoms into lighter atoms. When fission occurs, mass is lost and changed into energy.

Part IV

Teacher demonstration—10 minutes

"So, all energy transformations can be traced back to nuclear energy. The next thing I want each group to do is determine what percentage the six forms of energy contribute to the nation's energy needs. Look at the back of the Forms of Energy Sheet. You'll see the nation's top ten sources of energy, five renewable and five nonrenewable. Can anyone tell me the difference between a renewable and nonrenewable source of energy?

The first thing you must do is determine what form the energy is stored in each of the ten sources of energy. You should only go back one transformation, and not all the way back to nuclear energy. For example, wind energy is a result of moving air, or mechanical energy. If we go back two transformations for wind, we would see that the moving air is a result of the sun's radiant energy. Just go back one transformation and then write that form in the space provided on the sheet. I'll give you three minutes to identify what forms of energy are being stored or used in the ten sources of energy.

Now that we know what forms of energy are used or are stored in the top ten sources of energy, look at the pie chart and calculate the percentage of the nation's energy needs that each form of energy provides."

After one or two minutes ask groups for their answers.

1. Chemical (petroleum, natural gas, coal, propane, biomass)—89.3%

2. Nuclear (uranium)—7.5%

3. Mechanical (wind, hydropower)—3.5%

4. Thermal (geothermal)—less than 0.3%

5. Radiant (solar)—less than 0.01%

6. Electrical (a secondary source)—0%

"As you can see, the nation's, as well as the world's, economy is based on chemical energy. This is true not only now, but for as long as man has been around. Wood, animal, and human power have always been a result of stored chemical energy.

Optional Activity

"What do you think the graph of energy sources will be like in the year 2025? I would like each group to discuss what they think the roles of the ten major sources of energy will be in the year 2025 and what percentage of energy each will provide the nation. Then write down the percentage of energy provided by each of the six forms of energy." **[Give students three to five minutes to complete and then have students report their percentages and rationale for these numbers.]**

Part V

Activation energy—10 minutes

"Since the nation basically relies on chemical energy, we must also learn about activation energy. A pile of coal, a gallon of gasoline, or a cord of wood contains stored chemical energy. How do we activate that chemical energy? Once we activate it, will the release of chemical energy continue? **[Get answers.]**

"The best example of activation energy is the lighting of a match. I will strike the chemical end of the match against the smooth side of the match box. Why isn't it lighting? **[Get answers.]** Right, there isn't enough friction between the chemical side of the match and the surface of the box to provide the thermal energy to activate the reaction. Chemical reactions that give off heat energy require a push to get them going. When I slowly strike the chemical side against the rough texture of the striker, nothing happens. Why? **[Get answers.]** Once again, there isn't enough friction to provide the thermal energy to activate the reaction. When I strike the match quickly against the striker, enough thermal energy is produced by friction to activate the release of the chemical energy.

"What would happen if I strike the wooden tip of the match against the rough surface of the striker? **[Get answers.]** The friction between the wood and the striker doesn't produce enough thermal energy to activate the wooden tip of the match. Wood has a higher activation energy than the chemical compounds of sulfur on the tip of the match. **[Strike the chemical tip of the match against the striker.]** Yet, the thermal energy released by the chemicals on the tip of the match is enough to ignite the wood. Once the wood is burning, it produces enough thermal energy to keep the chemical reaction going until all the chemical energy in the wooden match is consumed.

"What provides the activation energy for gasoline inside an engine? **[Get answers.]** The electrical energy provided by a spark plug ignites the air-gasoline mixture inside the cylinder of an engine. The expanding hot gases move pistons up and down to provide the mechanical energy to move the automobile. Heating oil, propane, and natural gas require some activation energy, usually in the form of an electric starter, to get their reactions going inside a furnace. These sources of energy release their chemical energy and convert it into thermal energy to warm the house."

Class Session Two

Part VI

Tracing energy flows

"I would like everyone to trace the energy flow for the following demonstration. **[Darken the room and then gently tap the hammer directly on one of the caps.]** Why didn't the cap explode? That's correct, I tapped the hammer too gently. Only a small amount of thermal energy was produced by the mechanical energy of the hammer. There was not enough thermal energy to activate the chemicals in the cap. Now I will put more mechanical energy into the hammer, producing enough thermal energy to activate the chemical reaction in the cap.

" What three forms of energy were produced as a result of the exploding cap? The first form is radiant—you can see the light when the cap explodes. The sound we hear is the second form energy. Sound is mechanical energy and is caused by the movement of air molecules. The third form of energy is thermal energy.

"Now let's see if you can trace the energy flow of the following experiment. This flashlight **[hold up flashlight]** works by converting mechanical energy to electrical energy. Here, squeeze the handle of the flashlight. **[Hand flashlight to student and have him squeeze the handle several times.]**

"This flashlight is generating electricity to run the light. Here's how. The handle is hooked to a gear that spins a metal disk. **[Squeeze handle several times.]** This disk is actually a magnet. Below it is a thin coil of copper wire with two lead wires leading to the light bulb. The magnet spins around the wire, creating a current through the wire. The filament in the light is made of a very thin tungsten wire. When the electricity reaches the tungsten, there is a great amount of resistance. The resistance makes the tungsten very hot and causes it to emit light. If you squeeze the handle slowly, you can see the tungsten wire begin to glow. **[Squeeze handle slowly a few times.]**

"We will try it again, but this time instead of squeezing the handle slowly, we will squeeze it rapidly. **[Squeeze handle rapidly a few times.]** Notice how much brighter the light is. Why? **[Get answers.]** That's right. The more mechanical energy you put into the system, the more electrical energy you will get out. Now, starting with the light from this flashlight, I would like each group to trace the energy conversions back to nuclear energy. **[Give students two minutes to develop their list and have**

several groups report their energy conversions. Make a transparency of the Energy Transformations on page nine. Discuss the transformations with the class.]

"As you can see, one form of energy can be transformed into other forms of energy quite easily. During the next three days, you will be working with more than one dozen energy conversion experiments that demonstrate these energy transformations.

"I have divided you into seven groups. Each group will be responsible for a different energy conversion station. Your group will be responsible for learning how to conduct and present your energy conversion experiment(s). I will give you the rest of this class period to look through your station's write-up and practice your experiment and presentation. Half of your group will present your station's experiment(s) tomorrow, while the other half rotates through the other six energy conversion stations. On the following day, you will switch roles. The presenters will rotate through the six stations while the other students present their station's experiment(s) to the touring students.

"I am going to give each of you a Science of Energy Study Sheet which will help you prepare for the Science of Energy test your group will be taking at the end of the unit. You should take this Study Sheet with you to each of the stations. During the next three days, you should answer the questions on the Study Sheet. You should be able to answer the first four questions on the study sheet as a result of what you learned in class the past two days. All questions should be completed by the day of the test. Here are your Study Sheets and your Science of Energy Experiments. Please be careful not to break any of the equipment or needlessly use the supplies. Part of your grade will be based on how well your group works together today to prepare your presentation and how well you teach others about your experiments during the next two days." **[Distribute Study Sheets and Science of Energy Experiments.]**

Class Session Three and Four

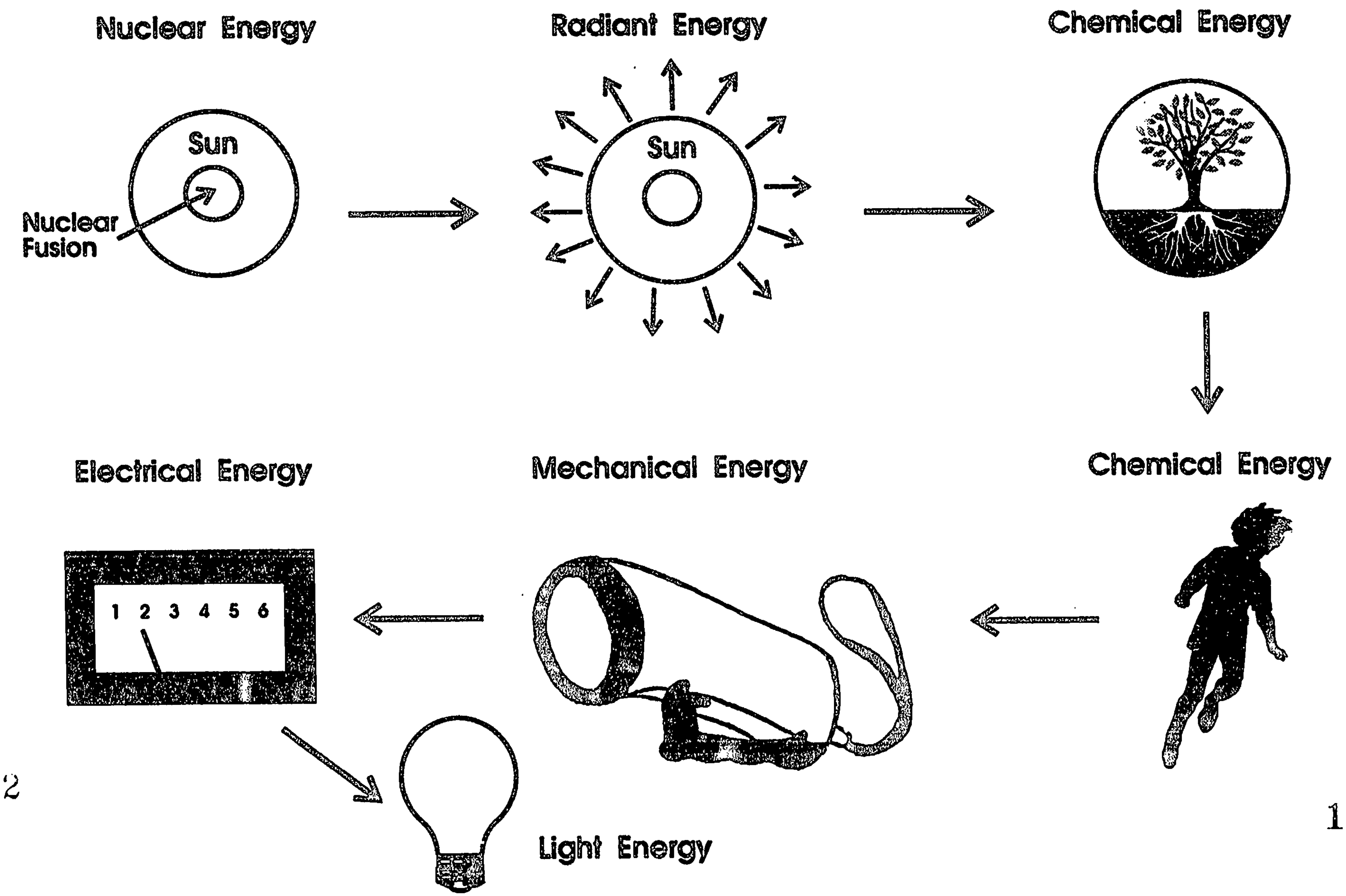
Students rotate through energy conversion stations. The teacher observes and grades the student groups on their performances.

Class Session Five

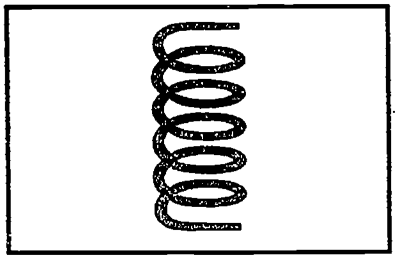
Using the Science of Energy Study Sheet, students review the information they have learned from the teacher demonstrations and from all seven stations. The teacher may lead a discussion following this group study session.

Administer the Science of Energy Test. The students will take the test by station group. Following the test, the teacher should go over test questions with the class and answer questions.

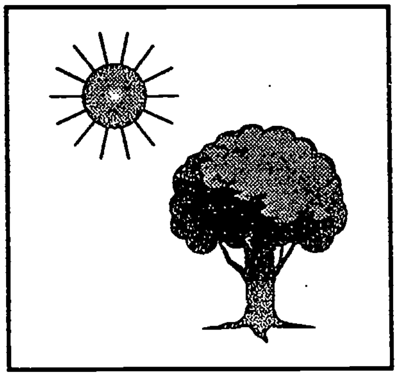
Energy Transformations



Forms of Energy



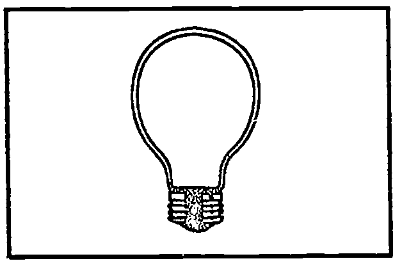
1. **Mechanical**—Mechanical energy is the energy of an object represented by its movement, position, or both. The energy of a moving object is called kinetic energy. The energy possessed by an object because of its position is called potential energy. Potential energy can also be stored in a spring by stretching or compressing it. The sum of an object's kinetic energy and potential energy is the object's mechanical energy.



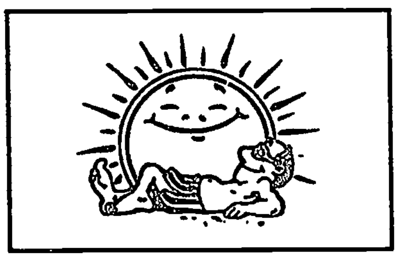
2. **Chemical**—Chemical energy is the energy that is stored in the bonds that hold molecules together. Chemical energy is stored in food, wood, and fossil fuels. Through photosynthesis, the sun's radiant energy takes elements and simple compounds and builds them into more complex compounds. When these bonds are broken, and transformed back into simpler compounds, they release stored chemical energy, usually in the form of heat and light.

$$6H_2O + 6CO_2 \rightarrow C_6H_{12}O_6 + 6O_2$$

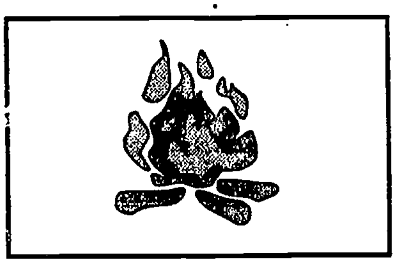
water	carbon dioxide	solar energy	glucose	oxygen



3. **Electrical**—Electrical energy is a special kind of kinetic energy. It's the energy of moving electrons. Electrical energy is always an intermediate form of energy produced by one of the other forms of energy. We use the effects of electrical energy to perform tasks like lighting a bulb, heating a cooking element on a stove, or moving a motor.

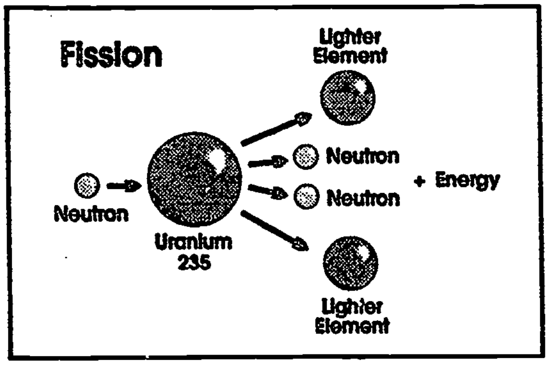


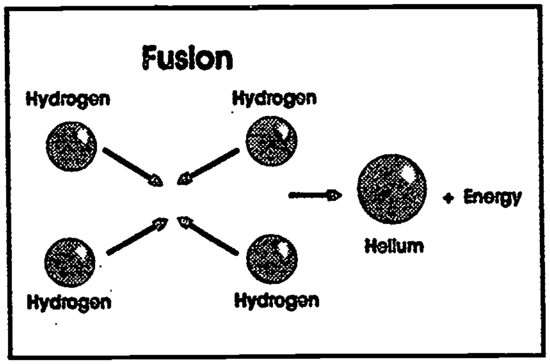
4. **Radiant**—Radiant energy is most commonly called light energy. However, light energy is not the only form of radiant energy. Radio and television waves are also forms of radiant energy, but they are less powerful than light. X-rays and gamma rays are more powerful than light waves and have the ability to pass through skin, bones, and several layers of concrete.



5. **Thermal**—Thermal energy, or heat energy, is also a special kind of kinetic energy. It is the kinetic energy of moving or vibrating molecules. The faster the molecules move or vibrate, the hotter the object becomes, and the more thermal energy it possesses. Thermal energy travels from hot objects to colder objects—never from cold to hot. For example, when you touch a cold glass, the heat from your hand is transferred to the glass.

6. **Nuclear**—Nuclear energy is the energy locked in the nucleus of the atom. It is the energy that keeps the positively charged protons packed closely together in the nucleus. One way nuclear energy can be released is by splitting the atom, as is done with uranium atoms in a nuclear power plant. Another way is by combining simple atoms like hydrogen into heavier atoms of helium, as is done in the sun's core or in a hydrogen bomb. In either case the mass lost is converted into energy, according to the equation $E=MC^2$.

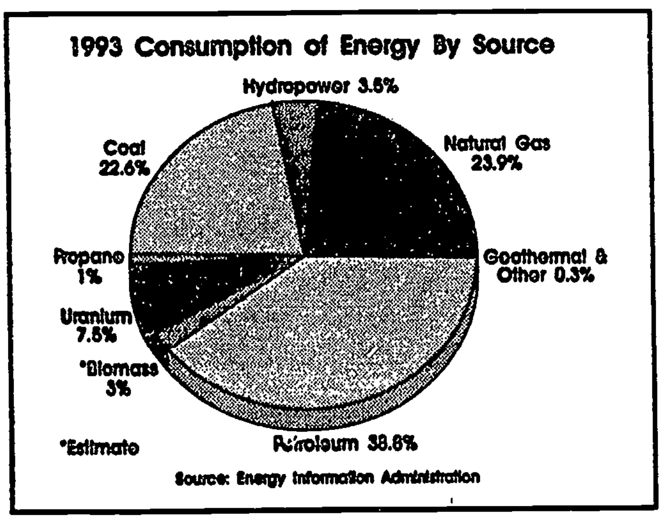




The six forms of energy are provided by the following sources of energy: List how energy is stored (mechanical, chemical, electrical, radiant, thermal, or nuclear) in each of the following sources of energy:

Nonrenewable		**Renewable**	
Petroleum	______	Wind	______
Coal	______	Solar	______
Natural Gas	______	Biomass	______
Propane	______	Hydropower	______
Uranium	______	Geothermal	______

Looking at the pie chart below, calculate what percentage of the nation's energy is provided by the six forms of energy.



U.S. Energy Consumption by Form

1. Mechanical ______%
2. Chemical ______%
3. Electrical ______%
4. Radiant ______%
5. Thermal ______%
6. Nuclear ______%

Science of Energy Study Sheet

1. List the six forms of energy and give an example of each. (*Teacher Demonstration*)

2. Trace the energy flow of a moving car back to the original form of all the earth's energy. (*Teacher Demonstration*)

3. A bottle of Nitroglycerin will explode when dropped from a height of only five feet. What does this tell you about the activation energy of Nitroglycerin? (*Teacher Demonstration*)

4. Explain why a ball dropped from a distance of one meter only rebounds 60 centimeters. (*Station One*)

5. Explain and give an example of an exothermic and endothermic reaction. (*Station Two*)

—OVER—

6. What three factors affect the amount of electricity a photovoltaic cell can produce. (*Station Three*)

7. Explain why bending a metal rod produces thermal energy. (*Station Four)*

8. Trace the energy transfers of a portable, battery-operated fan. (*Station Five*)

9. Explain what three factors affect the amount of electricity produced from a simple wet-cell battery. (*Station Six*)

10. Explain what effect the strength of the magnet, the number of turns in the coil, and the speed of the coil or magnet has on the production of electricity. (*Station Seven)*

The Science of Energy Test

Group Name:____________________________

Choose the letter of the response that best answers the question (two points per question).

_______ **1.** Which of the following is a source of energy?
a. thermal b. petroleum c. mechanical d. chemical

_______ **2.** Energy can be classified into how many different forms?
a. 1 b. 6 c. 10 d. unlimited

_______ **3.** All energy transformations can be traced back to this form of energy.
a. electrical b. chemical c. radiant d. nuclear

_______ **4.** The nation and the world rely on this type of energy for almost 90% of their energy needs.
a. chemical b. electrical c. nuclear d. mechanical

_______ **5.** If you decrease the amount of friction between the surface of a wooden board and a sliding object, the amount of mechanical energy the object would possess at the bottom of the ramp would:
a. increase b. decrease c. remain the same

_______ **6.** A magnet and a coil are moving in the same exact direction at the same speed. If the speed of both the coil and magnet are doubled, and they continue to move in the same direction as before the amount of electricity generated would:
a. double b. quadruple c. remain the same

_______ **7.** Increasing the amount of acid covering two IDENTICAL metals will cause the amount of electricity generated to:
a. increase b. decrease c. remain the same

_______ **8.** For photosynthesis to take place, a plant must:
a. absorb energy b. give off energy c. repel energy

_______ **9.** Electrical energy can be produced directly from:
a. mechanical energy c. radiant energy
b. chemical energy d. all three

_______ **10.** The human body utilizes the chemical energy stored in food to produce which type(s) of energy?
a. mechanical c. thermal
b. electrical d. all three

_______ **11.** An object is dropped from one meter and bounces back 70 centimeters. What percent of the original potential mechanical energy is transformed back into potential energy?
a. 0% b. 30% c. 70% d. 100%

_______ **12.** A mass of chemicals possesses 100 units of energy. After an explosion, the chemical energy is converted into thermal, radiant, and mechanical energy. What is the sum of these three forms of energy after the explosion?
a. 0 units b. 33 units c. 75 units d. 100 units

—OVER—

_______ 13. After a nuclear reaction, the mass of nuclear fuel will:
a. increase b. decrease c. remain the same

Please answer the following questions thoroughly (six points per question).

14. Give two examples of how a source of energy can be converted into one or more forms of energy.

15. Trace the energy transformations given off by a lightning bug, starting with radiant energy.

16. List and explain the five things energy enables us to do.

17. Explain how the activation energy of wood affects the ability to start a fire by rubbing two sticks together.

The Science of Energy

Station One

What You Need

Elastic/Inelastic Collisions

1 Set of Black Absorbent Balls	*1 Meter Stick
1 Super Ball	*1 Pair of Tongs or Spoon
*1 Cup of Hot Water (not boiling)	(*= not included in kit)

Storing Mechanical Energy

1 Toy Car	1 Yo-yo	Balloons

Note: The following presentation is intended as a sample only, and should serve as a source for examples and facts rather than as a rigid guideline. Even if you choose to follow the script, do not worry about word-for-word memorization. The facts themselves are important— don't mix them up or confuse them. Read through the script several times, both with and without the equipment. The script contains directions for using the equipment. The instructions will be enclosed in bold brackets **[like this]**. Be sure that your delivery of the information is clear and easily understood. Get some help from your teacher; have him or her listen to your presentation a few times before you actually give it to make sure that your facts are correct and that you are speaking clearly. Give the presentation to a group of fellow students to get used to presenting to a group. Be prepared.

Elastic/Inelastic Collisions

Equipment Preparation and Arrangement

A table with a hard flat surface.

Ask your teacher to pour a cup of hot water for you. The water should be very hot; not boiling, but fairly close. *Be careful!* The water could easily scald you or someone else.

Put one of each kind of ball somewhere on the table—just make sure that you know which ball is which when the presentation starts.

Sample Script

"When most people think of a collision, they think of a car accident. But a collision is simply a moving object striking another object. The energy of motion is called *kinetic energy*. **[Push one of the balls around the table at different speeds.]** When I push this ball, it gains kinetic energy from my hand. Of course, the faster it goes, the more kinetic energy it has. Now, what happens when something has a collision? **[Get answers from audience.]**

"Right! It stops. Now, if it stops completely, it loses all its kinetic energy. But energy can't just disappear. The kinetic energy in a collision is converted into other kinds of energy, like sound, heat, and light. Of course, in most cases, the object doesn't stop completely. It bounces off. This means that it has not lost all its kinetic energy—some is still in the object.

"So, for example, if I drop this ball from about a meter, **[hold elastic ball about one meter above the table]**, what will happen? When I hold it above the tabletop, we know that it will fall because of gravity. This is known as *potential energy*. When I let go, the potential energy begins to change to kinetic energy. How many centimeters will the ball bounce after striking the table if I drop it from one meter above the table? **[Get answers from audience.]** Let's watch how high the ball bounces. **[Drop ball and have an audience member or members gauge how high it bounces; it should be about 65 or so centimeters.]**

"So, the ball is keeping about 65 percent of its original mechanical energy. This is about a 65 percent elastic collision, then, because 65 percent of the mechanical energy is kept. When the elastic ball reaches its peak of 65 centimeters, all mechanical energy is in the form of potential energy. Why didn't the ball bounce up the full 100 centimeters? Where did the rest of the energy go? **[Get answers from audience.]** It is transformed into sound, partly. Listen. **[Drop ball again.]** Some of the mechanical energy is going into the air and tabletop to make sound waves. Some of the energy is going into heat or thermal energy. This ball is getting hotter each time I drop it, and the table is getting hotter too. Have you ever felt how hot a nail gets when you strike it repeatedly with a hammer?

"This ball is made of Neoprene {NEE-oh-preen} rubber, which is a common rubber. But watch this ball. **[Hold inelastic ball one meter above table.]** This ball is made of a different kind of rubber. **[Drop ball and gauge its bounce; it should hardly bounce.]** What happened? **[Get answers from audience.]**

"This ball isn't broken. It is made of Norborene {NOR-bor-een} rubber, which has a different molecular structure than the other ball. The inelastic ball is just losing most of its kinetic energy. Listen. **[Drop ball again.]** More of the energy from this ball goes into sound. The inelastic ball can also absorb more heat from the collision with the table than the other ball because it is made from a different rubber.

"But what happens if we lower the amount of heat that the ball can absorb? **[Get answers from audience.]** Right! It will retain more mechanical energy, since it cannot absorb as much heat from the collision. How can we get the ball to absorb less heat? **[Get answers from audience.]** Right! We can heat it. If the ball is already hot, it will be able to absorb much less heat from the collision.

"Before I put this inelastic ball into the hot water I would like members of the group to squeeze both the inelastic and elastic balls. Tell me what you notice. **[Get responses from audience.]** Right. The inelastic ball is easier to squeeze than the elastic ball. Now I will put the inelastic ball into hot water for one minute.

While we are waiting for the inelastic ball to absorb thermal energy I would like members of the group to squeeze the elastic ball and this multi-colored ball. I would like the group to predict if this multi-colored ball will bounce more, less, or the same as the elastic ball. How many centimeters do you think it will bounce if we drop the ball from the height of one meter? **[Get answers from group.]** Let's see how accurate your predictions are. **[Drop the ball several times and take measurements.]**

"Let's take the inelastic ball out of the hot water. **[Get ball, using tongs or spoon to avoid scalding.]** It is already very hot, so what will happen when I drop it? **[Drop ball from about one meter. It should bounce higher, up to about 30 centimeters.]** Since the ball could not absorb much more energy from the collision with the table, it retained more mechanical energy and bounced higher. As this ball cools and loses heat energy it will bounce less. **[Try to bounce the ball several times.]**

"A totally elastic collision is a collision in which no mechanical energy is lost. If the ball had bounced all the way back up to a meter, producing no sound or heat, then it would be a totally elastic collision. However, this is not possible. Each ball rebounds differently according to how much energy it can absorb. Norborene rubber is used in crash padding, tires, and other places where its energy absorbing abilities are useful. These collisions show a way of converting mechanical energy into heat and sound."

Storing Mechanical Energy

Sample Script

"As you saw from the previous experiment, mechanical energy can be stored by lifting an object. This is called potential energy. However, this isn't the only way you can store potential energy. Push down on the car. By pushing down on the car you are storing mechanical energy in the spring of the car. When you release the car, the energy becomes kinetic energy. The car will eventually stop due to the friction between the wheels and the internal workings of the machine. This friction will take the form of heat energy.

"Can anyone tell me how and why energy can be stored in this balloon? **[Get answers from group.]** That's right. Just as it took energy to compress the spring in the car it takes energy to stretch the rubber balloon. **[Blow up balloon.]** Now the potential energy is stored in compressed air instead of a compressed spring. What will happen when I let the air out of the balloon? **[Get answers and release the balloon.]**

Yo-yo

Sample Script

[Take a yo-yo and wind-up its string.] "If I let go of this yo-yo while holding the string, how far do you think the yo-yo will come back up? Let's see how accurate your predictions are. **[Release the yo-yo. You may have to give the yo-yo a little tug to bring it back up.]** Can anyone tell me where the energy is stored that makes the yo-yo rise after I release it? That's right. The energy is stored in the spinning yo-yo. So, energy can also be stored in a spinning object, sometimes called a flywheel.

"Thank you for listening."

The Science of Energy

Station Two

What You Need

Endothermic Reactions

1 Bottle of Vinegar
1 Thermometer
1 Container of Baking Soda
*1 Spoon
3 Empty Plastic Bags
1 Display Sheet

Exothermic Reactions

4 Hand Warmers
1 Display Sheet
1 Sealed Bag of Iron Oxide
*Scissors
1 Empty Plastic Bag

(* = not included in the kit)

Rubber Bands

1 Rubber Band for Each Student

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Endothermic/Exothermic Reactions

Equipment Preparation and Arrangement

The sealed bag included with the kit contains a used bag of the hand warmers. This is referred to in the script as the "old packet." A few minutes before the presentation, cut open a packet and pour its contents into the empty plastic bag. Keep the bag open so that the oxygen in the air can react with the black powder. This will be referred to as the "new packet."

Have all the other equipment present on the table as the presentation begins.

Sample Script

"All chemical reactions involve heat in some way, whether they give off heat or absorb it. A reaction that gives off heat is called an exothermic reaction (*exo* meaning out and *thermal* meaning heat); one that absorbs heat is called an endothermic reaction (*endo* meaning in and *thermal* meaning heat).

"What I'm going to show you today are two reactions that involve heat. The first will be endothermic; the second, exothermic. Since the easiest way to measure heat is by temperature, we will use a thermometer to show the changes in heat.

Endothermic Reaction

"The first experiment will involve acetic acid reacting with sodium bicarbonate—or, in simple words, vinegar reacting with baking soda.

"Now, first the vinegar. **[Pour about an ounce of vinegar into the empty plastic bag. Holding the bag at the top, tilt the bag so that all of the vinegar is in one of the bottom corners of the bag.]** This vinegar, as you can see, is just about room temperature. **[Take the temperature of the vinegar with the thermometer; it should be at or about room temperature.]** It is XX degrees. Feel the bag to measure the temperature by touch. Now, as I put in the baking soda, you will notice a violent reaction taking place. **[Leave the thermometer in the vinegar. Pour in about a teaspoonful of baking soda. Be careful; the reaction will foam up very high.]** Watch the thermometer. **[Over a span of about 30 seconds, the temperature of the foaming solution should drop about four or five degrees Centigrade.]** The temperature of the solution has dropped about four or five degrees Centigrade. Hold the plastic bag and tell me how it feels. Why has the temperature of the solution dropped when it looks like it is boiling? **[Get answers from audience.]**

"To understand why the temperature is lower, you have to understand what heat is. Heat is a form of kinetic energy. Objects that are hot have more energy than objects that are cooler. Also, objects that are hot will give their energy to cooler objects, like a burner giving its energy to a pan and to the food being cooked.

"Kinetic energy can do many things. It is required to break the bonds that hold compounds together, and is released when bonds are formed. In this experiment, kinetic energy is breaking the chemical bonds. **[Show the top of Display Sheet 1.]** This equation represents the acetic acid in the vinegar reacting with the sodium bicarbonate in the baking soda. It takes more energy to break the bonds on this side of the equation than is given off by the forming of these bonds.

"That extra energy has to come from somewhere. The reaction steals the extra energy it needs from the thermometer and surrounding area, causing the thermometer and the plastic bag to grow colder. This is what we call an endothermic reaction, since it absorbs heat from the surrounding environment.

Photosynthesis is an example of an endothermic reaction. The chemical equation for photosynthesis is as follows: **[Show bottom of Display Sheet 1.]**

Sunlight, or radiant energy, is needed to combine water and carbon dioxide to form more complex compounds. **[Put away the vinegar and baking soda.]**

Exothermic Reaction

"Now, most reactions are not endothermic. More than 90 percent of all chemical reactions are exothermic, which means that they give off heat. I'm going to show you a reaction that will give off heat. Earlier I opened a heat packet that contains mostly iron filings. Why do you think the heat packets are sealed in plastic? **[Show the plastic package that the heat packet came in.]** Right, the plastic package keeps oxygen from coming into contact with the iron in the heat packet.

"**[Hold up new packet.]** This packet is open to the air, and the oxygen in the air is rusting the iron. When iron rusts, it gives off heat. Of course, it usually rusts very slowly. That's where this packet is special." **[Show Display Sheet 2.]**

"As you can see, the iron is reacting with the oxygen to form iron oxide, or rust. But normally this can take a long time, and the heat given off when the compound is formed escapes so slowly that it is not noticeable.

"You can see the difference in these two examples. **[Show the new packet.]** This is a packet that I opened a few minutes ago. You can see that the filings are black and still largely iron. **[Show the old packet.]** In this packet, opened days ago, the iron is reddish and rusted. The iron is now iron oxide powder. Normally, this transition would take a long time and not give off noticeable heat. But two special things have been done to this iron.

"The first is that the iron is in small pieces, like grains of sand. This allows more oxygen to get to the iron and rust it quickly, the same way that wood shavings will burn more quickly than a wooden log. The second and more important thing is the catalyst. A catalyst is a substance that speeds up a reaction. In this case, it is activated carbon. The activated carbon attracts oxygen so that more oxygen can come into contact with the iron.

"Both special conditions help to make this little packet of iron into a hot and long-lasting heat pack, as well as a good example of an exothermic reaction.

[Hold the packet—it feels hot.]

When a fossil fuel or wood is burned, it produces an exothermic reaction and gives off heat energy. The energy in the fossil fuel or wood was stored as a result of the endothermic reaction of photosynthesis."

Rubber Bands

Sample Script

"Now let's do an experiment that gives off and absorbs energy without a chemical reaction. Hold the rubber band between your thumbs and your forefingers. Place it on your forehead so that both strands are touching your skin and stretch it at least twice its unstretched length. What do you feel as the rubber band is stretched across your forehead? **[Get answers from audience.]** If you do not notice anything, repeat this procedure several times.

"Repeat the step we just did, but let the rubber band contract to its original length while it is still against your forehead. What do you feel as the rubber band is contracted? **[Get answers from audience.]** Again, repeat this procedure until you feel something happen.

"When you stretch the rubber band you are putting stress on the molecules within the rubber band. To relieve the stress, the rubber band gives off heat energy. When the rubber band contracts, stress is being removed from the molecules and they absorb heat.

"Thank you for listening."

Endothermic Reaction

(g) gas (l) liquid (c) crystal (s) solid

Acetic Acid + Sodium Bicarbonate + Heat =

CH_3COOH (l) + $NaHCO_3$ (c) + Heat =

Water + Carbon Dioxide + Sodium Acetate

H_2O (l) + CO_2 (g) + $NaC_2H_3O_2$ (c)

Photosynthesis

Water + Carbon Dioxide + Solar Energy =

$6H_2O$ + $6CO_2$ + Solar Energy =

Glucose + Oxygen

$C_6H_{12}O_6$ + $6O_2$

Exothemic Reaction

Iron + Oxygen = Iron Oxide (Rust) + Heat Energy

$4Fe\ (s) + 3O_2\ (g) = 2Fe_2O_3\ (s)$ + Heat Energy

The Science of Energy

Station Three

What You Need

The Radiometer

1 Radiometer	1 Display Sheet	1 Overhead Projector

The Photovoltaic Cell

1 PV Meter	1 Photovoltaic Cell	1 Display Sheet

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The Radiometer

Equipment Preparation and Arrangement

It is best if the presentation is done near a window with a lot of sunlight. If not, place the radiometer on an overhead projector to create the same effect.

Sample Script

"Do you believe that light can make something move? It is possible to convert light, or *radiant energy*, into heat, or *thermal energy*, and then into motion, or *mechanical energy*.

"This is a radiometer. **[Hold up radiometer upside down, so that the audience can see the vanes without them turning.]** Inside this bulb is a near-vacuum—there is very little air in here. These black and white vanes are hanging freely on a needle. There is nothing else inside this bulb.

"But, as you can see, when I turn the radiometer upright, **[turn radiometer over]** the vanes begin to turn. The brighter the light, the faster they spin. Why? **[Get answers from audience.]**

"Now, most people know that black objects get hotter than white objects in sunlight. What color clothing do you wear in the summer? If you leave a piece of black metal and another identical piece of white metal out in the sun, the black one will get much hotter. This is because the black one will absorb more radiant energy from the sun. The white one absorbs some energy, but reflects most of it; the black one absorbs most of the energy and reflects some of it.

"When a strong light strikes the vanes of the radiometer, the vanes begin to heat up. When air molecules strike the heated vanes, they bounce off with more energy, pushing on the vane like a ball bouncing off a wall. If the vanes were the same color, they would never move because the push would be equal on both sides.

"But the vanes are not the same color. The black one is absorbing much more energy than the white one. When the molecules hit the black one, they rebound with more energy than they do when they hit the white one. Look at this diagram. **[Hold up Display Sheet.]** When the molecules hit the white vanes, they push a little. But when the molecules hit the black vanes, they push much more. This means that the vanes rotate in the direction of the white ones. This is a way of converting radiant energy through thermal energy into mechanical energy."

The Photovoltaic Cell

Equipment Preparation and Arrangement

Connect one alligator clip from the positive terminal of the meter to the positive terminal of the PV cell, and connect the other clip from negative terminal of the meter to the negative terminal of the PV cell.

Place the meter where the audience can easily see the dial. It is best if this presentation is done near a window with a lot of sunlight; however, DO NOT point the PV cell directly at the sun. If sunlight is not available, an overhead projector can be used to create the same effect.

Sample Script

"We can use light to make electricity. This is converting *radiant energy* (light) into *electrical energy*. Probably all of you have seen things that use this conversion, like solar calculators, solar toys, or solar panels on a telephone box on a highway.

"Most of the energy we use comes from stored sunlight in the form of fossil fuels. Converting light directly into electricity is one of the cleanest and simplest ways of generating power. Unfortunately, it is not very efficient, costing approximately five times as much per kilowatt-hour as conventional sources like coal and nuclear.

"What I have here **[show PV meter and photovoltaic cell]** is a piece of equipment called a photovoltaic ('fōt-ō vōl 'tā-ik) cell that can generate electricity from light. Photovoltaic comes from the words *photo* meaning light and *volt*, a measurement of electricity. **[Uncover the photovoltaic cell.]** This PV meter is measuring the amount of electricity produced by the photovoltaic cell. Does anyone know how photovoltaic cells produce electricity? **[Get answers from audience.]**

"A photovoltaic cell is made of two thin slices of *silicon* sandwiched together and attached to metal wires. The top slice of silicon, called the N-layer, is very thin and has a chemical added to it that provides the layer with an abundance of free electrons. The bottom slice, or P-layer, is much thicker and has a chemical added to it so that it has very few free electrons.

"When the two layers are placed together, an interesting thing happens—an electric field is produced that prevents the electrons from traveling from the top layer to the bottom layer. This junction with its electric field becomes the central part of the PV cell.

"When the PV cell is exposed to sunlight, bundles of light energy known as photons can knock some of the electrons from the bottom P-layer out of their orbits through the electric field set up at the P-N junction and into the N-layer.

"The N-layer, with its abundance of electrons, develops an excess of negatively charged electrons. This excess of electrons produces an electric force to push the additional electrons away. These excess electrons are pushed into the metal wire back to the bottom P-layer, which has lost some of its electrons.

"This electrical current will continue flowing as long as radiant energy in the form of light strikes the cell and the pathway, or circuit, remains closed.

"The amount of power produced by photovoltaic cells depends in part on the number of cells hooked up. Watch. If I cover half the cell with my hand, **[cover half the photovoltaic cell with your hand]** the amount of electricity flowing through the wire is about half.

"There are other ways of increasing the amount of power that a photovoltaic cell produces. Watch. **[Angle the photovoltaic cell towards and away from the light source.]** More power is produced if the light is shining directly on the photovoltaic cell, striking the silicon layers at a 90 degree angle. That's why most large photovoltaic boards are motorized to follow the sun as it travels through the sky.

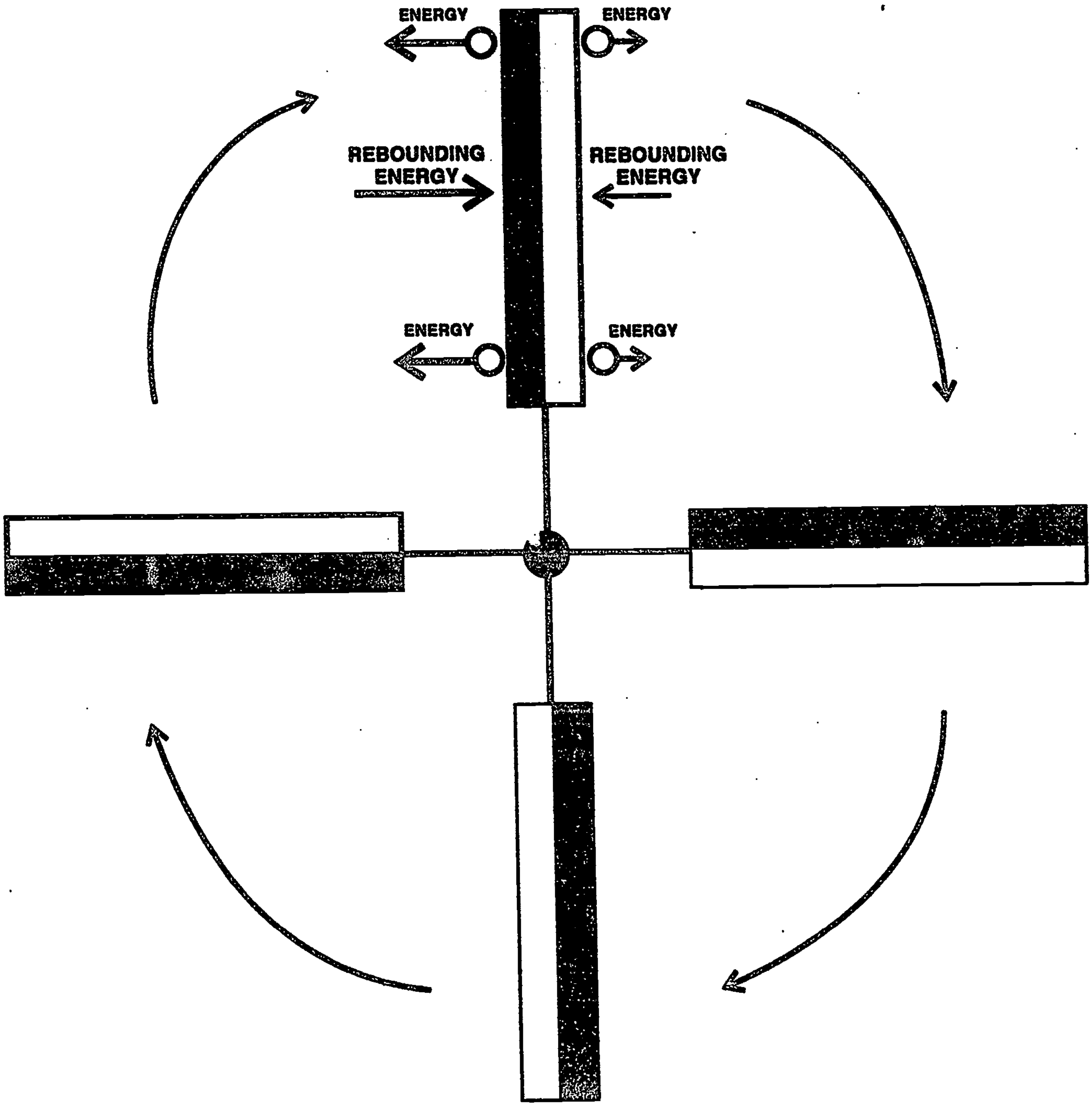
"While photovoltaic cells are a clean way to generate electricity, they are not very efficient. They are only about 10 percent efficient, which means that only about 10 percent of the sunlight that goes into them is converted into electricity. The rest of the sunlight is changed into heat or reflected off the surface of the photovoltaic cell. However, scientists are currently conducting research to increase the efficiency of PV cells. In fact, a new PV cell on the market is about 24 percent efficient, but it is more expensive than conventional PV cells."

Radiant to Thermal

On a window, tape one thermometer pointing towards the sun, and the second thermometer pointing away from the sun. If you don't have a sunny window, use an overhead projector and tape the thermometers to the wall.

"You have probably heard people use the expression, "It was 105 degrees in the shade." Why do they say in the shade? **[Get answers.]** That's correct, because it feels hotter standing in direct sunlight than in the shade—the sun's radiant energy makes you feel hotter. In the shade, you only feel the heat from the hot air molecules striking your body. I will demonstrate this principle using two thermometers.

The first is in the shade, and the other is in direct sunlight. Notice the difference in temperature. The temperature of the thermometer in direct sunlight is higher than the temperature of the thermometer in the shade. So, stay in the shade on hot days and cut down or eliminate the amount of radiant energy striking your body."



Top-view of Radiometer

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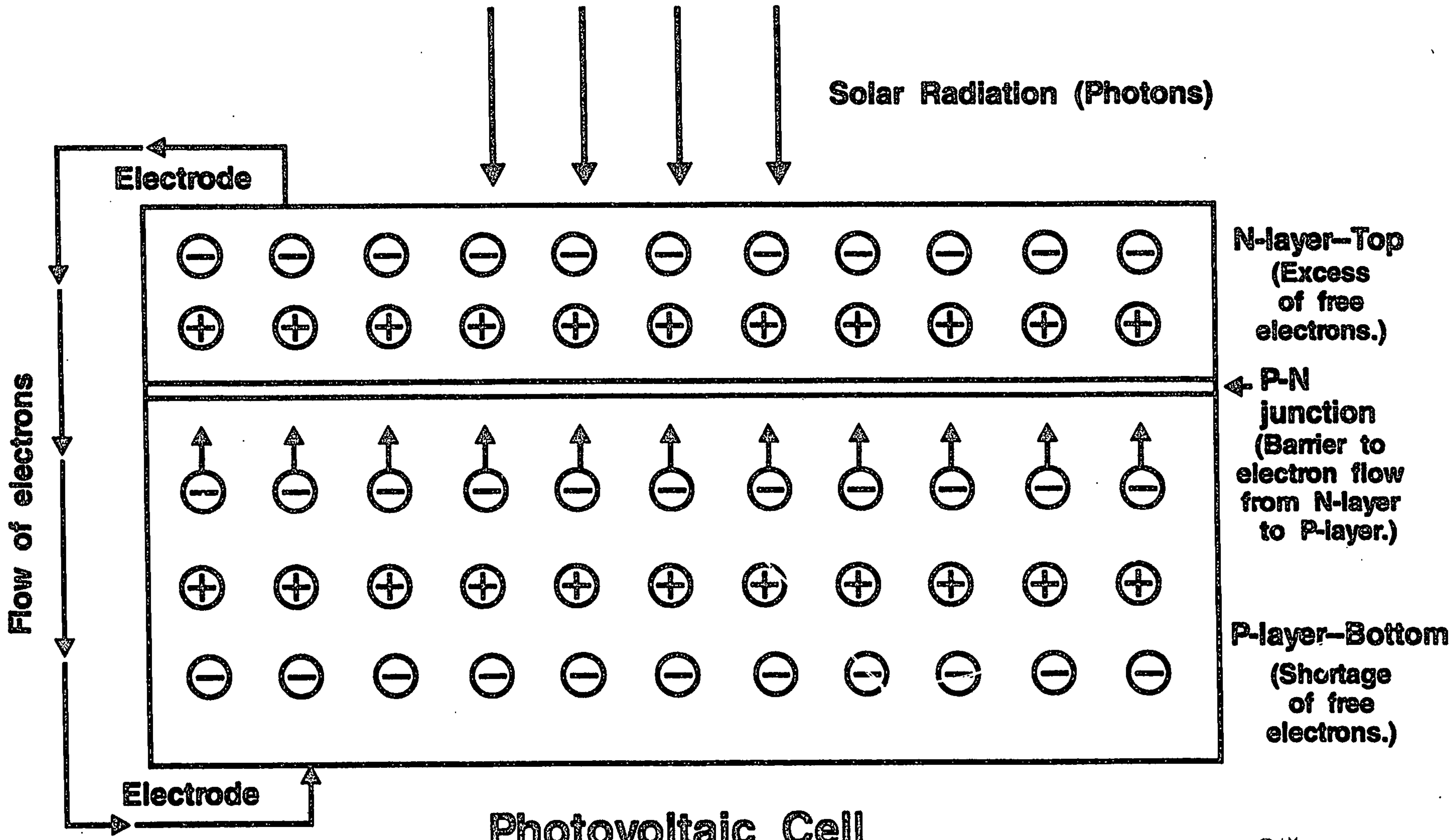

Photovoltaic Cell

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The Science of Energy

Station Four

What You Need

The Thermobile

1 Thermobile

1 Live Wire

*1 Foam Coffee Cup

*1 Cup of Hot Water

*1 Pair of Tongs or a Spoon

(* = not included in kit)

The Wire Heater

*1 Metal Coat Hanger (cut in two pieces)

(* = not included in kit)

The Jumping Disc

1 Jumping Disc for Each Student

1 Flat Piece of Metal

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The Thermobile

Sample Script

"I'm going to show you how a metal with a memory can be used as a power source. We will be converting *thermal energy*, or heat, into *mechanical energy*, or motion.

"This is called a Thermobile. **[Hold up Thermobile.]** It is simply a pair of pulleys and a curved wire made out of Nitinol, which is a mixture of nickel and titanium.

"Nitinol has what is called a "memory." This wire was originally straight; it was bent into this circular shape and pulled over these pulleys. Most metals maintain whatever shape they are bent into, but Nitinol "remembers" its original shape when it is heated. Nitinol was first discovered in 1962. Since then it has been used in a variety of ways. Nitinol is used in space to deploy satellite antennae. When heated, Nitinol wire can act like a muscle to move a robot arm. Also, the temperature of a greenhouse can be controlled by a Nitinol spring which pushes a door open when the air becomes too hot.

"Here is another piece of Nitinol wire. It's original shape looks like this **[hold up wire—it should be in the shape of a "U"]**. I will now bend the wire into a coil shape. **[Bend wire into coil shape. Do not tie wire in a knot.]** When I drop the wire into this hot water it should "remember" its original shape. **[Drop wire into hot water and then remove it with the tongs or spoon—wire has returned to the shape of a "U."]**

"Now, let's use the "memory" property of Nitinol wire to produce mechanical energy. Watch. **[Place half of the Thermobile's small wheel in the hot water. Make sure the water doesn't touch the plastic—just half the wheel.]** This water is hot, which means that it has a great deal of thermal energy. The Nitinol wire will absorb the energy, and the wire will begin to straighten out to its original shape. **[If the Thermobile has not started spinning yet, give the big wheel a slight push. It should begin spinning. If the Thermobile still hasn't started spinning perhaps the water isn't hot enough. You may need to replace the hot water after every demonstration.]**

"The little wheel is made of brass; the big one is plastic. The brass wheel also absorbs the heat from the water and transfers it to the Nitinol wire. But, as the wire travels around the plastic wheel, it loses heat to the air. As the wire loses heat, it stops "remembering" its original shape and goes back to a loop. However, since the brass wheel is absorbing heat all the time, the part of the wire in contact with the brass wheel tries to return to its original shape and pushes the whole loop along.

"It's an interesting engine—but is the energy in the wheel free? Do we have to pay to get this mechanical energy from the spinning of the wheel? **[Get answers from the audience.]** Right! Energy is required to heat the hot water. That's why this isn't a free energy engine."

The Wire Heater

Sample Script

"Now I am going to do an experiment that will accomplish the opposite of what we just did with the thermobile. I am going to produce *thermal energy* from *mechanical energy*.

"First I am going to bend the hanger like this **[bend hanger back and forth about eight times at the center]. [Caution: bending the hanger more than eight times will produce an extreme amount**

of heat and may cause injury.] Please carefully touch the spot that was bent. How did the spot feel? That's right, it was hot. When we bend the wire we are putting mechanical energy from our muscles into the wire. Our muscles convert chemical energy from the plants we eat to mechanical energy. The plants convert light (radiant) energy from the sun to chemical energy. The sun received its energy from nuclear fusion.

The wire was heated due to the molecules of metal moving faster at the bent spot and creating friction which caused the wire to feel warm to the touch. If you continue to bend the wire, it will eventually break—a phenomenon known as *metal fatigue*.

"Another demonstration to show how mechanical energy is converted into thermal energy is one that you probably have done on a cold winter day. First, place both of your hands on your face to measure how hot your hands are now. Your hands probably feel about the same temperature as your face. Now, rub your hands briskly together for about ten seconds. Place your hands back on your face. You should feel an increase in temperature as the heat from your hands is transferred to your face."

The Jumping Disc

Sample Script

"Take your Jumping Disc and click it several times back and forth. Next, take your thumb and push down on the logo side of the disc until the disc becomes saucer shaped. Keeping the Jumping Disc in your hand, press down on the silver side with your thumb until it clicks and stays in the clicked-in position. The logo side should be outward or convex in shape. Once the disc stays in the clicked-in position, put the disc with the logo side up on this piece of metal—a hard, smooth surface that conducts heat well. *Caution! Do not look directly down at the jumping disc as it may cause injury if it hits your face or eye.*

"The Jumping Discs are made of two different metals—nickel and stainless steel—that expand and contract at different rates. When the Jumping Disc leaves your hand it is approximately 98.6 degrees. When placed on a hard, cool surface the disc will experience about a 20 degree temperature change. The heat in the jumping disc is being absorbed by the piece of metal. The energy it took to click the disc into a convex shape is released when the disc jumps into the air.

"When you click the Jumping Discs you are putting potential energy into the disc. You can measure the amount of potential energy you have stored in the Jumping Disc by seeing how high it jumps into the air.

Note: *The Jumping Disc performs best at temperatures between 72 degrees and 78 degrees. Below 70 degrees it may be difficult to put a disc into the clicked-in position. At 80 degrees and above the disc may delay a long time before jumping. If your disc doesn't jump or is too slow, don't think it is broken or worn out. Simply press the disc back into its original saucer shape, pushing in on the label side, and start over. If it's difficult to put your disc back into the click-in position, or if it jumps too fast, make the disc warmer by clicking it in and out several times.*

The Science of Energy

Station Five

What You Need

Omniglow Lightsticks

Omniglow Lightsticks

*1 Pair of Tongs or Spoon

*1 Cup of Hot Water (not boiling)

*1 Cup of Cold Water

(* = not included in kit)

Electric Motors

1 9-Volt Battery With Holder Attached

2 Motors

1 Disassembled Motor

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Omniglow Lightsticks

Equipment Preparation and Arrangement

Remove two lightsticks from their foil packages. Hold one of the lightsticks up so that the audience can see it clearly.

Sample Script

"This experiment will show you how chemical energy can be converted into radiant (light) energy. Notice the small glass ampule inside the lightstick. This ampule is filled with hydrogen peroxide which is commonly used to disinfect cuts or bleach hair. The plastic tube of the lightstick is filled with a liquid called an ester. These two liquids are kept separate by the glass ampule. When the ampule is broken by bending the plastic tube, the hydrogen peroxide comes into contact with the ester. **[Gently bend the lightstick until you hear the glass ampule snap. Vigorously shake the lightstick for 10 seconds.]**

NOTE: *ONLY break the lightstick for the first group that observes the demonstration. For all other groups hold up a lightstick that has not been broken and repeat the following words:*

> *"Notice the small glass ampule inside the lightstick. This ampule is filled with hydrogen peroxide which is commonly used to disinfect cuts or bleach hair. The plastic tube of the lightstick is filled with a liquid called an ester. These two liquids are kept separate by the glass ampule. When the ampule is broken by bending the plastic tube, the hydrogen peroxide comes into contact with the ester.* ***[Hold up a lightstick that has been broken.]*** *Here is a lightstick in which the glass ampule has been broken and the two liquids have been mixed. Notice how it is glowing."*
>
> *Continue with the remainder of the demonstration as written. If you find that one of your lightstick is becoming very dim, break one of the extra lightsticks included with the kit and discard the dim lightstick.*

"The lightstick is producing radiant energy. Where is this light coming from? **[Get answers from audience.]** When the two chemicals are mixed together, the hydrogen peroxide reacts with the ester to form different chemical compounds. These newly formed compounds require less energy to keep their molecules together. Therefore, they give off this excess energy in the form of light or radiant energy. Most chemical reactions give off heat, only a very few give off just light. This light is then absorbed by a fluorescent dye and becomes excited. When the fluorescent material returns to a normal state it give off its light, and it is this light we see. You have probably seen lightsticks of different colors. The only difference between them is the fluorescent dye put into the tube; the initial chemical reaction with the ester and peroxide is the same.

"I am going to put this lightstick in cold water. But before I do, I want you to observe its brightness. **[Put the lightstick in the water.]** Is the lightstick in cold water brighter or dimmer than it was when it was at room temperature? **[Get answers from audience.]** Right, in cold water the lightstick is dimmer than it was at room temperature. Next, I will take the lightstick out of the cold water and put it in hot water. **[Take lightstick out of the cold water and put it in the hot water.]** As you can see, when the lightstick is in hot water, it is much brighter than when it was in cold water or at room temperature. **[Pull lightstick out of the hot water with a pair of tongs.]**

"The lightstick in hot water glows the brightest because the hot water has transferred some of its energy to the chemicals inside the lightstick. If the molecules in the lightstick are given more energy, the rate of reaction will increase. The hot water has helped to activate the chemicals in the lightstick. The lightstick at room temperature should produce light for approximately one hour. Since hot water speeds up the reaction and produces more light, the hot water lightstick will only glow for about 20 minutes.

"The lightstick in cold water is the dimmest because the cold water has removed some of the activation energy of the chemicals in the lightstick. Remember the activation energy needed to light the wooden match during the teacher demonstration? Since the reaction between the chemicals in this lightstick occurs at a much slower rate, the cold water lightstick should glow for up to six hours.

"All lightsticks contain basically the same amount of chemicals. However, if we increase the rate of the chemical reaction, the lightstick will give off more light for a shorter period of time. If we decrease the rate of the chemical reaction, the lightstick will give off less light for a much longer period of time.

The lightstick is a good example of chemical energy converted into radiant energy. Another example is the male firefly. The male firefly can convert about 88 percent of its molecular reactions into light energy. This is very efficient when compared to the Omniglow lightstick, which is only about 20 percent efficient."

Electric Motors

Sample Script

"Do these small electric motors look familiar? You may have seen similar motors in toys or small portable electric fans. These motors produce mechanical energy, or energy of motion. Let's take a look inside one of the motors. **[Hold up the disassembled motor.]** You can see a coil of wire that is mounted on a shaft. Magnets surround the coil of wire.

"When an electric current is sent through the wire, it produces a magnetic field. The wire will act as if it were a bar magnet. What happens when you bring the north sides of two magnets close together? That's right, they repel or push each other apart. The same thing happens when you bring the south sides of two magnets close together.

"Inside the motor, the stationary magnets repel the magnetic field produced by the coil of wire. This produces rotary motion. Therefore, the mechanical energy produced by the motor is a result of electrical energy. Can anyone tell me what produces the electrical energy in toys and small portable electric fans? **[Get answers from the audience.]** That's right, the electrical energy comes from batteries. The batteries produce electrical energy from chemical energy stored inside the battery.

"Let's connect the wires from the battery to the motor. **[Clip the wires from the motor to the wires from the battery.]** As you can see, the shaft of the motor is spinning. The motor is producing mechanical energy as a result of the electrical energy from the battery. The electrical energy is produced by chemical energy in the battery. What happens to a toy car when the batteries weaken? That's right, the car moves slower when the amount of chemical energy inside the batteries drops. Less mechanical energy is produced because the batteries are producing less electrical energy.

"Now let's see if we can make a second motor produce mechanical energy without the use of a battery. Let's connect the clips from the first motor to the two metal prongs on the plastic end of the second motor—one clip to each prong. It doesn't matter which clip you connect to which prong. **[Connect the clips.]** I will spin the gear connected to the shaft of the motor, changing it from a motor into a generator. This generator will then produce electricity. The electricity is sent to the second motor which causes it to turn. **[Spin the gear of the first motor as quickly as possible.]**

"Please note the speed at which I am turning the shaft of the generator. Compare this speed to the speed of the shaft of the second motor. Is it moving faster, slower, or at the same rate? **[Get answers from the audience.]** Correct, it is moving slower. Can anyone tell me why? **[Get answers.]**

"When I spin the shaft of the generator, some of the initial mechanical energy is lost to friction, producing thermal energy. The same is true when the electricity from the generator is sent to the second motor. Again, some of the energy is lost to friction. A small amount of energy is also lost to thermal energy as the electrons travel through the wire to the motor. Because of this energy loss, the shaft of the second motor moves slower. Thank you for listening."

The Science of Energy

Station Six

What You Need

The Electrochemical Cell

2 Zinc-plated Nails	1 Thick Copper Wire	1 Display Sheet
1 Thin Copper Wire	1 Electrochemical Meter	
* 1 Apple		(* = not included in kit)

Note: The following presentation is intended as a sample only, and should serve as a source for examples and facts rather than as a rigid guideline. Even if you choose to follow the script, do not worry about word-for-word memorization. The facts themselves are important—don't mix them up or confuse them. Read through the script several times, both with and without the equipment. The script contains directions for using the equipment. The instructions will be enclosed in bold brackets **[like this]**. The script assumes that your audience is close enough to handle your equipment; if they are not, modify your script so that you use all the equipment. Be sure that your delivery of the information is clear and easily understood. Get some help from your teacher; have him or her listen to your presentation a few times before you actually give it to make sure that your facts are correct and that you are speaking clearly. Give the presentation to a group of fellow students to get used to standing in front of a group. Be prepared.

The Electrochemical Cell

Equipment Preparation and Arrangement

Place the meter in full view on the table. Each line on the meter represents 20 microamps. If the meter needle gets stuck during the presentation, gently tap the face of the meter. Have the zinc and copper electrodes nearby along with the apple. The display sheet should be stored out of audience view at the beginning of the presentation.

Sample Script

"When most people think about energy, one of the first things they think about is electricity. Our electricity comes from many sources. In most cases, electricity is generated using turbines to rotate copper coils in a magnetic field. Power plants can use chemical energy, such as coal or nuclear energy from uranium, to produce steam to spin the turbines. In the case of water or wind turbines, the mechanical energy from falling water or moving air spins the turbines.

"However, there are many ways to convert other forms of energy into electrical energy. In this presentation, I will demonstrate one form of energy that we can convert into electricity.

"Today we will concentrate on chemical energy. Chemicals are everywhere. Actually, everything is made up of chemicals. For example, this apple. **[Hold up apple.]** The apple is made up of many chemical compounds. Who can tell me what common acid is in this apple? **[Get answer from audience.]**

"That's right, tannic acid. We're going to use the tannic acid in this apple to show how a battery works.

"Electricity is electrons flowing along a wire. This is called an electric current. To create an electric current, all we need to do is make electrons flow. But how do we do that?

"The way to get electrons is by freeing them from something. The way we'll do that is by putting a metal, like copper or zinc, into an acid, like tannic acid. The acid frees some electrons from the metal.

"When we put this piece of copper wire into the apple about one centimeter, **[push thin copper wire about one centimeter into apple]** the tannic acid frees electrons from the copper. The same thing happens when zinc enters the acid, like this nail coated with zinc. Put this nail into the apple about one centimeter, please, but make sure that it is not touching the copper. **[Push zinc nail about one centimeter into apple, making sure that it is not touching the copper wire.]**

"The chemical reaction of the tannic acid on the two metals frees many electrons from both metals. But the zinc and copper lose electrons in different amounts. **[Show the Display Sheet.]** Let's say, just to keep it simple, that for every two electrons the copper loses, the zinc loses four. This is a simplification to make it easier to understand. Let's see what happens when we connect them with a wire.

"First, take the zinc-coated nail and attach it to the meter. **[Attach zinc nail to the alligator clip with the green label.]** Then please attach the copper wire to the meter. **[Attach copper wire to the alligator clip without a label.]**

"Because the clip is made out of metal leading to a wire, where the clip touches the copper and zinc it forms a circuit that electricity can pass through. This meter measures the electrical current flowing through it. What is happening? Why is there electricity flowing?

"Since the zinc is losing more electrons than the copper, it tries to take some electrons from the copper to equalize the electric charge. Let me give you an example using water in a fish tank. Let's begin with a fish tank that has a wall dividing the tank in half. There is a cork at the bottom of the wall plugging a hole. On one side of the wall the water level is high and on the other side the water level is low. What would happen if the cork is removed? **[Get answers from audience.]** That's right! The water would flow from the side of the tank with more water to the side of the tank with less water. Basically, the same thing is happening with the zinc and copper. The copper, even though it has lost electrons, has more electrons available than does the zinc. The electrons flow from the copper to the zinc to try to equalize the electrical charge.

"What happens when the metals are pushed all the way into the apple? Will the amount of electrical current increase, decrease, or stay the same? **[Get answers from the audience.]** Push the electrodes about four centimeters into the apple, please. **[Push electrodes four centimeters into the apple.]**

"Right! The electrical current is greater, because the amount of copper and zinc in the acid is greater. This means more free electrons, and more current.

"What if only one of the wires is pushed all the way in? Pull the copper wire out, please. **[Get answers and pull the copper wire out to a depth of one centimeter.]** As you can see, the electric current has dropped because less metal is in contact with the acid. Now, let's keep the zinc coated nail four centimeters in the apple, and push both the thick and thin copper wires four centimeters into the apple. I will first connect the clip to the thin copper wire and get a reading. **[Record this reading.]** Will the amount of electric current produced increase, decrease, or remain the same when I clip the lead to the thick copper wire? Why? **[Get answers. Then move the clip from the thin copper wire to the thick wire.]** Since the thick copper wire has more surface area, more metal is in contact with the acid, and more electricity is produced.

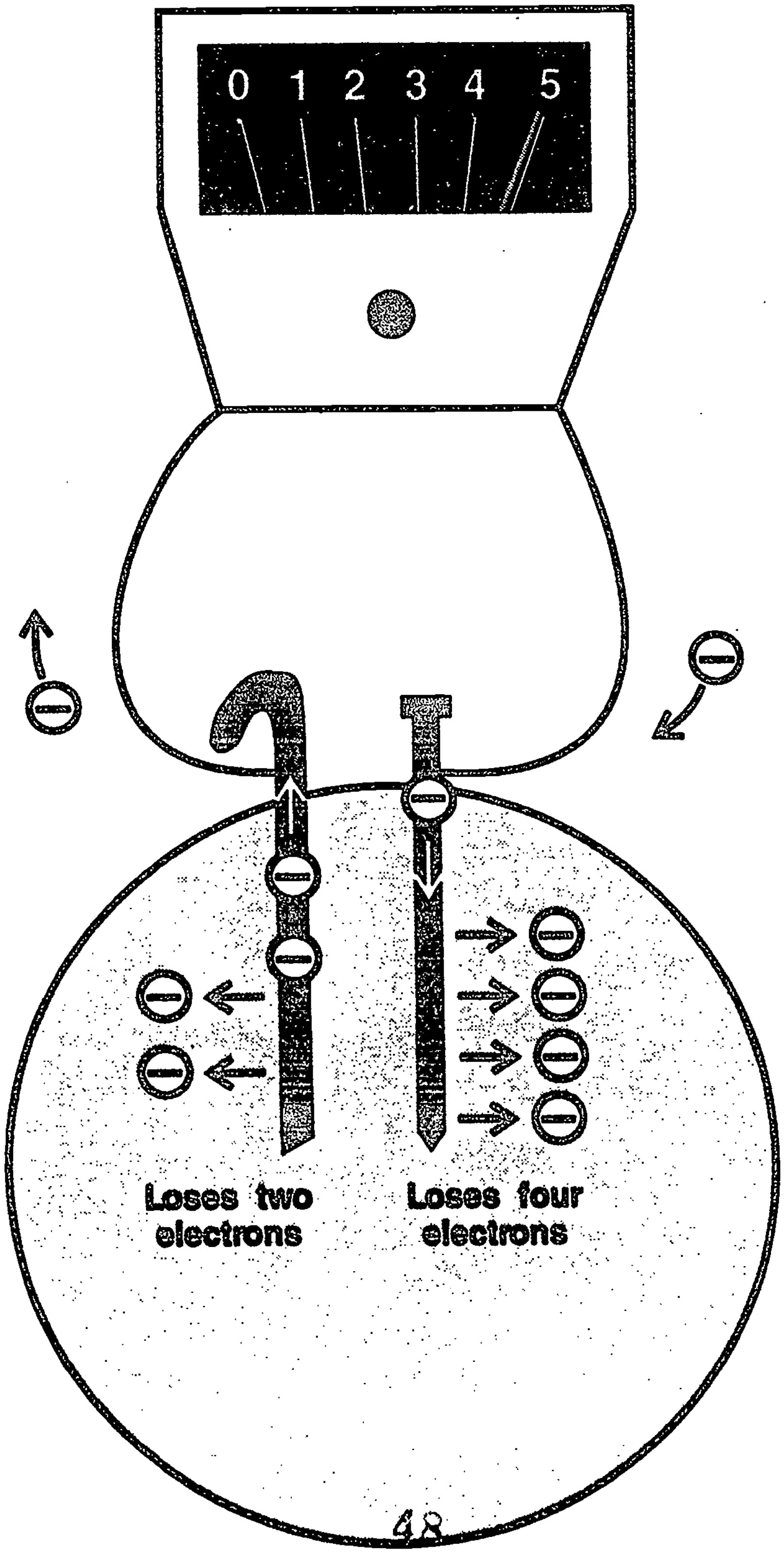
"Based on what you now know, what will happen if I put two coppers or two zincs in? Try that. **[Get answers and remove the copper wire and lead. Attach the lead to the other zinc coated nail and insert the zinc coated nail into the apple so that it is the same depth as the other zinc nail.**

"Right. If this were a perfect situation, no electricity would flow because the electron loss would be the same for both metals. Let's return to the analogy of the fish tank. This time the water levels are the same on both sides of the wall. When the cork is removed from the hole at the bottom, no flow will occur because there is no difference in water pressure.

"Now let's use two different metals again; however, this time I want you to push the metals in so that they touch each other inside the apple. What do you expect the meter reading to be? **[Get answers first and then push the copper and zinc into the apple until they touch.]** Why don't we have an electron flow through the meter? **[Get answers from the audience.]** The reason is because the easiest path for the electrons is directly between the metals rather than traveling through the meter. This is called a short or a short circuit because the electricity is taking the shortest distance.

"This is the way that all batteries work. Car batteries, as well as little flashlight batteries, all work on the principle of making electrons flow from one area to another. This is converting chemical energy into electrical energy. Thank you."

The Electrochemical Cell



The Science of Energy

Station Seven

What You Need

The Electromotor Force

1 EMF Meter	1 Large Coil of Wire
1 Large Magnet	1 Small Coil of Wire
1 Small Magnet	1 Display Sheet

Compass and Magnetic Field

1 Wire	1 Battery

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The Electromotor Force

Equipment Preparation and Arrangement

Connect the two leads from the EMF meter to the large coil of wire. It doesn't matter which lead you connect to which side of the wire. If the meter needle gets stuck during the presentation, gently tap the face of the meter.

Sample Script

"Electricity is one of the most widespread forms of energy—the one most people think of and use most. In fact, one third of all the energy we consume goes to make electricity. Can you imagine living today without electricity? Of course, there are many places in the world that are without electricity, but modern civilization demands it. You may want to know how we produce all this electricity.

"More than a 160 years ago, an Englishman named Michael Faraday discovered that moving a magnet through a coil of copper wire creates an electric current in that wire. All our electric power plants are based on his finding.

"A modern electric power plant **[show Display Sheet]** uses some form of energy to spin a huge turbine that rotates a magnet (magnetic field) in a copper coil. Because the coils are cutting across the magnetic field, electricity begins to flow through the wire. Many different kinds of energy are used to spin the turbine.

"For example, in this presentation I will show you how to turn mechanical energy into electrical energy. In this hand I have a large bar magnet and in the other hand I am holding a large coil of wire connected to a meter. **[Place the flat side of the magnet on top of the yellow label on the coil. Move the magnet away from the coil.]** When I provide the mechanical energy to move the magnet away from the coil, electricity is generated and you can see the meter's needle move to the (right/left). Next, I will flip the magnet over so the other side of the magnet is touching the bolt. Before the needle moved to the (right/left). Now that I have reversed the direction of the magnetic field, which way do you think the needle will move?

"Notice what happens to the movement of the needle when I move it towards or away from the coil. The needle alternates between right and left because the current is alternating from one direction to the other. This is an example of AC or alternating current—the same current that we use in our homes, schools, and businesses. Direct current can be produced by using either batteries or a DC electric generator.

"If I place the magnet on top of the coil without moving it, you see the needle remains stationary; no electricity is being generated because no mechanical energy is being expended.

"What do you think will happen if we place the magnet on the table, keeping it stationary, and move the coil away from the magnet? **[Get answers from audience.]** Let's try it. As you can see, it doesn't matter if the coil moves or the magnet moves as long as one of them moves while the other one remains stationary. If I move both the coil and magnet at the same speed and in the same direction, no electricity is produced. **[Place magnet on top of coil and move up and down.]**

"What affects the amount of electricity we can generate with this magnet and coil? Let's first move the magnet slowly away from the center of the coil. **[Slowly move the magnet away from the coil.]** How much does the needle move? **[Get answers.]** Do you think the needle will move more, less, or the same when I move the magnet quickly away from the center of the coil. **[Get answers from audience.]** Right! The faster I move the magnet the more mechanical energy I put into the system and the more electrical energy is generated. Two other factors that can increase the amount of electrical energy produced are the strength of the magnet and the number of turns in the coil of wire.

"What affect will a smaller magnet have on the large coil if the speed of motion remains the same? **[Try both large and small magnets with the coil and record meter readings for both.]** As you can see, a stronger magnet field will generate more electricity.

"This time I will use the large magnet with two different coils. First, let's try the large coil and record the meter reading. Using the same magnet and moving it at the same speed, I will now try the small coil. What do you think will happen? Will the meter reading of the small coil be more or less than the large coil and why? **[Get answers from audience.]** Let's try. Why does the large coil produce more electricity than the small one? It's because there are more copper atoms in the large coil, therefore more electrons can move in the circuit.

"As you can see, the amount of electricity generated is affected by the strength of the magnetic field, the speed at which the magnet or coil is moved, and finally the number of turns in the coil."

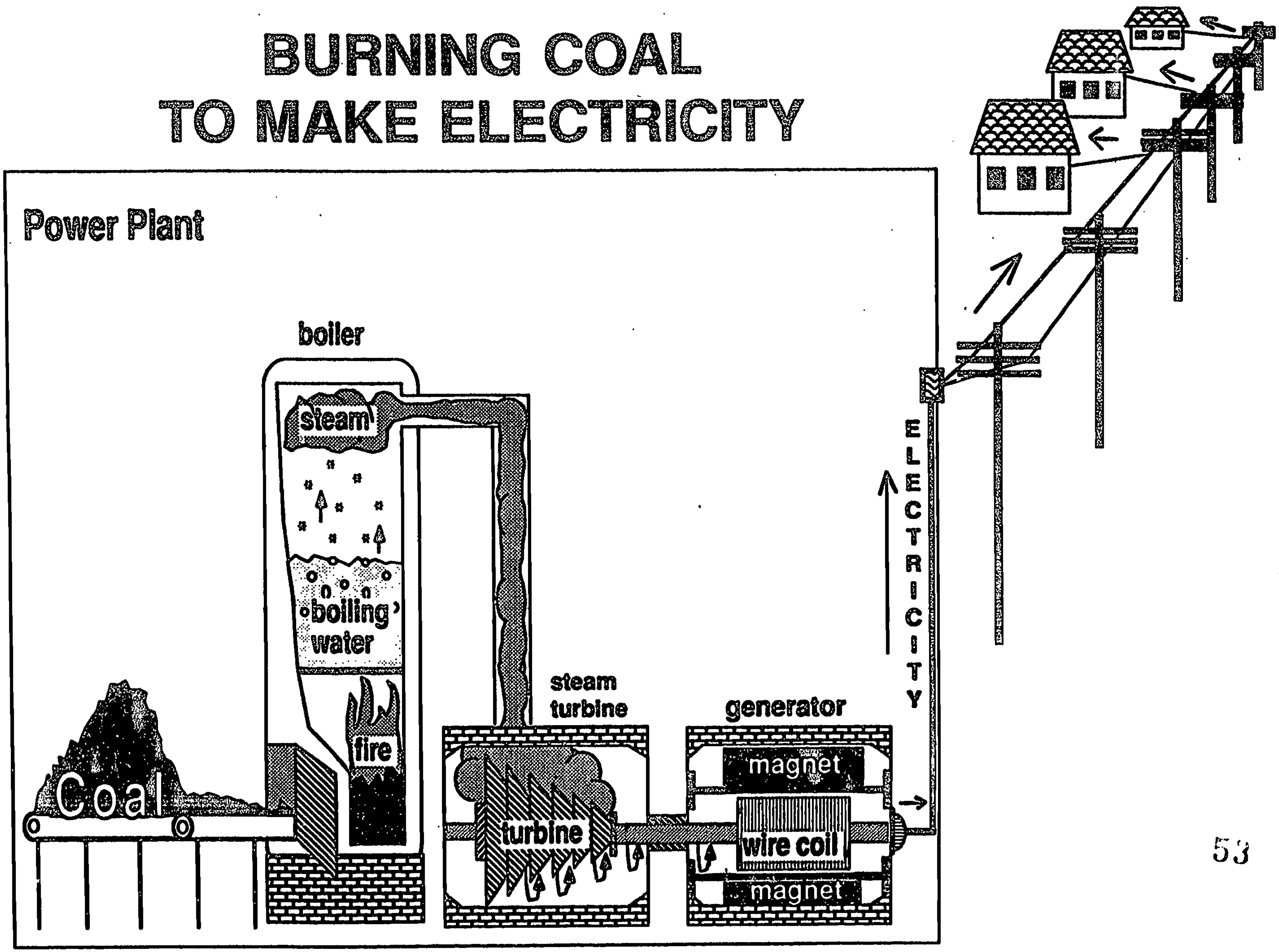
Compass and Magnetic Field

Sample Script

"From our previous experiments you have seen how mechanical energy can be converted into electrical energy using magnets and coils. In this experiment we will do the opposite—electrical energy will produce mechanical energy.

"On the table you will see a simple compass with its needle pointing to magnetic north. Now, I will connect one end of this wire to the positive end of the battery and one to the negative end. This will cause electrons to flow along the wire. When I place the center of the wire directly over the compass needle so that the wire and needle point in the same direction, you can see the needle move. Why does this happen? **[Get answers from audience.]** That's right. The electric current in the wire produces a magnetic field. This magnetic field affects the magnetized needle and makes it move. Have you ever tried to pull or push one magnet using a second magnet? In this case, the second magnet is an electromagnet. Notice what happens when I pick up the compass and hold it above the wire versus when I hold the compass below the wire. The compass needle points in one direction when it is above the wire and in the opposite direction when it is below the wire. This is because the magnetic field around the wire is in a circular pattern. Thank you very much."

BURNING COAL TO MAKE ELECTRICITY



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